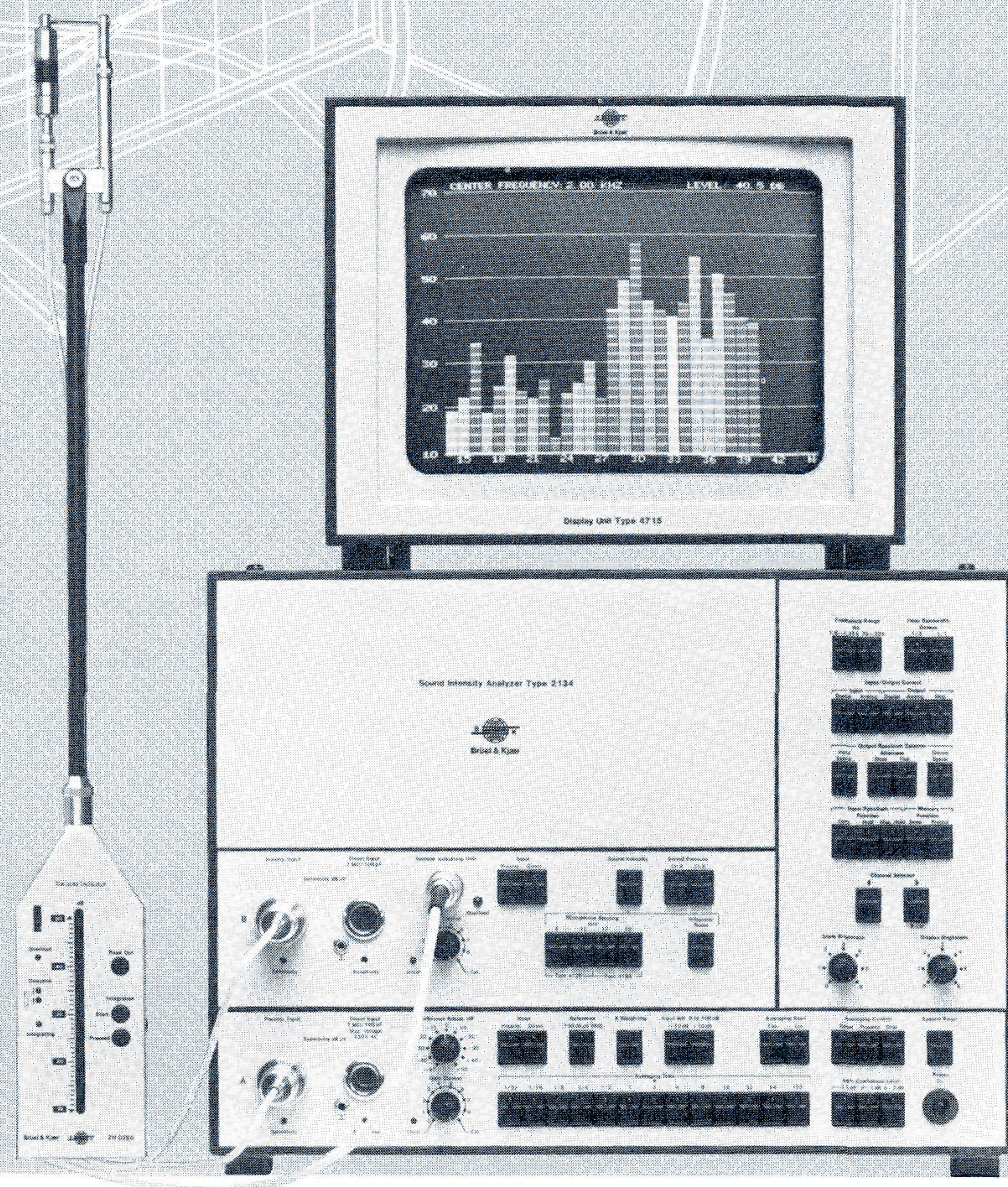


Part 2.

Sound power determination using sound intensity measurements



Sound power determination using sound intensity measurements

Part II

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Introduction

The aim of these measurements was to determine the sound power radiated from the motor and the pump respectively in a motor/pump assembly.

