Application Notes

Sound Power Determination of Household Appliances on the Production Line

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Introduction

A low noise level is becoming a significant parameter when choosing household appliances. For instance, it is not uncommon in Central and Northern Europe to see operating sound pressure levels advertised for household appliances, the advertised values having been taken from manufacturers' original data or measured by consumer associations. One problem with these data is that they are inconsistent; they depend on the location in which the data are taken. Hence, faced with competitors quoting the noise levels of their products, and the possibility of consumer associations measuring and advertising the noise levels of his own products, it is becoming increasingly important that a manufacturer is aware of how much noise his products make. In particular, he must determine their sound power output so that, if necessary, this can be reduced in order to remain competitive and, in some cases, comply with regulations. A Danish company, Nilfisk, takes this further step by specifying both the operating sound pressure and the sound power for their appliances in their brochures. The measurements in this brochure were all taken at the Nilfisk factory.

Fig. 1. Set-up for sound power determination of a Nilfisk industrial vacuum cleaner (Courtesy of Fisker & Nielsen A/S)

Up until recently, the only way of determining sound power has been through the measurement of sound pressure levels. Such measurements involve the use of special facilities, i.e. anechoic and reverberation chambers, which involve a considerable investment on the part of the manufacturer and may be beyond the means of a small company.

This problem, however, no longer exists as a method has been developed which allows the determination of sound power in an ordinary room, even with considerable levels of background noise. This is done through the measurement of sound intensity (see Fig. 1).

Sound Intensity in Sound Power Determination

Sound intensity is measured using a two-microphone probe. By determining the average sound pressure level between the two microphones and the pressure gradient over a fixed distance between them, the pressure and particle velocity are determined. From these the sound intensity level is calculated. Sound intensity is a vector quantity, i.e. has both magnitude and direction. Since the result obtained depends on the pressure gradient between the two microphones, it is the component of the intensity vector along the axis of the probe (defined as a line joining the centres of the two microphones) which is determined.

A measuring surface is defined around the object for which the sound power is to be determined. This surface may be of any shape and size as long as it encloses *only* the source to be investigated. Measurements are then made by dividing the surface up into segments and determining the sound intensity for each segment. By taking measurements with the axis of the probe at right-angles to the measuring surface, it is ensured that the contribution of all sound energy leaving the volume enclosed by the surface will be measured.

The vector nature of sound intensity is the great advantage of this method of sound power determination. This vector nature is directly responsible for the ability to conduct measurements in any room and in the presence of background noise. That this is possible can be seen by studying Fig. 2. Provided the source within the measuring surface is non-absorbing, any sound entering the volume enclosed will either pass straight through or be reflected out again. Thus, although the background noise will effect the result of a measurement for a single segment, when the result is found for the entire surface, contributions will cancel: the only sound contributing to the measurement result is that originating from the source under investigation.

