Proceedings of the Institute of Acoustics

SOUND POWER INSTRUMENTATION

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1. INTRODUCTION

In broad terms there are two techniques for the determination of sound power; based on measurements of sound pressure and sound intensity. These two different techniques mean that there are also two distinct sets of requirements from the instrumentation used. This paper examines the current instrumentation and calibration requirements for the determination of sound power. It also goes on to look at the trends in the development of new measurement systems.

2. INSTRUMENTATION FOR MEASUREMENTS OF SOUND PRESSURE

2.1 Measurement Instruments

In determining sound power levels from measurements of sound pressure the importance of the measurement environment is much greater than that of the instrumentation. As a consequence the instrumentation requirements detailed in the measurement standards ISO3740 to ISO3746 are quite straightforward and are similar irrespective of the measurement environment. The differences between the requirements of the different standards are related more to the classification of the method - precision, engineering or survey.

The standards for precision grade measurements require an instrument capable of either exponential or linear averaging and fitted with octave or third octave filters complying to IEC225:1966. The system could be a sound level meter complying to IEC651. Irrespective of which instrument is used the microphone response should be calibrated for random incidence when used in a reverberant room. The measurement standards classified as precision methods require calibration before and after the measurement using a calibrator with a precision of $\pm$ 0.2dB.

The methods classified as engineering level (grade 2) have a requirement for an instrument with an A-weighting network, with the option of octaves, as with the precision methods this could be a sound level meter meeting the requirements of IEC651. A calibrator should be applied to the whole instrument before a measurement and this calibrator should have an accuracy of $\pm$ 0.5dB.

The lowest level of measurement method is those giving a survey grade result and these methods require a sound level meter with an A-weighting network and having a slow response.

At the current time the requirements detailed in the standards add up to a choice between two different measurement solutions; a sound level meter with or without a filter set or an analyser capable of measuring in octaves or 1/3 octaves in real time.

There are several advantages in using an analyser capable of real-time measurement in octaves or third octaves, the main one being the much reduced measurement time compared to the serial filters fitted to many sound level meters. This reduced measurement time means that there need be less emphasis on the stability of the noise source and will significantly reduce measurement costs. The newest sound level meters, such as the 2260 Investigator shown in figure 1, include parallel 1/3 octave filters and many of the other features previously limited to analysers.

2.2 Spatial Averaging

The measurement methods all require the sound levels around the source should be spatially averaged. The measurement system may well include a mechanism for averaging the sound field around the source, whether this is a rotating boom or a multiplexer, to switch between a series of microphone positions. The diagram in figure 2 shows a typical measurement system for the determination of sound power from sound pressure, showing a real time analyser used with a new 12 channel multiplexer and PC software to control a sound power measurement. It is possible to meet the instrumentation requirements of the engineering and survey grade methods using a relatively low cost sound level meter with octaves.

2.3 Calibration

All of the standards require a calibration check using a sound pressure calibrator at one or more frequencies before measurements are started. For the precision methods this calibrator must have an accuracy of $\pm$ 0.2dB. For the other methods $\pm$ 0.5dB is satisfactory. The calibrator should itself be checked annually and the full instrumentation system should be calibrated by the manufacturer at the specified interval. At Bruel & Kjaer this would normally be either eighteen months or two years.

3. INSTRUMENTATION FOR SOUND INTENSITY MEASUREMENTS

3.1 Sound Intensity Measurement Methods

It is worth remembering that the current techniques for measuring sound intensity are relatively recent. The first Bruel & Kjaer sound intensity analyser was released in 1977 based on an existing single channel digital filter analyser extended to two channels and a sound intensity probe using a pair of spatially separated and phase matched microphones. The operation of the current generation of instruments from all manufacturers now follows this basic example in terms of probe configuration, however, the processing techniques vary and include systems based on both analysers and PC's and processing based on both digital CPB filters and FFT. The current Sound Power Instrumentation generation of analysers are smaller and cheaper than the originals and the probes have become more robust. Together with the improved acoustic performance of the measuring systems this has made sound intensity a workable measurement technique and especially effective for the determination of sound power.

Sound intensity is calculated from a measurement of sound pressure from two microphone positions and a calculation of particle velocity based on a measurement of the pressure gradient between two microphone separated by a known distance. So the sound intensity probe is simply a device that measures two sound pressures at a known separation. The processor then calculates the mean sound pressure between the two microphones. The particle velocity is calculated from a finite difference approximation of the pressure gradient at the mid-point of the two microphones and by knowing the density of the air in which the measurement is made the particle acceleration and therefore the particle velocity can be calculated. Then the sound intensity can be calculated by multiplying this signal with the mean pressure signal and time averaging. This calculation is shown graphically in Figure 3.

