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A HAND-HELD SOUND INTENSITY SYSTEM

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1. INTRODUCTION

Although the advantages of the sound intensity technique for several types of acoustical measurements have been acknowledged for many years, the technique has not yet been fully exploited in industrial situations due to a lack of convenient instrumentation. The first commercially available systems in the mid 1980's had limited functionality and were around 30kg in weight. By the 1990's, functionallity and user friendliness was increased and weight was reduced to 5kg. The use of PC's has also contributed greatly to the ease of use of intensity systems. However, there are still a number of practical considerations which need to be addressed before one can say one has a hand-held sound intensity system. This paper presents a hand-held sound intensity system at under 2kg in weight, specifically designed to make on-site sound intensity measurements easy to perform and to determine sound power according to standards without the use of extra processing power.

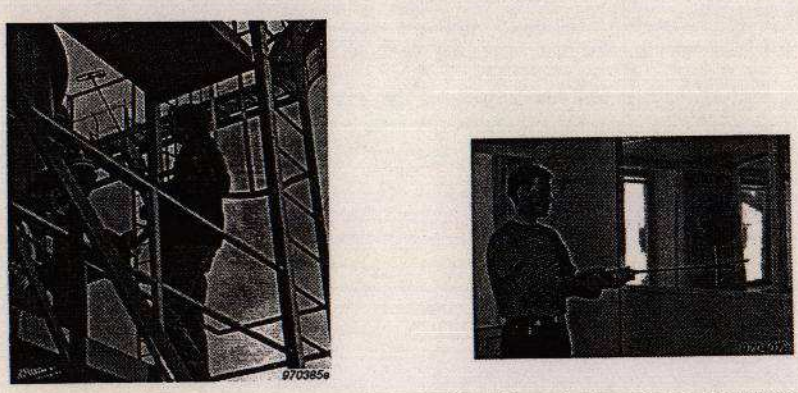

Fig.1. Hand-held Sound Intensity System equipped with intensity probe based on a sound level meter platform for determining sound power on site (left); for determining intensity sound reduction index (right)

2. REQUIREMENTS FOR ON-SITE MEASUREMENTS

For measurements on-site, the requirements are that the sound intensity system needs to be:
1. Hand-held equipment which means only one person is required to perform the measurement
2. Cable free to enable the user to climb up ladders, along cat-walks etc., without hindrance
3. On the spot results to enable the operator to verify the measurements before leaving the site
4. Battery operated to give the user increased autonomy.

3. IMPLEMENTATION IN A HAND-HELD SYSTEM

Based on a type 1 sound level meter, a sound intensity system has been developed, which conforms to IEC 1043 (1993) "Sound intensity instrumentation Class 1" , IEC 1260 (1995) Octave and 1/3 octave bands Class 0 and ANSI S1. 11 (1986) Octave and 1/3 octave bands, order 3 type 0. The system consists of an analyser (Investigator Type 2260) a software package (BZ7205), a sound intensity probe (Type 3595) and a number of accessories specifically designed with on-site measurements in mind. Measurements and calculations can be made according to the following standards (Table 1).

Standard	Degree of support
Sound Power ISO 9614-2 (1996). Sweep method	*All criteria directly supported*
Sound Power ISO 9614-1. Point method.	*Only a few criteria supported*
Sound Power ECMA 160 (1992). Sweep method.	*All criteria directly supported*
Sound Power ANSII S12.12 (1992)	*Most of the relevant criteria are supported*
Building Acoustics ISO 140-5, (Draft 1996) appendix E	*All criteria directly supported*

Table 1. Measurements and calculations supported by the hand-held sound intensity system

Until recently, it was the accepted measurement practice that for sound intensity measurements up to 5kHz a pair of 1/2" microphones and a 12mm spacer was used and for measurements up to 10kHz a pair of 1/4" microphones and a 6 mm spacer was used. Based on recent work by F.Jacobsen, V.Cutanda and P.Juhl at the Technical University of Denmark, described in an article in Technical Review No.1 1996 entitled "A sound intensity probe for measuring from 50Hz to 10kHz" [ref.1], it has been shown that one can measure up to 10kHz using the usual 1/2" microphone pair and a 12mm spacer. The reason is that for this particular probe configuration, the resonances in the cavities in front of the microphones give rise to a pressure increase that, to some extent, compensates for the finite difference error thus extending the frequency range. The analyser contains a correction which supports this measurement method. The correction is added to the measured sound pressure and thus to the sound intensity spectrum.
Note that the limitations for sound intensity measurements at low frequencies are unchanged. These limitations are due to:
1. The spacer length
2. The Pressure Intensity Index of the sound field
3. The Pressure Residual-Intensity Index of the instrumentation which is usually limited by the phase matching of the microphones
4. The dynamic capability stipulated by the standard being followed.