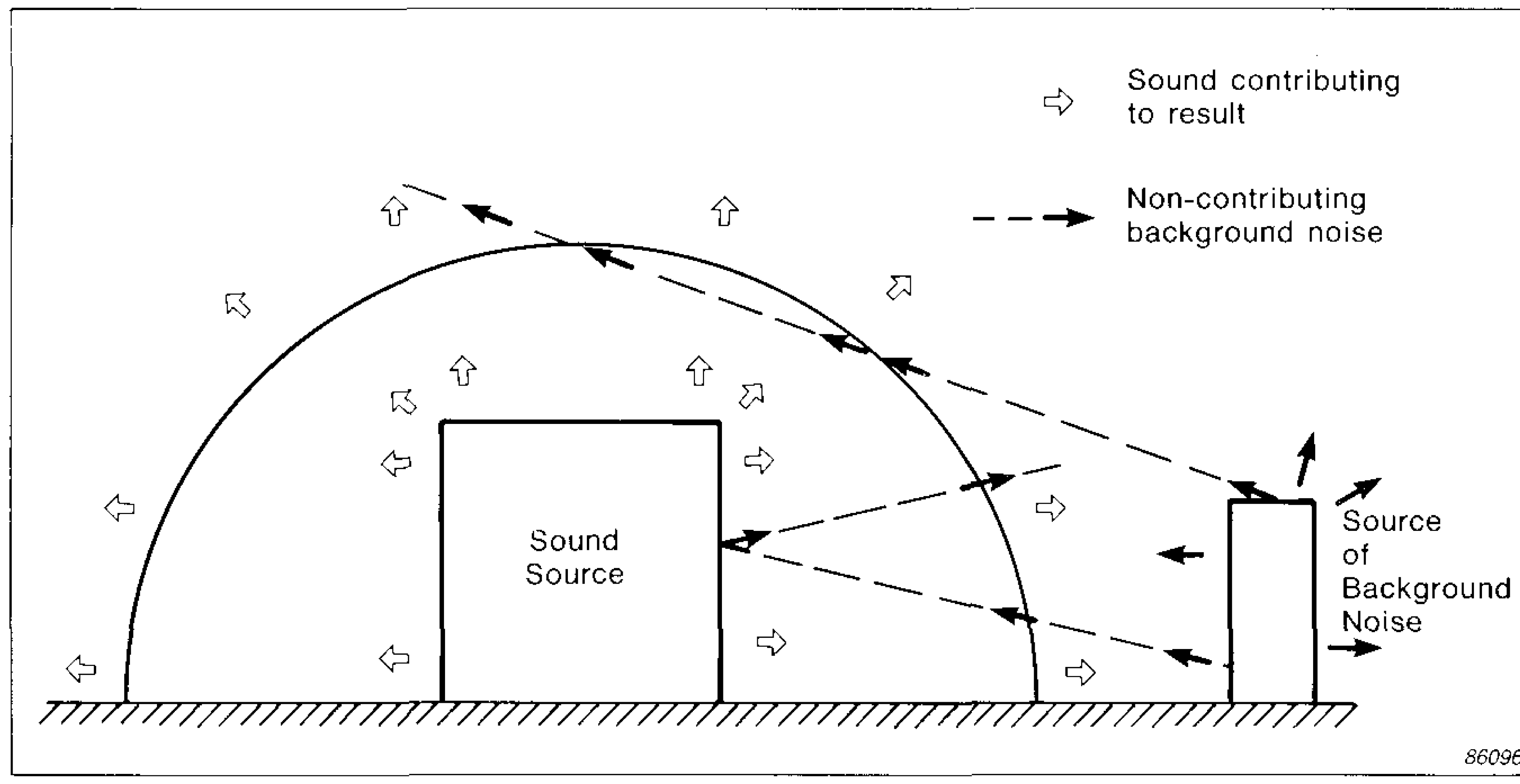

Fig. 2. Background noise and reflections do not contribute to the result of a sound power determination made by measuring sound intensity

Point or Sweep Measurements?

There are two ways of making measurements:

(i) Point measurements. A measurement point is assigned to the centre of each segment of the measuring surface and a single measurement taken for each point.

(ii) Sweep measurements. While the measurement is being made, the probe is swept over a path which covers the entire segment as uniformly as possible.

The methods have both advantages and disadvantages. For point measurements, repeatability is high, but closely spaced points are needed for an irregular sound field: the method is slow. With sweep measurements there is the possibility of errors arising from irregular sweeps, but the method is fast and repeatability can easily be checked.

Measurement Accuracy

To ensure repeatable measurements, a sufficiently long averaging time should be used. This can be checked by doing a number of linear averages at a point or over a surface and comparing the results. If the variation is too large, then the averaging time should be increased.

If high levels of background noise are present or if the field is very reverberant, the results may be incorrect. To check this, compare two measurements at the same point but with the probe reversed 180° for the second measurement. Results should be the same but with opposite sign. A shift in level of 2dB indicates a bias error of 1dB [ref. 1].

Instrumentation

The equipment necessary [ref. 2] for a sound power determination in situ is illustrated in Fig. 3. The advantages of using this equipment are that it is all portable and battery operated and so can be used anywhere. Also, using the 12mm spacer, a frequency range of 100Hz to 5kHz can be covered accurately (see Fig. 4).

