

# Guided Tour

## Sound Power Determination using Type 3554, with or without ISO 9614-1

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### Noise Directives – Machinery

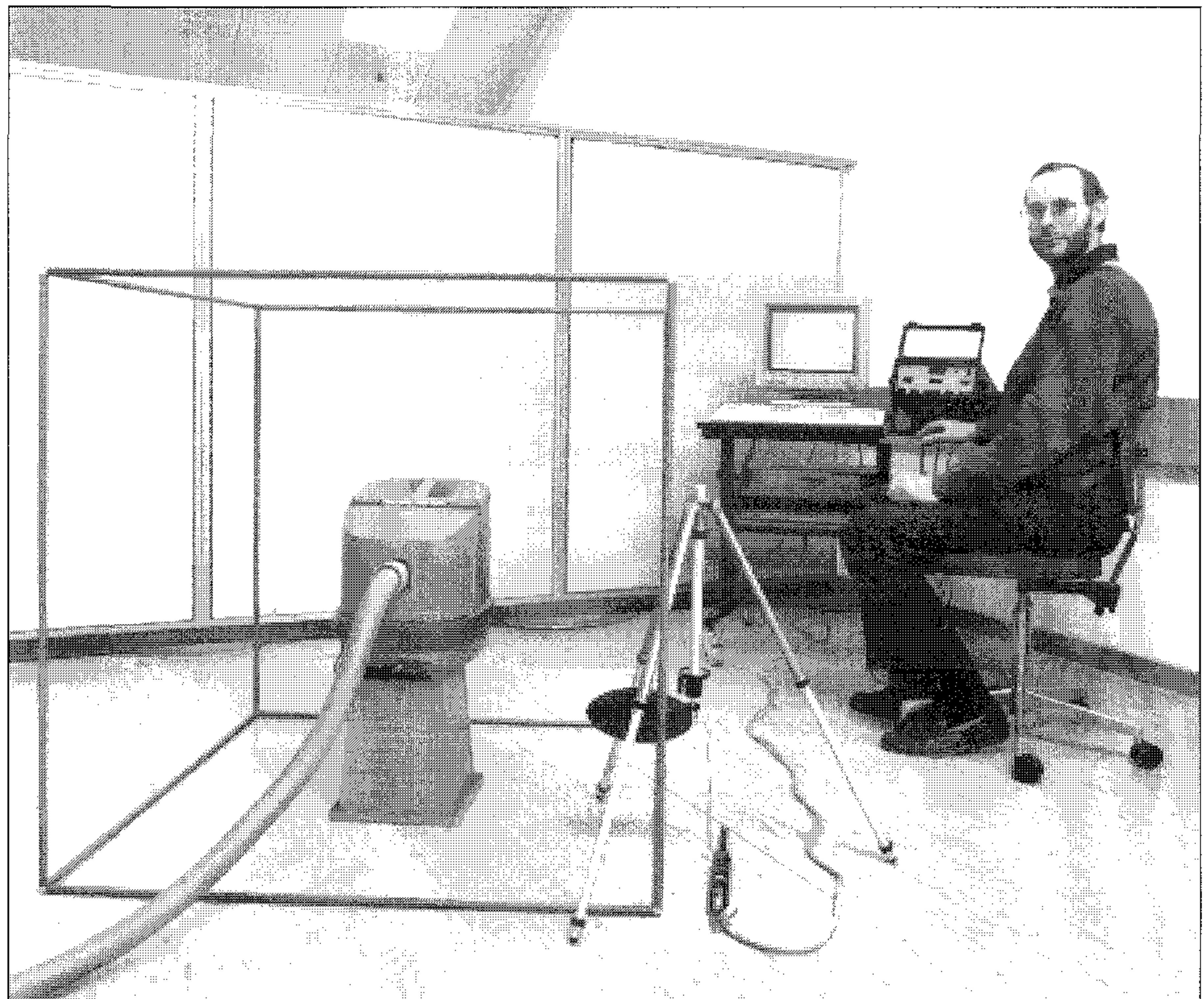
In Europe, a new “Machine Directive” has been written, coming into force from 1/1/95. The purpose of this directive is to ensure the health of people using machines.