Description of the motor, pump and the test conditions

The motor used during the measurements was a Loher GmbH 20 kW, 1470 rpm, asynchronous type. The motor was placed on top of an oil reservoir of dimensions 100 cm × 67 cm × 75 cm (see drawing on front cover). The pump was a Danfoss VPA 20, operating pressure 180 bar, with 7 pistons and with a capacity of 20 cm³ per revolution. Thus the number of pulsations from the pump was $7 \times 1470 / 60 = 171,5$ per second.

The motor/pump assembly was mounted in a standard 200 m³ reverberation chamber so that conventional sound pressure measurements could be used to determine the sound power of the assembly in accordance with ISO 3741. These measurement conditions provided an excellent opportunity for verifying that intensity measurements can be used in highly diffuse sound fields.

The use of *sound pressure* measurements to determine the radiated *sound power* from the various parts of the machinery was impossible since the noise from the pump could not be dissociated from the noise of the motor. However the sound pressure methods revealed that the sound power from the unloaded motor was approximately 65 dB(A) re 1 pW and that the sound power from the motor when coupled to the pump was approximately 88 dB(A) re 1 pW. Thus the pump appeared to be the cause of the noise problem.

In contrast to conventional sound pressure measurements, *sound intensity* measurements were able to

separate and determine the radiated *sound power* of the motor (loaded by the pump) and the pump (loaded and connected to the motor) respectively, under normal operating conditions.

The advantages of the intensity method for determining sound power can be summarised as follows:

1. No restrictions upon the room where the measurements are performed provided that the sound field is stationary.
2. Measurements may be performed in the near- as well as the far-field. Near-field measurements improve signal to noise ratio and require less "free space" about the source under test.
3. The intensity method places no restrictions on the shape or size of the hypothetical enclosing surface used in the measurement.
4. The sound power determinations are not influenced by continuous background noise. Furthermore the influence of impulsive background noise can be minimised by the choice of a long measuring time.

Instrumentation

The measurements were performed with the B&K third-octave, real-time, Sound Intensity Analysing System Type 3360. For convenience the results were stored on the Digital Cassette Recorder Type 7400. One tape cassette can contain more than 1200 third-octave or 2400 octave spectra (Fig.1).

Measurement surfaces and measurement points

A rectangular box-shape was chosen as the enclosing surface for both the motor and the pump (see Figs.2 & 3). On each of the eleven sides (5 around the motor and 6 around the pump) 25 measurement points were defined (only 20 points were defined