The method used to measure sound intensity means that the minimum requirements for instrumentation to measure sound intensity are different from those for the determination of sound power from measurements of sound pressure. Not least because the determination of sound intensity relies on pairs of spatially separated microphones and is consequently always a two channel measurement. However, because the measurement of sound intensity requires a measurement of sound pressure and because some parts of the instrument requirements are the same (the detectors and the filter characteristics for example) an instrument used for measuring sound intensity can also be used to measure sound pressure. It also true that while the determination of sound power from measurements of sound pressure puts most emphasis in the measurement environment with sound intensity the emphasis is on the performance of the instrumentation.

3.2 Sound Intensity Instrumentation Standards

Because sound intensity is a more recent technique for the determination of sound power the standards for the measurements and the instrumentation are more closely related than those for sound pressure measurements. In fact, BS 7703:Part 1 1993 (ISO 9614-1:1993) Determination of sound power levels of noise sources using sound intensity measurement at discrete points includes specific requirements for sound intensity instruments. It states that a sound intensity measurement instrument and probe that meet the requirements of IEC1043 shall be used, with the additional requirement that Class 1 instruments shall be used for grade 1 and grade 2 determinations.

3.2.1 Processing

IEC 1043: 1993 Instruments for the measurement of sound intensity - Measurement with pairs of pressure sensing microphones, was released at the end of 1993 and is the only current instrumentation standard for this class of instruments. The standard defines two degrees of accuracy designated class 1 and class 2 although there is an additional class, class2X, which has the same requirements as Class 2 but is applied to instruments which do not operate in real time in 1/3 octaves at frequencies of 7.1kHz and below.

The requirements for these two main classes are identical, however the tolerances for class 2 are less stringent. There is also a difference in the requirement for the pressure-residual intensity indices.

3.2.2 Sound Intensity Probes

The same standard specifies requirements for the second component of a measuring system which is the sound intensity probe

The basis for the sound intensity measurement technique means that it is not always possible to measure across the entire frequency range with one probe configuration. It may be necessary to change the spacing or even the microphones to cover parts of the frequency range. The standard requires that it is possible to measure over at least three consecutive octave bands with the same configuration.

The standard also requires that the pair of microphones are of the same type and that if the transducers can be removed they should have identifying serial numbers so that the matched pairs can be identified. It is also a requirement that the probe can be checked with a sound pressure calibrator and a residual intensity testing device.

Figure 4 shows the latest probe configuration form Bruel & Kjaer with a new robust brace and all the parts identified by serial numbers as required by IEC 1043:1993. As with the processor the sound intensity probes are classified in two levels of performance class 1 and class 2.

3.2.3 Complete Systems

A sound intensity instrument comprises a processor and a probe. The degree of accuracy is determined by the lowest class of either component so that a class 1 processor used with a class 2 probe is a class 2 instrument and therefore cannot be used for either a grade 1 or grade 2 determination according to ISO9614-1.

3.2 Sound Intensity Calibrators

Sound intensity instruments needed to be calibrated as sound intensity measurement devices. It is not enough on its own to calibrate them for sound pressure although is a useful check and part of a sound intensity calibration. To perform a proper calibration requires a sound intensity calibrator which can generate a known sound pressure, intensity and particle velocity in a small coupler into which the microphones can be attached. One of the main purposes of this calibration is to determine the residual pressure intensity index and therefore the effective sound intensity measurement range. The dynamic capability of the instrumentation is calculated from the pressure residual intensity index and this indicator of instrument performance, together with the characteristics of the source and environment, is critical in the determination of the validity of the final result. The method for determination of the final accuracy of a sound power measurement is detailed in the measurement standard and requires knowledge of the dynamic capabilities of the instrument.

The dynamic capability is dependent on the pressure residual intensity index which is itself dependent on the inherent phase mismatch in the instrumentation. If we were to feed the same signal to the two microphones then in an ideal system with two totally matched channels the measured intensity would be zero, however in real measurement systems there is some phase mismatch between the two channels and this will mean that even with two identical signals there is some measurable sound intensity. This quantity can be measured by applying the same signal to two channels and measuring the intensity but because the residual intensity actually varies with pressure so the residual sound intensity is expressed as the difference between the measured residual intensity and the measured pressure level known as the pressure residual intensity index.

A sound intensity calibrator, like the Bruel & Kjaer 3541, can be used to check the pressure calibration of the two microphones but more importantly it can also be used to check the pressure-residual intensity index and calibrate for sound intensity by applying a signal to both microphones simultaneously..

In the arrangement used to check pressure-residual intensity index the two microphones of the sound intensity probe are both placed in the same cavity and are fed with pink noise so that the level over the frequency range 45Hz to 7.1kHz differs by only 0.1dB at each microphone and that the phase difference between the signal at the two microphones differs by less than 0.054 degrees at the highest frequency. The difference in phase and level at the microphones is so small that any sound intensity measured by the instrument will be due to phase mismatch in the probe and signal conditioning. The pressure residual intensity index is determined by subtracting the residual intensity level from the sound pressure level in the coupler.

By placing a known phase difference between the acoustic signals at the two microphones the same calibrator can be used to calibrate sound intensity and particle velocity directly. In this type of calibration the two microphones are placed in a single cavity but separated by a coupler which produces a calibrated phase difference between the two sections of the cavity. A pink noise signal is then fed into the bottom cavity and the intensity between the two is measured.