The directive states, among other things, that all equipment sold in Europe must fulfil specified noise demands. The equipment covered by his directive is everything from tooth-brushes, washing machines, office machines and hand-held drills to cars and heavy vehicles.

What should be stated on the equipment?

If the A-weighted sound pressure level is below 70 dB(A), no action needs to be taken. Between 70 and 85 dB(A), the A-weighted sound pressure level should be stated, and if the noise exceeds 85 dB(A), the A-weighted sound power level should be stated. If the machine is very big, the sound power level is replaced by the sound pressure level measured at significant positions.

If the noise contains peaks exceeding 130 dB, this must also be stated.



### Introduction

Driven by the new Directive, a large number of factories, producers and small contractors will in the near future begin to make sound power measurements. For some, these measurements will be their first contact with the acoustic environment.

The purpose of this application note is to show novices how easily the sound power measurements can actually be performed. For this purpose we have chosen a modern “Nilfisk” vacuum cleaner from the Danish manufacturer Fisker & Nilsen. The measurements are first done according to ISO 9614-1 and then as simply as possible. As you will see, the results are very close.

### Instrumentation

For the sound power determination of the vacuum cleaner we have chosen the low-cost sound power package **Type 3554**, containing all the necessary equipment and software.

To fulfil the ISO 9614-1 standard, you must measure the “Dynamic Capability” of your equipment. This can be done by placing the two microphones in the small acoustical coupler DP 0888 (included) and exposing it to any broadband noise source, but for precision measurements it is strongly recommended to use the Brüel & Kjær Sound Intensity Calibrator **Type 3541**.

### Calibration

The first thing we should do before making any measurements, is to calibrate our instrumentation. Use Sound Level Calibrator Type 4231. Loosen the preamplifiers and remove the spacer. Mount microphone A and B in the acoustical coupler DP 0888 and put it onto the Type 4231.

Check that the switches on the back of Type 4437 are set correctly (12 mm, 200 V, 12.5 mV/Pa).

When we turn on Sound Intensity Analyzer Type 4437, it wakes up in exponential averaging, measuring A-weighted sound intensity. Select the “Parameter” “ $L_{pA}$ ” and adjust the “Sensitivity A” with a small screwdriver until you get correct reading

on the display (normally 97 dB). Channel A is now calibrated. Repeat the sound pressure calibration for channel B. The system is now calibrated. Select the 12 mm spacer for the intensity probe.

## Making measurements according to ISO 9614-1

To perform measurements according to the standard, you need a IBM PS/2 or IBM PC AT computer (or compatible) with a National Instruments IEEE interface board. The computer acts as controller and Sound Intensity Analyzer Type 4437 as front end.

Connect the IEEE cable between your computer and your analyzer, and mount the software protection key on the back of your computer. Whenever the "protection key" message turns up on your computer screen, press <Enter> to continue. Check that your GPIB Device Map in the C:\MC-GPIB\IBCONF.EXE file contains a device called [BK4437] with primary GPIB Address 16 (Default factory setting of 4437). The other settings are not important.

Start Brüel & Kjær Sound Intensity Program WT9378.

First select the correct analyzer and the standard according to which you will measure in the **Config** menu. Select **Edit**, then **Program**.

You will now select Sound Intensity Analyzer Type 4437. You can change analyzer by pressing <space> on the computer. Accept the settings by pressing the function key <F2>.

Next to be selected is the **standard**. You will select the standard "ISO 9614". This standard provides three grades of accuracy:

- Precision
- Engineering
- **Survey**

Note that only the survey grade supports A-weighted sound power determination.

To ensure the quality of the sound power determination, the standard prescribes a number of checks (boolean expressions). These checks are based on different measurement calculations called **Field indicators**.

The next two lines control the "short time average". This is used for the field indicator F1 (normalized standard deviation of the intensity flow from the source).