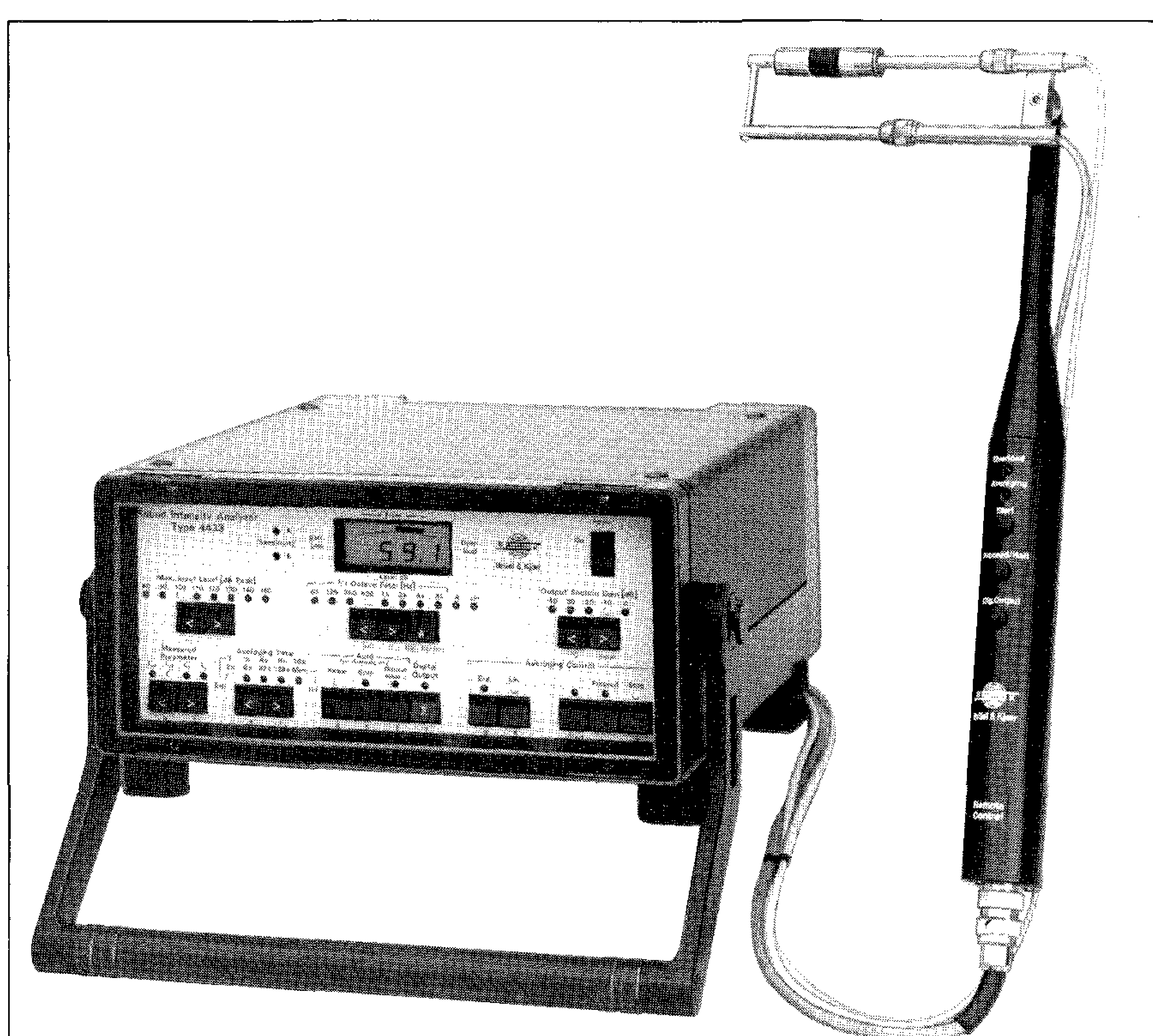

Fig. 3. Equipment used for sound power determination in situ

Case History*

Measuring conditions

The case considered here is that of the determination of the sound power of a Nilfisk industrial vacuum cleaner using the measurement set-up shown in Fig. 1. The measuring surface, defined by the wooden frame seen in the figure, was 1 m square and 1,2 m high in order to allow a reasonable distance from the surface of the vacuum cleaner to the measuring surface.

