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DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING SOUND INTENSITY POINTS VERSUS SCANNING

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Part 1 of ISO 9614 is concentrating on measurements at discrete points. Part 2 deals with measurement by scanning. As both standards claim the same accuracy of the sound power level determination, but require widely different qualification procedures, it may be pertinent to point out the application area of each standard. In practice both methods offer advantages and disadvantages.

The excisting line of "old" standards specifying methods for determining the sound power levels of machines and equipment based on sound pressure levels clearly divides methods in different standards and list tables on their use and accuracy as shown in table 1. (ISO 3741).

International Standard No.*	Classification of method**	Test environment	Volume of source	Character of noise	Sound power levels obtainable	Optional information available
3741	Precision (grade 1)	Reverberation room meeting specified requirements	Preferably less than 1 % of test room volume	Steady, broad-band	In one-third octave or octave bands	A-weighted sound power level
3742				Steady, discrete-frequency or narrow-band		
3743	Engineering (grade 2)	Special reverberation test room		Steady, broad-band, narrow-band, or discrete-frequency	A-weighted and in octave bands	Other weighted sound power levels
3744	Engineering (grade 2)	Outdoors or in large room	Greatest dimension less than 15 m	Any	A-weighted and in one-third octave or octave bands	Directivity information and sound pressure levels as a function of time; other weighted sound power levels
3745	Precision (grade 1)	Anechoic or semi-anechoic room	Preferably less than 0,5 % of test room volume	Any		
3746	Survey (grade 3)	No special test environment	No restrictions: limited only by available test environment	Any	A-weighted	Sound pressure levels as a function of time; other weighted sound power levels
3747	Survey (grade 3)	No special test environment; source under test not movable	No restrictions	Steady, broad-band, narrow-band, or discrete-frequency	A-weighted	Sound power levels in octave bands

Table 1 – International Standards specifying various methods for determining the sound power levels of machines and equipment

9614-1 Annex A calls for the calculation of field indicators. F_1 is an indicator for temporal variability of the sound field

Evaluate a typical value of the temporal indicator, F_1, of the sound field at an appropriate position selected on the measurement surface and calculated from equation (A1):

$$F_1 = \frac{1}{\overline{I_n}} \sqrt{\frac{1}{M-1} \sum_{k=1}^{M} (I_{nk} - \overline{I_n})^2} \qquad \ldots (A.1)$$

where

$\overline{I_n}$ *is the mean value of I_n for M short-time-average samples I_{nk} calculated from equation (A.2):*

$$\overline{I_n} = \frac{1}{M} \sum_{k=1}^{M} I_{nk} \qquad \ldots (A.2)$$

NOTE 9: M vill normally take a value of 10. A recommended short averaging time is between 8s and 12s, or any integer number of cycles for periodic signals.

In practical situations the temporal variability is determined by the source, the filter bandwidth (BT product), the reactivity (Pressure-Intensity) and the analyzer real-time capability. It is therefore important anyway to adjust the processor to a proper time constant. This is easy done on most real-time analyzers by doubling the integration time until a desired repeatability is obtained. Little experience is necessary to enable an operator to discriminate between source variability and instrumentation variability. In practice 2-4 sec. time constant is most frequently used. 10 sec. are used for very slow repeated events at once per second.
The most important indicator is the Pressure Intensity indicator F_2.

Calculate the surface pressure-intensity indicator, F_2, from equation (A.3):

$$F_2 = \overline{L_p} - \overline{L_{|I_n|}} \qquad \ldots (A.3)$$

where

L_p *is the surface sound pressure level, in decibels, calculated from equation (A.4):*

$$\overline{L_p} = 10 \lg\left(\frac{1}{N} \sum_{i=1}^{N} 10^{0.1 L_{pi}}\right) \text{ dB} \qquad \ldots (A.4)$$

and

$\overline{L_{|I_n|}}$ *is the surface normal unsigned sound intensity level, in decibels, calculated from equation (A.5):*

$$\overline{L_{|I_n|}} = 10 \lg\left(\frac{1}{N} \sum_{i=1}^{N} |I_{ni}|/I_0\right) \text{ dB} \qquad \ldots (A.5)$$

where $|I_{ni}|$ *is the unsigned normal sound intensity at measurement position i.*

This is best dealt with by measuring the P-I ratio on the instrumentation.