Test of the equipment phase mismatch  $L_d$ : Set the **Dynamic Capa-**

**bility averaging time** to 32 seconds, press <F2> to accept the changes and <Esc> to return to the **Config** menu. Move the cursor down to **Store** and press <Enter>.

### Measurement Set-up

Select **Analyzer** and the type of surface you would prefer. Choosing the **Grid** normally gives the easiest and fastest sound power determination.

The program provides two lines of text information. In **Text1** line you can, e.g., write "Vacuum Cleaner", and in **Text2** line you can write "ShoeBox: All 5 areas" or you can state the name of the model. The **Filename** can, e.g., be "VAC01".

Move the cursor down to **Weighting** and select "Linear" (the program calculates the A-Weighted power).

Because only the A-weighted value is of interest, you will select the **Frequency range** and write: "125 - 4000" which is the maximum range for a 12 mm spacer.

Select **Microphone spacer** and write "12" mm. The next two lines must correspond to the environment, or the sound intensity and power determination will not be correct.

The **Averaging time** should be selected carefully. If you select a short time (2 s) the measurements will be very fast but the accuracy will be poor and the ISO 9614 field indicators will probably stop you. A long averaging time (64 s) will give very precise measurements, but take a long time to perform. Note that the optimum averaging time depends on the filter bandwidth and the "reactivity" ( $\delta_{pl}$  index) of the sound field.

A good default choice is 8 seconds.

The last parameter is the **Surface specification**. The number of points depends on the noise source. If the source is a nice "point" source, you only need a few points (e.g. 5). As a rule of thumb the intensity level should be constant over the "partial area" and not vary more than a few dB between two neighbouring points. The program automatically uses the field indicators to check this for you and informs you if you don't have enough points.

For our vacuum cleaner a cubic box of  $1 \times 1 \times 1$  m (shoebox) with 4 measuring points on each surface is suitable. We therefore declare 5 rows (= surfaces) and 4 columns (= positions) each with Area/point of  $0.25 \text{ m}^2$ . When OK, press <F2> to continue.

### Field Indicators

Each time we measure a new noise source, we need to make two checks.

First we will measure the dynamic capability index  $L_d$  of the measurement instrumentation. This takes about 3 minutes. The program will ask you to place the two microphones in the coupler of the Sound intensity Calibrator Type 3541. If you don't have this calibrator, insert the microphones in the small DP0888 coupler and expose it to any broadband stationary noise with the "hole" pointing in the direction of the source (e.g. 1 m from our vacuum cleaner). Last we will check the Temporal variability indicator of the sound field,  $F_1$ . If you accept the default settings made above (short time average), this test takes approx. 15 minutes.

Note, it is a good thing to try to place the probe in a position with a certain amount of energy flow.

### The Measurement

Now all is ready for the "final" measurement. On the screen you will see the selected array of measurements, five "lines" with four "positions".

Place the intensity probe in position number one on the first partial area. The probe should be placed in the centre of the  $0.25 \text{ m}^2$  area with the probe axis perpendicular to the surface and with microphone A closest to the noise source. The easiest way of fixing the probe is to use a tripod. Unscrew the microphone holder and mount it on the tripod. Just let the remote handle hang in its cables. To prevent the vacuum cleaner's outgoing airflow from influencing the measurement, you should use the ellipsoidal windscreen (UA0781).

The screen cursor will be positioned on the "Start" field and, when ready, just press <Enter> on your keyboard. After a while, the screen cursor moves to the "Transfer Data" field, and you can then press <Enter>. When the measurement has been made for all selected octaves and the data has been transferred to the computer, you are requested to move the intensity probe to position number two and press <Enter>.

If the intensity probe is hand-held, just press <Dig. Out> on the remote control to start a measurement. Data are then transferred automatically.

Because we are interested in the total sound power only, it doesn't matter how we define positions one, two, three, and so on, but keep in mind that microphone A must always

be the one closest to the noise source (the probe measures the energy flow out of the one cubic meter box).