The hose of the Nilfisk was laid out to its maximum extension so that noise from the nozzle was produced outside the measuring surface and, being steady, could thus be ignored for the purposes of the sound power determination. All other noise produced within the factory was also outside the measuring surface and of a constant level** and gave no contribution to the result.

Measurements of sound intensity level were made by using the sweep technique with the 4433 set to Manual averaging so that measurement could be stopped as soon as a sweep was completed. Thus, the average sound intensity was found for each segment in turn and from a knowledge of the segment areas the sound power calculated.

Measurements

The following measurements were taken (Note: all measurements were A-weighted):

1. Pressure measurements in the 63 Hz to 8 kHz octave bands plus a broadband measurement.
2. Sound intensity measurements in the 500 Hz to 4 kHz octave bands plus a broadband measurement, swept over the measuring surface divided into five segments.
3. Two broadband intensity measurements over the measuring surface divided into five segments.
4. Broadband intensity measurement over the measuring surface divided into twenty segments.

* All measurement results are reproduced with the permission of Fisker & Nielsen A/S.

** Except for an airgun in the packing area. The sound from the gun, although audible and non-stationary, did not influence the measurements, as shown later.

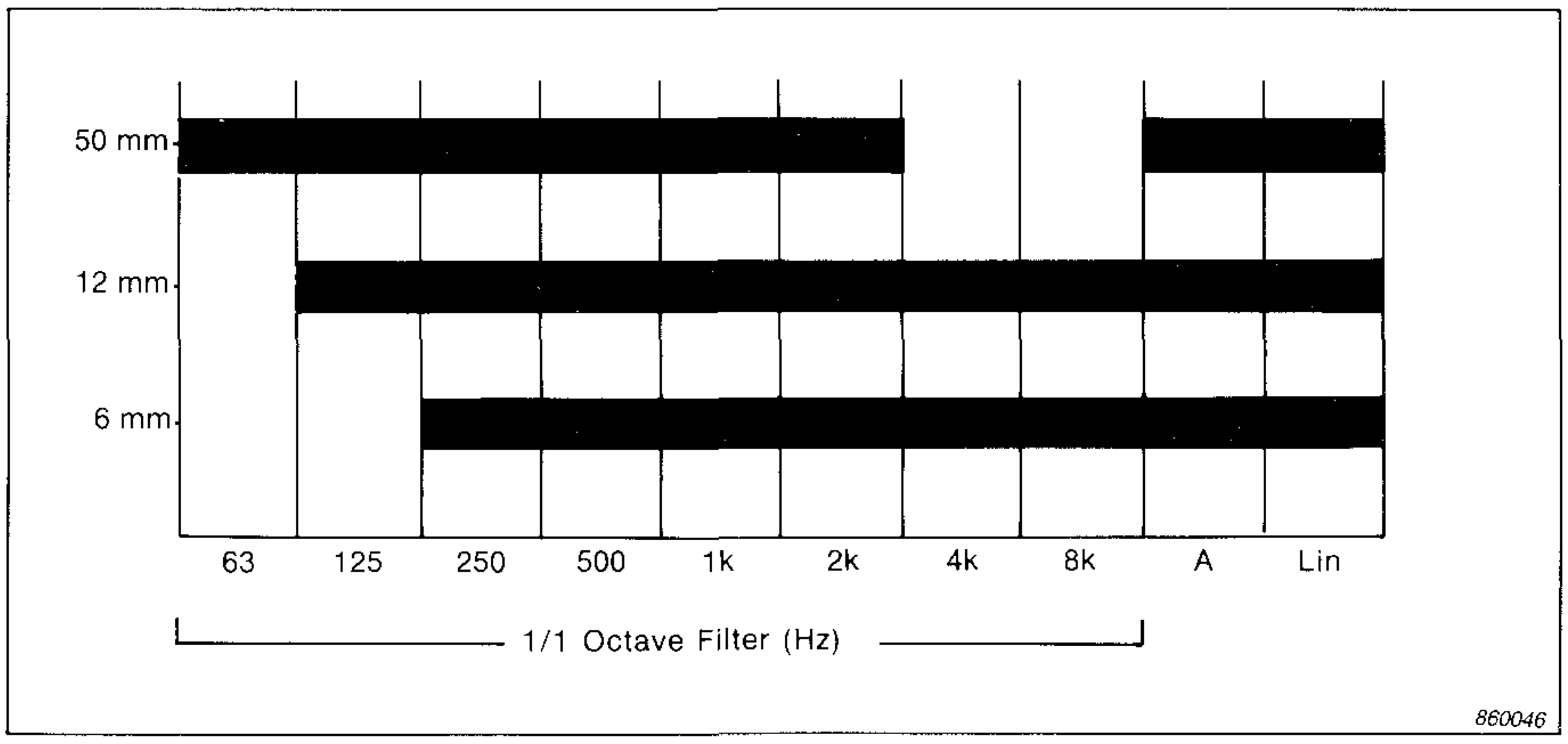

Fig. 4. Range of filters available for intensity and velocity measurements using the 4433 and 3520 with microphone separations of 6, 12 and 50 mm

These will now be considered in more detail.

1. Pressure measurements, taken over the top face of the measuring surface, were made in the octave bands from 63 Hz to 8 kHz. The values in the octave bands from 500 Hz to 4 kHz were summed to compare with the results of a broadband measurement taken under the same conditions. The results are presented in Fig. 5. Assuming that the A-weighted sound pressure spectrum measured is a good representation of the spectral shape of the A-weighted power, it can be concluded that the bulk of the A-weighted power is found in the frequency range from 500 Hz to 4 kHz. Since the intensity probe fitted with a 12 mm spacer measures with high accuracy in this frequency range, the A-weighted sound power may be determined directly from a broadband measurement.

2. To verify the assumption stated above, the A-weighted sound power in the 500 Hz to 4 kHz octave bands as well as the broadband power were determined by intensity measurements. The Sound Intensity Probe was swept over each of the five faces of the measurement surface in turn. The areas over which measurements were taken were accounted for and the results averaged to obtain the sound power. The results gave very good agreement, in-