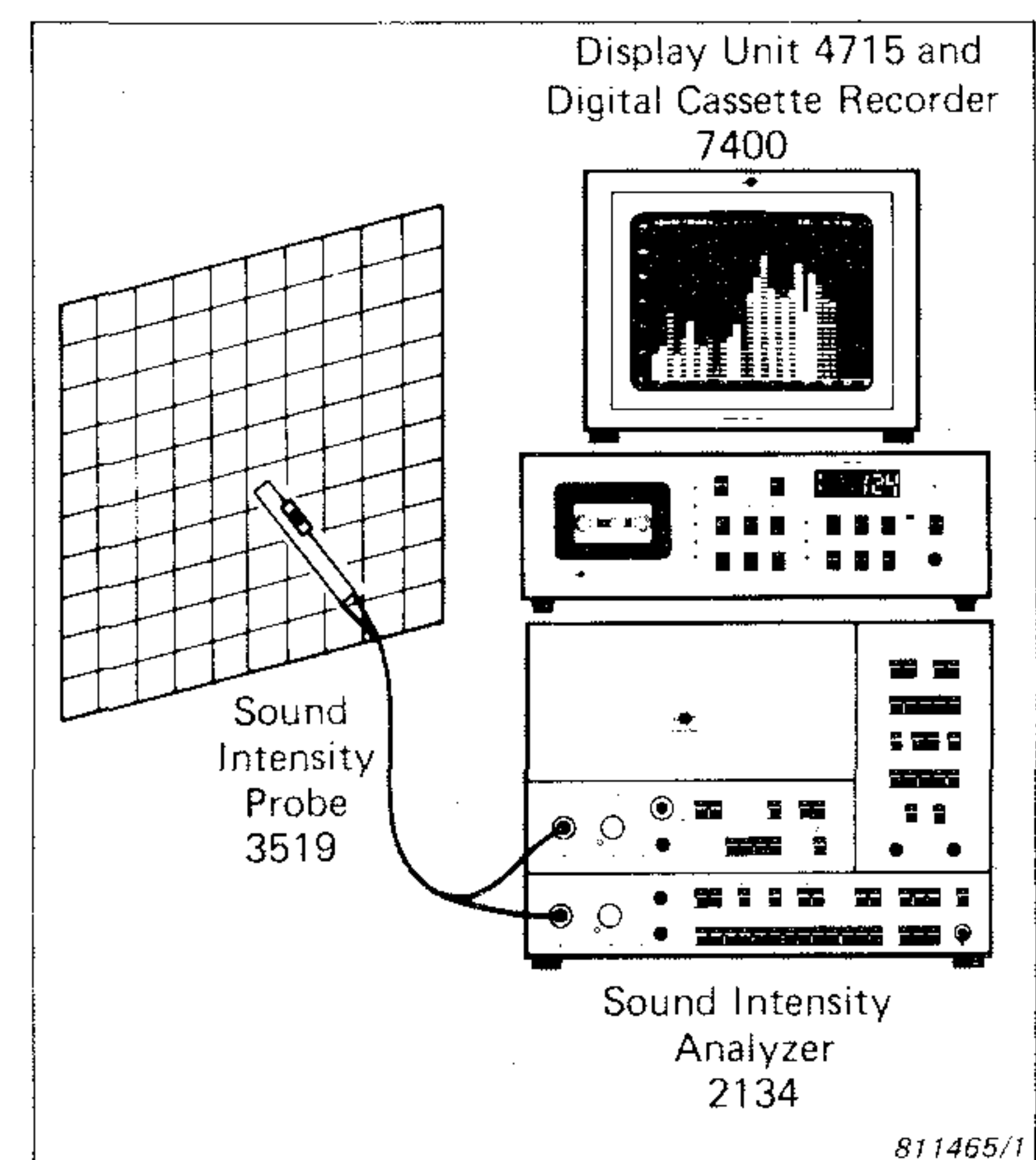


Fig. 1. Instrumentation used for sound intensity measurements with a schematic representation of a measurement grid

on the rear side of the pump due to the presence of the coupling) yielding 270 points in all which was considered to be adequate. Each point represented 0,09 m² around the motor and 0,01 m² around the pump. To facilitate the positioning of the measurement probe at the measurement points, a rectangular frame with a grid of string was constructed. The distance between the strings was 10 cm (see drawing on the front cover).

To measure the sound intensity level at the measurement points, the Sound Intensity Probe was fitted with two 1/2" phase matched microphones and a 12 mm spacer. This combination enables sound intensity measurements to be performed in the frequency range 125 Hz to 5 kHz with an accuracy of ± 1 dB and up to 10 kHz with an accuracy of $+1$ to -4 dB.

The probe was mounted on a tripod and fitted with a spherical wind screen to reduce the effect of airflow from the fan of the electric motor.

A linear averaging time of 8 s was used which yielded a total measuring time of 36 minutes.