When all five box surfaces have been covered, the measurement is concluded and the program automatically calculates the field indicators and that all criteria are fulfilled. If the measurement is passed, you receive a short listing of the checking results; if not, an error message appear on the screen and you must repeat your measurement.

You can repeat the measurement without running the “Field indicator” measurements. Just press <Esc> to skip the calibration. When the array appears on the screen, you repeat the measurement. It is recommended to use another file name, e.g. “VAC02”.

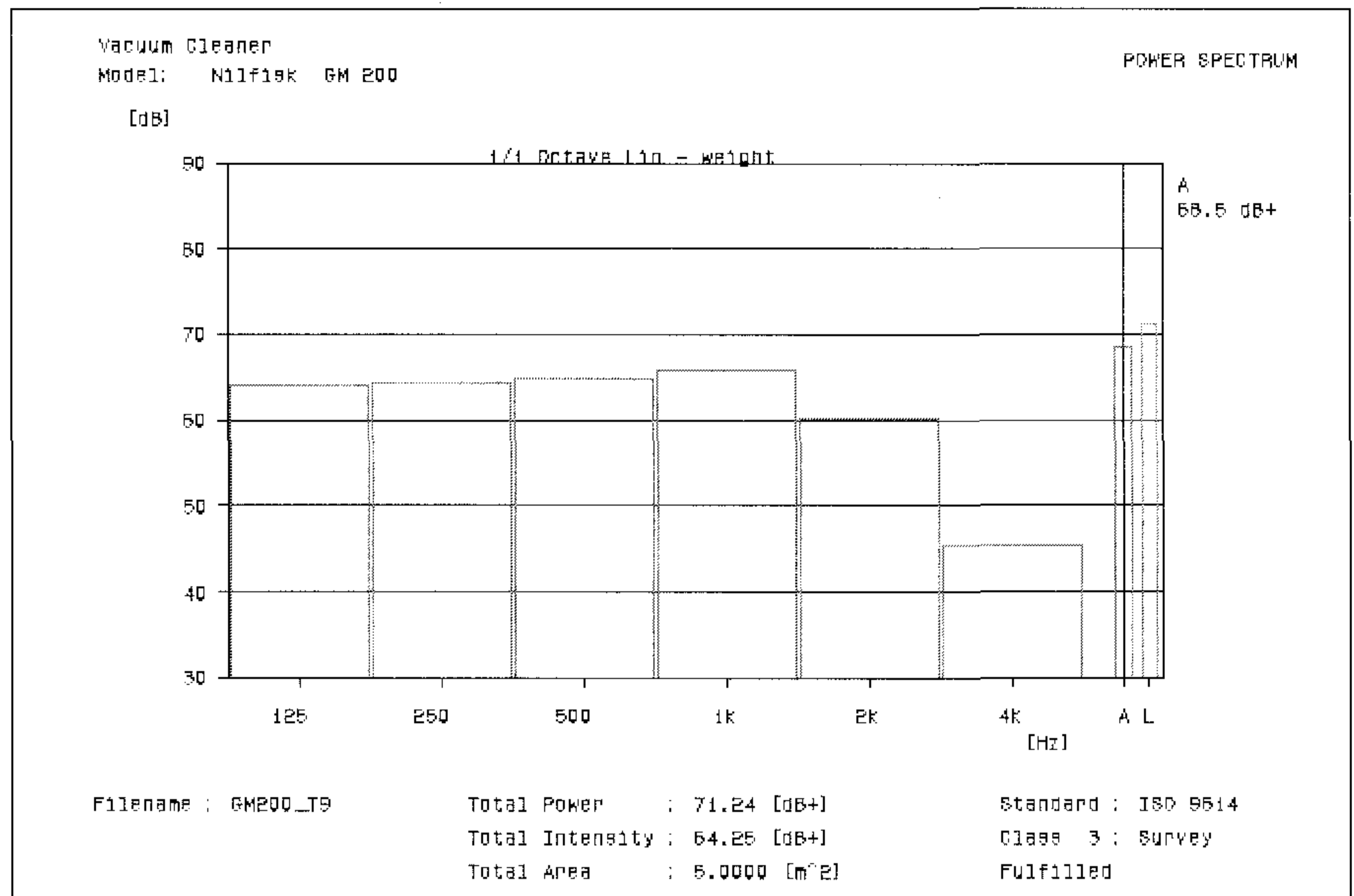


Fig.1 When fulfilling the machine directive, only the A-weighted sound power is of interest