For measurements carried out on equipment, which fulfil IEC 1043, class 1, the P-I index has no significance for the accuracy of practical Sound Power measurements, only for the ability to carry out critical engineering work e.g. structural analysis.
The negative partial power indicator F_3 simply indicates, that if there is more sound power in a given frequency band outside the measurement surface than inside, one cannot use the result. This is very easily realized looking at the measurement results. Normally a change in measurement surface (go closer) or a change in measurement to one with lower disturbing noise, improves the situation. If not, it has no significance for practical noise rating anyway.

Calculate the negative partial power indicator, F_3, from equation (A.6):

$$F_3 = \overline{L_p} - \overline{L_{in}} \qquad (A.6)$$

where

$\overline{L_p}$ *is the surface sound pressure level, in decibels, calculated from equation (A.4)*

$\overline{L_{I_n}}$ *is the surface normal signed intensity level, in decibels, calculated from equation (A.7):*

$$\overline{L_{I_n}} = 10 \lg \left| \frac{1}{N} \sum_{i=1}^{N} I_{ni}/I_0 \right| \text{ dB} \qquad \ldots (A.7)$$

and

I_{ni} *is the signed magnitude of the normal sound intensity component measured at position i on the measurement surface.*

I_0 *is the reference sound intensity ($= 10^{-12}$ W/m²).*

If the normal sound intensity component level L_{in} at position i is expressed as XX dB, calculate the value of I_{ni} from the equation

$$I_{ni} = I_0 \times 10^{XX/10}$$

If the normal sound intensity component level L_{in} at position i is expressed as (-) XX dB, calculate the value of I_{ni} from the equation

$$I_{ni} = -I_0 \times 10^{XX/10}$$

If $\Sigma I_{ni}/I_0$ is negative in any frequency band, the test conditions do not satisfy the requirements of this part of ISO 9614 in that frequency band.

The Field non-uniformity indicator F_4 may leau to extremely high number of measurement points.

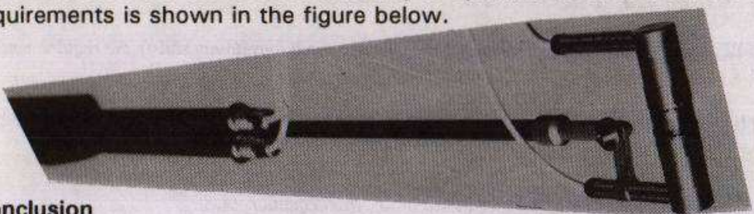
Calculate the field non-uniformity indicator, F_4 from equation (A.8):

$$F_4 = \frac{1}{\overline{I_n}} \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (I_{ni} - \overline{I_n})^2} \qquad \ldots (A.8)$$

where I_n is the surface normal sound intensity calculated from equation (A.9):

$$\overline{I_n} = \frac{1}{N} \sum_{i=1}^{N} I_{ni} \qquad \ldots (A.9)$$

If all measurement points are reported, a desired degree of accuracy may be obtained by considering the max. variation of measured sound intensity in adjacent points in areas containing all points within 3dB of the total power and 6dB of the total power.
In practice one should allways quote the difference obtained by doubling the number of measurements until a desired accuracy or repeatability has been reached. The point method is valid for any measurement surface shape and give information about the energy flow from the source. The point method is the most important engineering method. It offers great reproducibility. If all points are reported, the accuracy is documented. It is easy to use for inexperienced operators. The present 9614-1 should be reserved for inter-laboratory comparison in research situations. A practical engineering part is needed. A first step could be to change Annex A and B into informative instead of normative for practical engineering work.
9614-part 2 covers practical determination of sound power levels using sound intensity measurements by scanning. The scanning method involves a continous motion of the intensity probe over the measurement surface. It is therefore restricted to simple surface areas. It disregards temporal variations in the signal at discrete points, and it is difficult to measure sound sources close to the boundaries of the measurement surface. It is therefore restricted to well distributed sources and continous sources. It is not suited for source location and source ranking. It should not be used for inter-laboratory comparison of measurement results, but for rutine measurements on products allready qualified for scanning measurements using Part 1 or for survey measurements.
The intensity probe shall comply with IEC 1043. For practical measurements especially for the scanning technique, it is important that the probe is light-weight, has low sensitivity to vibration and is easy to rotate in the sound field and it must be rotational symmetric in order to meet the field check procedure prescribed in 9614 part 1 and 2. A probe which meets these demands and is easy to optimize for all the standard requirements is shown in the figure below.



Conclusion

9614 part 1 should be divided in: 1) Precision method, theoretical documented. 2) Precision method for engineering. 9614 part 2 should be devided in: 1) Precision engineering method for overall Sound Power measurements on non-complicated sources. 2) Survey measurements.