During the initial measurements, it was discovered that the presence of

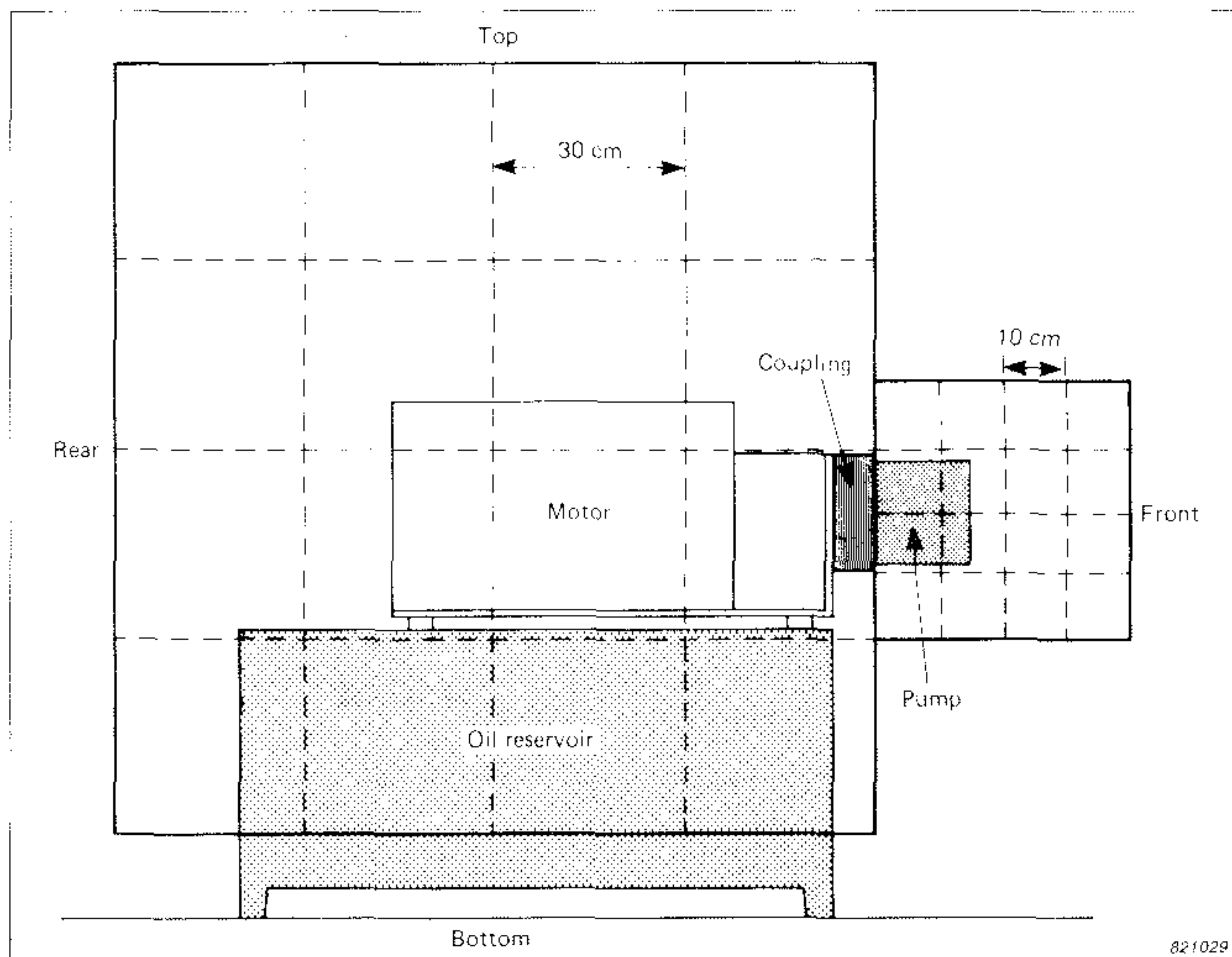


Fig. 2. View of assembly from left hand side showing measurement points and surfaces

a person in the reverberation chamber affected the measurements. Upon reflection, this was to be expected. The reverberation chamber itself contained very little absorption and that was distributed fairly evenly throughout the chamber. The presence of a person introduced a relatively large amount of absorption which moved about in the room during the experiment. This had considerable effect on the highly reactive sound field. Entering and leaving the chamber to move the probe from position to position was therefore necessary and this procedure was time consuming. Fortunately such large disturbances of the sound field are not usually encountered during measurements *in situ*. After the measurements, the 270 spectra were recalled from the Digital Cassette Recorder onto the display screen to check that all the results were on tape.

Results of sound power determination

The sound power was calculated using a desk-top calculator and the spectra for the motor and the pump are shown in Figs.4 and summarised in Table 1. The overall sound power spectrum for the motor/pump assembly is shown in Fig.5. The sound intensity measurements show that the sound power level from the motor and the oil reservoir is 2,5 dB(A) higher than that from the pump. This means that the motor radiates more noise than the pump, a result which cannot be concluded from the sound pressure measurements. The explanation is that the pump transmits vibratory energy to the motor via mechanical vibrations and pulsations. The vibratory energy causes the large surfaces of the motor and the oil reservoir to radiate more sound power than the pump's own surface.