## Analysis of power

When the measurement is concluded, or if you recall an old measurement from disk, a menu appears on the screen. If one of your measurements was unsatisfactory, you can choose [Repeat], select the position and repeat the measurement. When you are satisfied, select **Analysis**. You can now change the analysis parameters and select only the part of information which is of interest to you. But normally you would like to have the information exactly as it was measured, and therefore just press <F2> to accept the default settings.

Press <Esc> to return to the main menu. Move the cursor to the right and select **Power**. The power menu offers several options, but according to ISO 9614 only the A-weighted sound power level is of interest. Select the **Power Plot** (see Fig.1) and move the cursor to the A-weighted column on the right of the spectrum.

According to the standard (ISO 9614-1 table 2) the uncertainty in the determination of A-weighted sound power levels is 4 dB. In view of the wide variation of equipment for which the standards may be applied, the value given is only tentative!

$$L_w = 68.5 \pm 4 \text{ dB(A) re } 1 \text{ pW}$$

## Making measurements without any standard

Measurements according to no standard give you a high degree of free-

dom, but to trust the results, you must be extra careful when verifying.

You start by calibrating your instruments. The calibration should be performed exactly as described above.

Before we start making any measurements, we need to know the capability of our instrumentation.

If you have a sound level meter displaying 25 dB(A) re 20  $\mu$ Pa in a very silent room, and you then place it in the sound field you are going to measure, and the reading is 22 dB(A), everybody can see that a result 3 dB below the internal noise cannot be trusted. But if you measure an intensity level of 85 dB(A) re 1 pW/m<sup>2</sup>, can you then trust the result? Well that depends on the sound pressure level. If the sound pressure level was 90 dB(A), then yes, you can trust your measurement, but if it was 130 dB (A), then the difference between pressure and intensity ( $\delta_{PI}$ -index) is larger than the “Dynamic Capability” of your equipment. The result can **not** be trusted. Therefore, to verify the validity of the results, you must always know the dynamic capability of your instrumentation and compare it to the  $\delta_{PI}$  index of each of your measurement. The Dynamic Capability can either be measured or you can use the manufacturer’s specifications ( $\delta_{PI}(A) > 17$  dB). You can perform the “field check” the following way: Insert the microphones in the small DP 0888 coupler and expose it to any broadband stationary noise with the “hole” pointing in the direction of the source (e.g. 1m from our vacuum cleaner). Set the Analyzer Type 4437 as follows: **Linear Averaging, A-**

**weighting filter**, “Parameter”  $\delta_{PI}$ , and “Averaging Time” **16** seconds. Start a measurement. The displayed parameter  $\delta_{PI}$  now shows the dynamic capability of your equipment. Note that interchanging the microphones might improve the phase matching!