4. CURRENT TRENDS IN THE DEVELOPMENT OF INSTRUMENTATION

The need for sound power measurements is driven almost totally by legislation and competitive pressure. The amount of legislation especially from the EC is growing and its scope is become broader so that many engineers who have little or no acoustic knowledge are going to have to specify sound power levels for their products. Sound power measurements by whichever method is employed are more complex than a simple measurement of sound pressure and in general the equipment or special environments required make these measurements more expensive and time consuming.

The emphasis now is not on greater complexity of analysis but rather on making the current measurement techniques more simple. This means making the instrumentation as portable and robust as possible to allow measurements in normal industrial environments and with equipment which has already been installed. One example of this trend is the new 2260 sound analyser from Bruel & Kjaer which includes two channel real-time analysis in a format which would previously been associated with a sound level meter but in fact include much of the analysis power which would previously be found in only large laboratory analysers.

The second main area of development is in software for the determination of sound power from both main methods. An example of this is the new Bruel & Kjaer 7679 Sound Power Software which uses a straight forward flow chart layout to make measurements to ISO9614.2 as simple as possible for the non-specialist engineer. The role of the software in the complete measurement system can be seen in Figure 1 where it is used to control the measurement, calculate the indices, validate the measurement and suggest remedial actions if the measurement is not fulfilling the requirements of the standard. The same software will also produce reports and store a full set of measured data.

The newer legislation relating to noise from products will continue to emphasise the importance of sound power, at the same time the cost of the special environments required to determine sound power levels from measurements of sound pressure will make these techniques prohibitive. Therefore it is likely that sound intensity techniques will continue to be a key area of development for the instrumentation measurement systems manufacturers. In addition given the types of industry which will be effected by the legislation the emphasis will be on making sound intensity more accessible rather than on developing even more advanced analysis techniques.

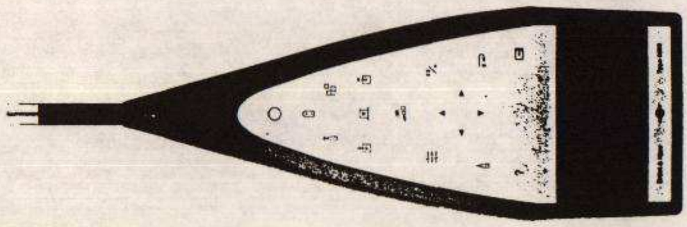

Figure 1: Bruel & Kjaer 2260 Hand Held Analyser

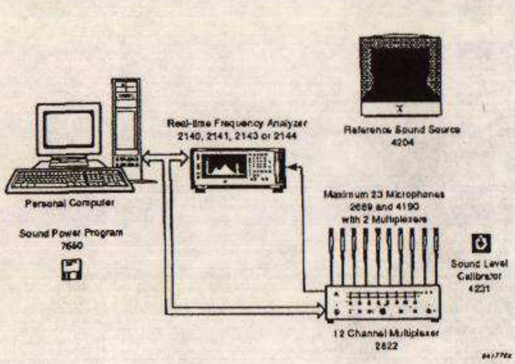

Figure 2: Sound Power Measurement System

Sound Power Instrumentation

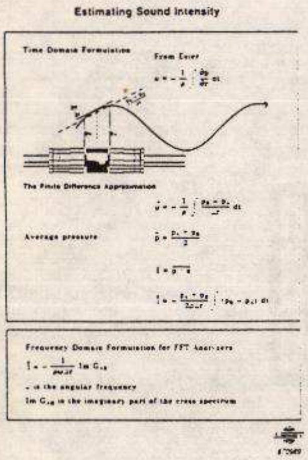

Figure 3: Sound Intensity Calculation

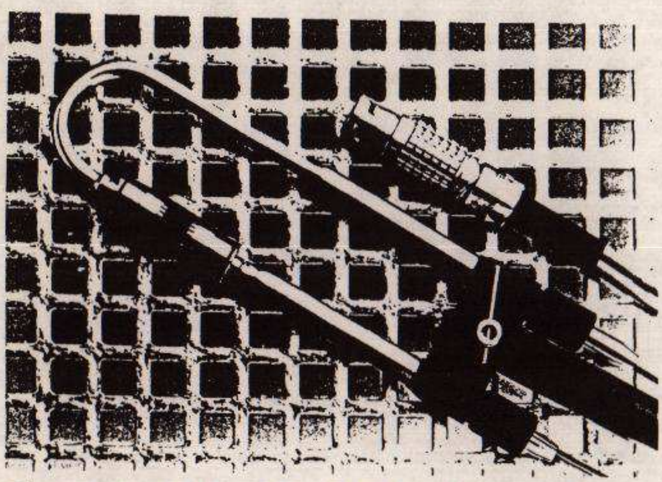

Figure 4: Bruel & Kjaer Type 3548 Sound Intensity Probe