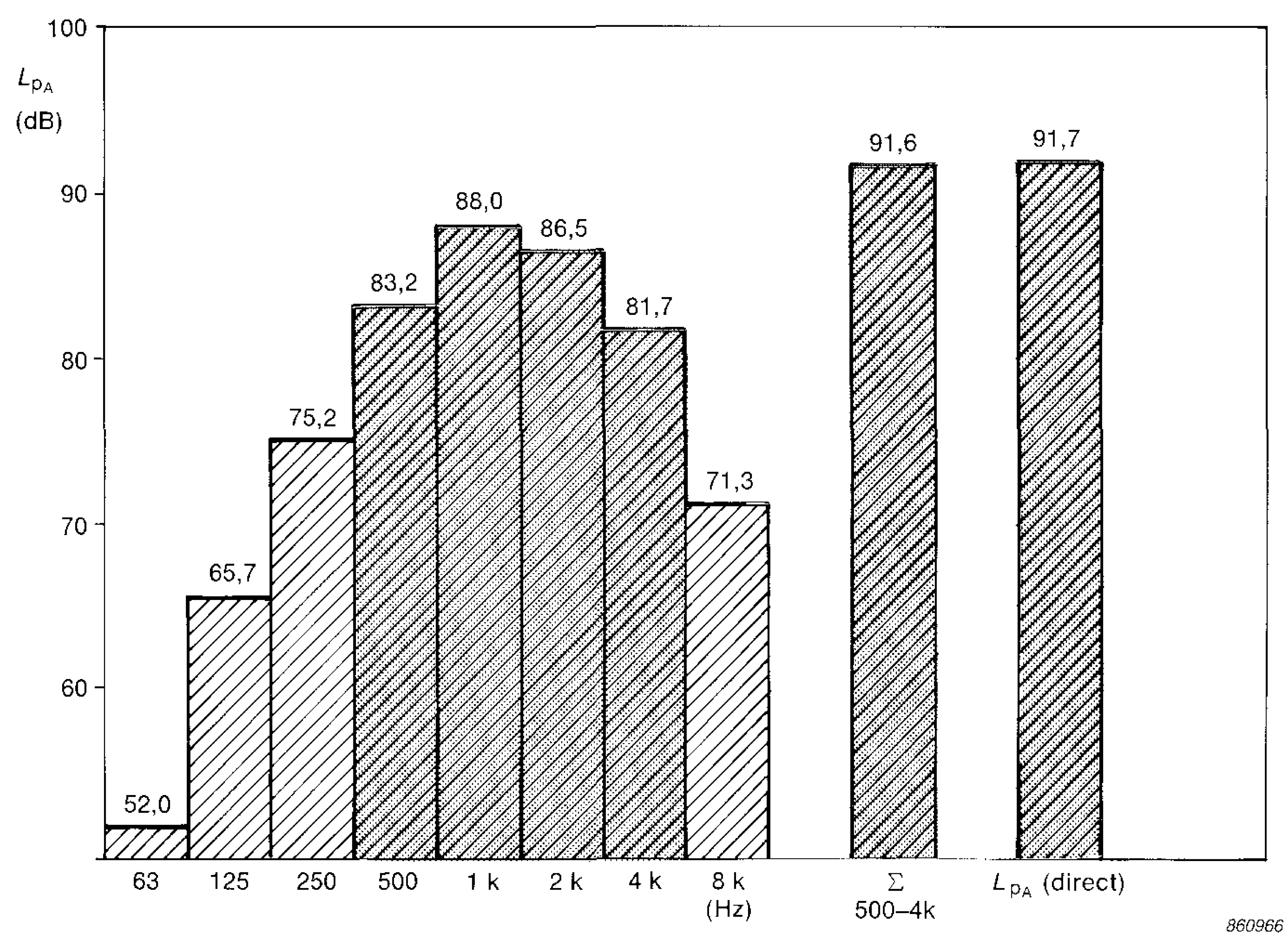

Fig. 5. Comparison of octave (500 Hz to 4 kHz) and broadband measurements of sound pressure level above the vacuum cleaner

dicating the validity of using broadband measurements to determine the sound power. The results are presented in Fig. 6.

3. To check reproducibility of the results, the broadband measurement described in (2) was repeated twice. The results are also presented in Fig. 6.

4. Finally, string was used to divide each of the five faces into four equal parts so that the measuring surface comprised twenty segments. If the inevitable non-steady movement of the probe during the sweep gives rise to inaccuracies, measurement over the twenty segments should give a different and more precise result. As can be seen from the results (Fig. 6), the same answer is obtained as for five segments so the results of a five-segment measurement can be accepted with a good degree of confidence.