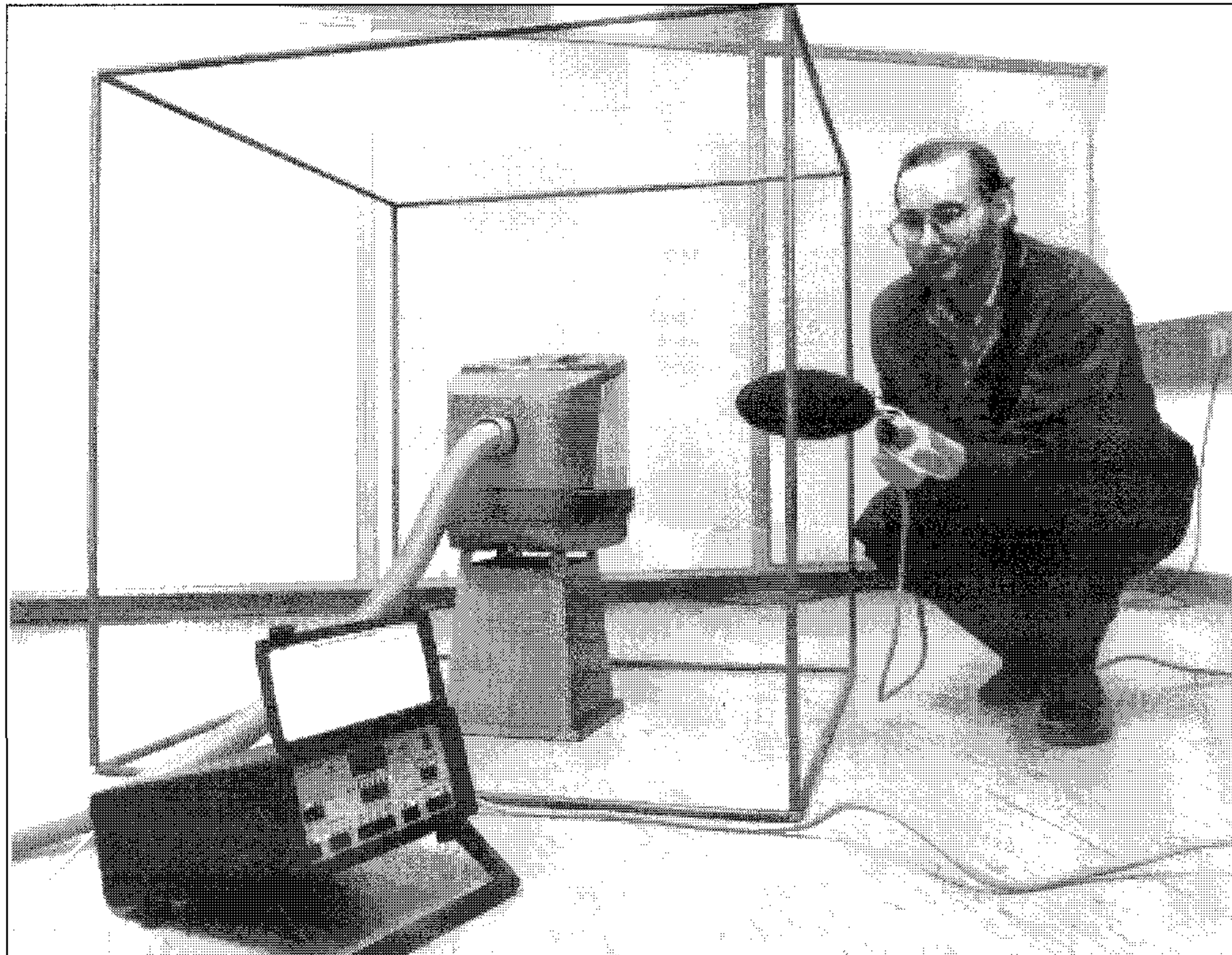
### The Measurement

Now we are ready for the measurement. Select a proper area. For our vacuum cleaner a “shoebox” of 1 times 1  $\times$  1 m is suitable. Divide each 1m<sup>2</sup> surface into 4 partial sub-areas (only because a small area is easier to scan). The “shoebox” now consists of 20 partial areas of 0.25 m<sup>2</sup>.

Sound Intensity Analyzer Type 4437 should be set up to: Select “1/1 Octave Filter” **A**, press <Exp> averaging and place the intensity probe on the measuring surface where the sound pressure level is expected to be highest. Press <Auto Range>.

Press <Lin> averaging and select “Averaging Time” **M** (the left LED).

Move the intensity probe to the first partial area (0.25 m<sup>2</sup>), press <Start> on the remote control and begin scanning over the surface. The scanning must be made at a steady speed between 0.1 and 0.3 m/s. Try to cover equal areas in equal time. When the scanning of the first partial area is concluded, press <Proceed/Halt> on the remote control. Move the intensity probe to the next partial area, press <Proceed/Halt> again and begin scanning. During the measurements the display will show you: “P1”, “P2”, ... indicating the number of the partial area.