4. SOUND POWER DETERMINATION

The most appropriate standard for on site determination of sound power is the sweep method as described in ISO 9614-2 (1996). The Hand-held Sound Intensity System has been optimised to support this standard by means of time saving procedures, status codes and easy-to-use tools to help navigate

through the measurements. The degree to which the various standards are supported by the system is given in Table 1. If, however, the user wishes to work according to his own procedure, he is free to do so.

It has been usual practice that the first step in a sound power determination is to define a measurement surface divided in segments and then to made measurements in a predefined sequence. This method does not allow for unforeseen occurrencies such as the need for extra segments or a changed measurement sequence. With the hand-held sound intensity it is not necessary to make an advanced plan when making sound power determinations. The user can:

1. define the surfaces and measurement sequence and measure as instructed OR
2. just start measuring, store the results and define the areas afterwards OR
3. define the surfaces and the measurement sequence, measure as instructed and modify the surfaces as and when required.

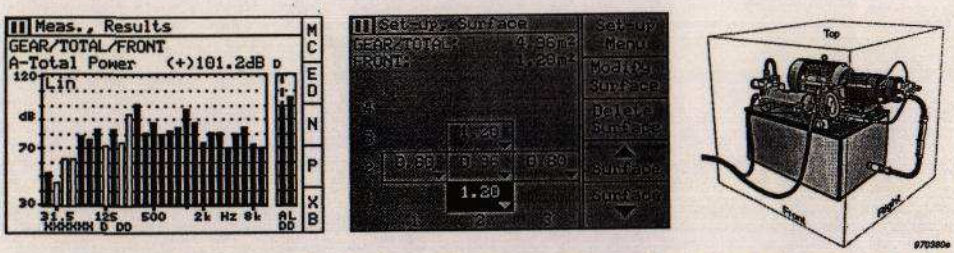

Fig. 2. Screen showing sound power spectrum with status information (left); predefined surfaces on the screen (centre) representing the measurement surface surrounding the sound source (right)

The system helps the user by providing automatic selection of the next predefined segment, together with visual and aural feedback via head-phones to give step by step guidance. As an example of a time saving feature of the system, consider the "repeat scan" feature used when making measurements on a number of surfaces. The ISO 9614-2 standard prescribes two scans on each measurement surface. The second scan must be orthogonal to the first. By using just one soft key on the instrument, a complete measurement sequence can be performed as the key changes function underway from "Start first scan" on the first surface, "Start 2nd scan" on the first suface, "Stop and store", "Start 1st scan" on the second surface and so forth until all surfaces are measured.

The quality of the results can be evaluated by means of the status codes associated with each spectrum (e.g. repeatability failed, Dynamic capability failed, excluded segment or frequency band, area not defined). The status codes have various degrees of severity (e.g. warning or fatal) and are prioritised on the screen.

The user interface provides two modes of operation one for measuring (where the measurement grid and relevant status codes are shown) and one for evaluating (where the measured spectrum is shown). In each mode, one can switch from the "measurement control" to "results" by one key push. There is no time consuming storage and then recall of data; the user can toggle between relevant screen displays.

When the measurement is finished, the user can navigate through the results using the softkeys on the instrument. From the total power (Fig.3), the user can choose to see more detail of the measurement by looking at the power on each surface. He can then step further, to see the power on each of the segments

which comprise the surface. At each "level" of detail, the user may choose to see the corresponding sound power spectrum.