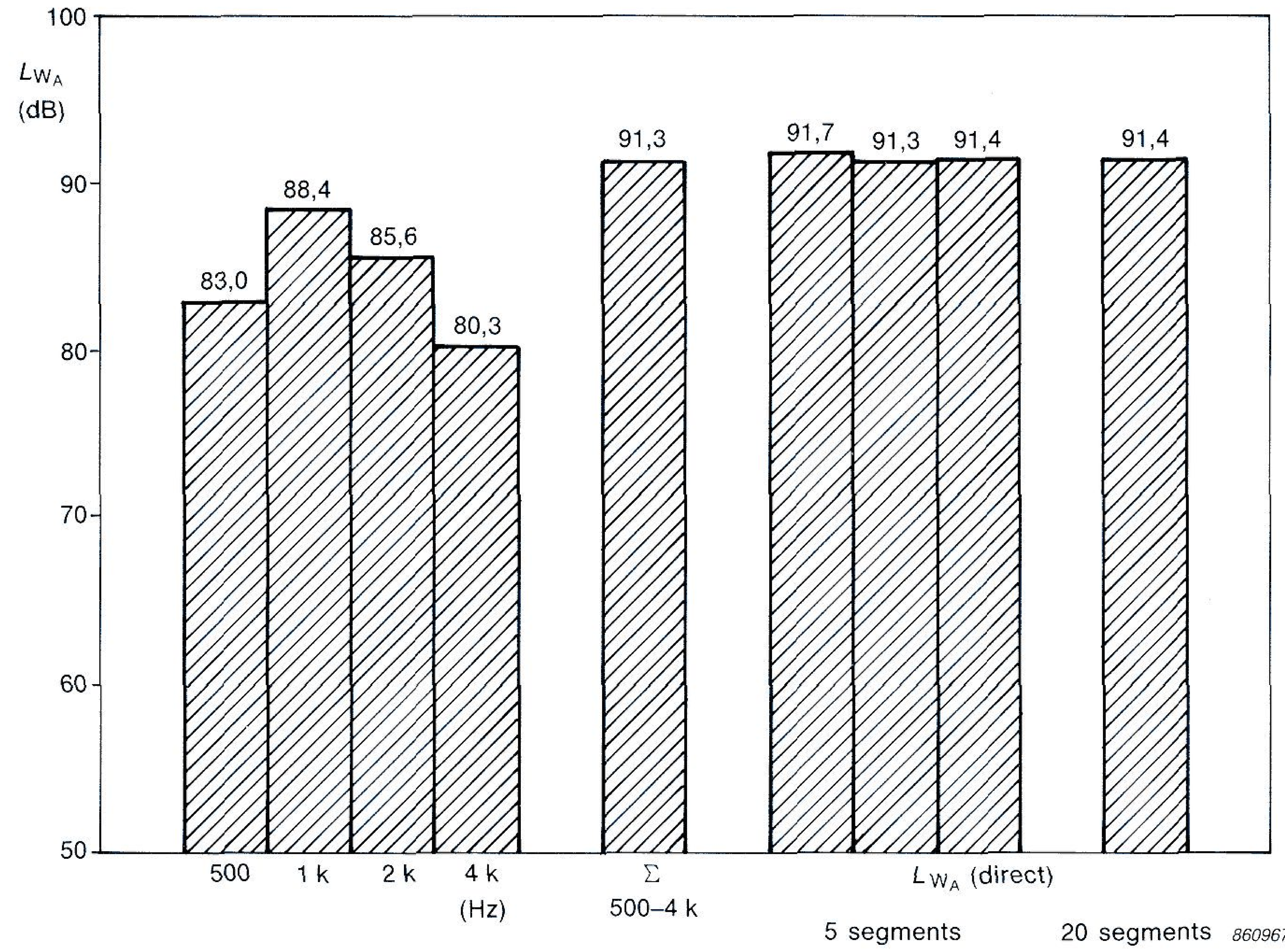

Fig. 6. Comparison of octave (500 Hz to 4 kHz) and broadband measurements of sound intensity over the five faces of the measurement surface. Also presented are the results of sound power determinations with the measuring surface divided into five and twenty segments

Conclusions

It has been shown in the case of the Nilfisk vacuum cleaner considered here, that the sound power can be determined by broadband sweep measurements over the five faces of the measuring surface. Consequently, now that the initial investigation has been made, any future sound power determination can be made in the same way. This can be done in less than two minutes!

In conclusion, it can be said that fast and simple quality control of household appliances is no longer a problem. The measurements made here on the factory floor imply that tests can be made on the production line – they can be done very quickly and no expensive facilities are needed!

References

[1] More information on sound intensity and how to measure it can be found in the B&K Handbook "Sound Intensity". A description of similar measurements under adverse conditions (high levels of background noise and strong reflections) can be found in: Nielsen, T.G., "Field Measurement of Total A-weighted Sound Power and Sound Insulation using a Battery Operated Intensity Analyzer", Internoise Proc. (1985).

[2] Details on the instrumentation can be found in the Product Data Sheets for the Sound Intensity Analyzer Type 4433 and the Sound Intensity Probes Types 3519, 3520.

Further Reading

For an in depth discussion of sound intensity measurements, see the B&K publication "Validity of Intensity Measurements in Partially Diffuse Sound Field", Technical Review No.4 – 1985. Further articles can be found in Proc. 2nd Int. Congress on Acoustic Intensity, CETIM, Senlis, 1985. A list of further references can be found in the B&K publication "Reference Literature for Sound Intensity".

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