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 Brüel & Kjær  
 4437  
 Sound Intensity Analyzer  
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Date: 94.2.9 Sig: ECP 1  
 Subj: Nilfisk GM 200  
 Average of 20 positions  
 Microphone dist. 12 mm  
 Surface Area 5.0 sq.m  
 Air Temperature 20 C  
 Air Pressure 1013 mbar  
 Sound Power Avg.T:MANUAL

Filter: Lw: Time:  
 A-Weigh. 68.1 dB 567 s

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 Average of 20 positions  
 Filter: Lp: Time:  
 A-Weig. 64.1 dB 567 s

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 Average of 20 positions  
 Filter: Lp-LI: Time:  
 A-Weig. 3.0 dB 567 s  
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Fig.2 Using WT9347, you can transfer documentation directly to the PC

### The machine directive

According to the machine directive, the noise specification depends of the A-weighted sound pressure level. This can be determined from the sound power level.

We need to know the sound pressure level in free-field conditions one meter from the vacuum cleaner. We therefore subtract the number of dBs corresponding to the area of a hemisphere with a radius of one meter:

$$10 \cdot \text{Log}(2\pi r^2) = 8 \text{ dB.}$$

The **sound pressure level** is then:

$$69 \text{ dB(A)} - 8 \text{ dB} = \mathbf{61 \text{ dB(A)}}$$

According to the machine directive, the Danish manufacturer, Nilfisk, only have to state that their vacuum cleaner is "low noise". But as a competitive parameter for the future, it might be a good idea to state the sound pressure (at 1 m) and/or sound power level:

$$\mathbf{L_p: 61 \text{ dB(A) re } 20 \mu\text{Pa}}$$

$$\mathbf{L_w: 69 \text{ dB(A) re } 1 \text{ pW}}$$

When all 20 areas have been scanned, key in the correction parameters, if not already done. Keep  $\langle \text{Stop} \rangle$  (2<sup>nd</sup>) pressed when pressing  $\langle \text{m}^2 \rangle$  and  $\langle 5 \rangle$ . Release  $\langle \text{Stop} \rangle$ . If necessary, correct  $\langle ^\circ\text{C} \rangle$  from the default 20 $^\circ\text{C}$  and  $\langle \text{mbar} \rangle$  from 1013.

The A-weighted sound power level, which you need to fulfil the machine directive, can now be read directly.

The accuracy depends of the difference between the measured  $\delta_{pl}(\text{A})$  index and the dynamic capability of the instrumentation. As a rule, we can say that if  $0 \text{ dB} < \delta_{pl}(\text{A}) < 7 \text{ dB}$  (probably more than 10 dB from the dynamic capability) then the standard deviation is 1 dB, and if  $7 \text{ dB} < \delta_{pl}(\text{A}) < 10 \text{ dB}$  then it is 1.5 dB.

On the display we can, in this example, read 3.0 dB (see Fig.2). That means that the chosen room has only minor reflections from the walls, and that the true sound power is

$$\mathbf{L_w = 68.1 \pm 1 \text{ dB(A) re } 1 \text{ pW}}$$

## Conclusion

We have made two different types of sound power determination, one according to ISO 9614-1 and one very

simple according to no standards. From the results it appears that both methods have proved equally good.

The machine directive does not say anything about how the results should be obtained, but for most people it is important that their measurements are made according to an international standard. That gives a sort of security. But don't despair because the "no standard" measurement is actually described in a Nordic standard called INSTA 121.

Regarding point measurements, one of the main problems is that, especially at low frequencies, a relatively high negative intensity flow and/or standing waves can occur. This is due to reflections from walls, and can be difficult to get rid of. One way is to move the vacuum cleaner around in the room, another is to go closer to the noise source, facing near field problems instead. Before making the measurement, try checking the intensity flow in each planned position. This is easily done moving around with the 4437 displaying "Fast" exponential averaged intensity.

The point measurement took nearly two hours, calibration included, where the sweep measurement was concluded in less than half an hour!

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