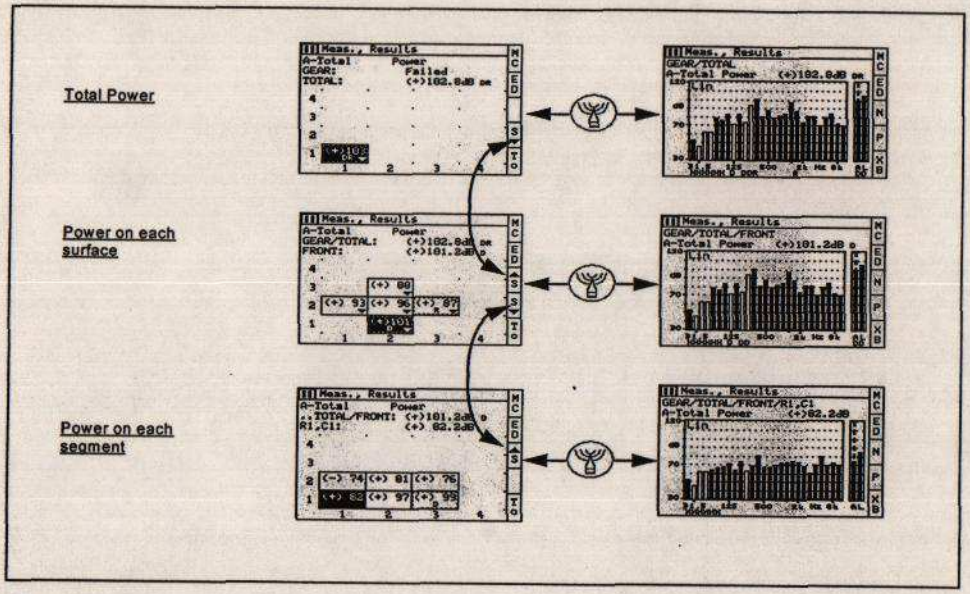

Fig.3. User interface enables one to navigate easily through the various levels of detail of the sound power mesurement. Total sound power (top), sound power on surfaces (centre), sound power of one of the segments of the front surface (bottom)

5. CALIBRATION AND VERIFICATION

Complete calibration, including a verification of the Pressure Residual-Intensity Index, can be made using a Sound Intensity Calibrator. If required, the system can be supplied with documentation for an initial Pressure Residual-Intensity Index verification. Pressure calibration alone can be performed using a Sound Level Calibrator and a coupler. The probe reversal, sound intensity check, as described in the standards, is supported by the system.

6. NOISE SOURCE LOCATION & NOISE MAPPING

Being hand-held, the system is very effective for tracking down, for example, squeaks and rattles in vehicles. A compass display and instantaneous spectrum are available for on line source location. The compass data shows the direction of incidence of the sound energy relative to the probe. With its advanced book-keeping features, the hand-held sound intensity system is capable of collecting and

storing a large number of spectra in a simple and flexible manner. Up to 400 measurement points can be displayed on the screen in a grid of rows and columns as a noise number map.

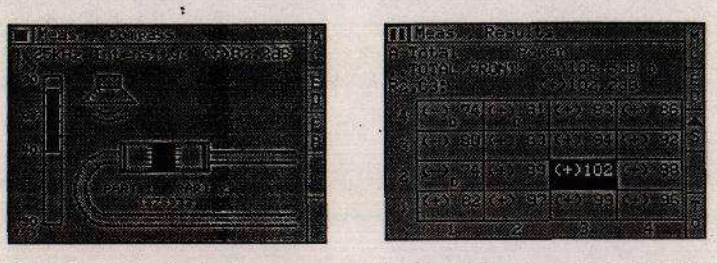

Fig.4. Compass display for noise source location (left); noise number map(right).

7. BUILDING ACOUSTICS AND USEFUL EXTRAS

Building Acoustics ISO 140-5, (Draft 1996) appendix E is supported by the system enabling intensity sound reduction index to be measured in order to obtain information about contributions from various flanking and leakage transmissions to the total sound reduction index. Used together with the noise number map, this is a powerful tool to reveal "hidden" flanking transmission paths.

To reduce the likelihood of any part or accessories being forgotten, the complete system can be stored and transported in a weather-proof case. In situations where the user needs both hands free to gain access to the measurement site, it is a great advantage to wear the carrying harness. It can hold the analyser close to the body by means of velcro straps or on a leash when measuring. The sound intensity probe and a telescopic boom (with an extended length of 4,2m) can also be firmly attached to the harness while climbing.

8. SUMMARY

A complete, hand-held sound intensity system has been described. The fundamental idea behind the design is that sound intensity measurements have to be made simple. By means of extensive help functions, visual and aural guidance, extra accessories and low weight, the system is eminently suitable for on site, sound power determinations based on standardised intensity measurements without the need for extra processing power.

9. REFERENCES

[1] F.Jacobsen, V.Cutanda and P.Juhl, Technical University of Denmark, "A sound intensity probe for measuring from 50Hz to 10kHz", Brüel & Kjær Technical Review No.1 1996

[2] Product Data sheet "Hand-held Sound Intensity System consisting of 2260 Investigator and Intensity Software BZ7205 (Type 2260E) and Sound Intensity Probe Kit for 2260 (type 3595)", Brüel & Kjær