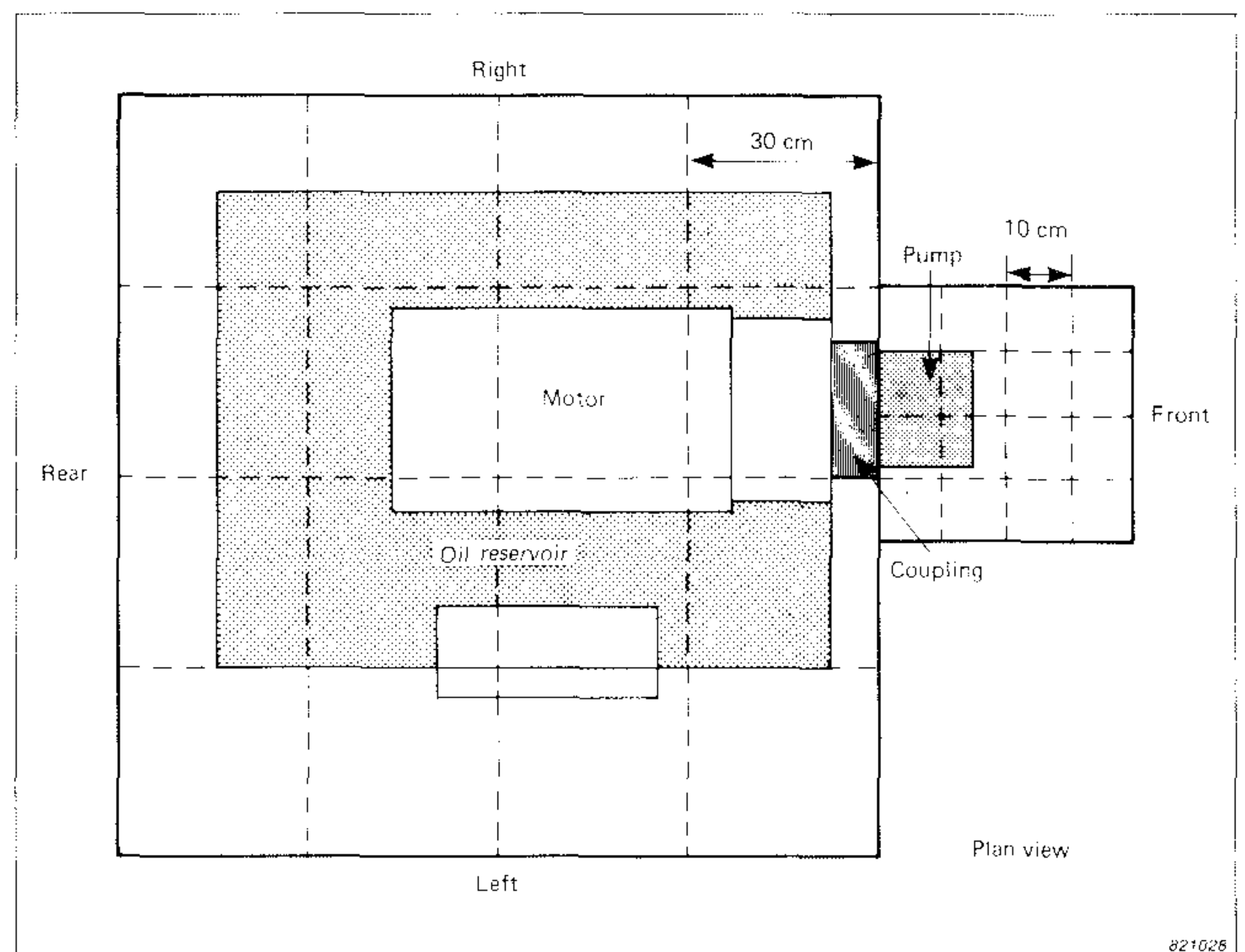


Fig. 3. Plan view of the assembly showing measurement points and surfaces

Sound power calculated from reduced amount of data

It was not known initially how many measurement points would be required. However after the measurements, the sound power calculations were repeated using reduced amounts of data and surprisingly few measurement points were required to yield reliable results. The results are shown in Table 2 together with the total number of points used in each calculation and the point configuration on each side. Despite the fact that the measurements were performed in a highly reactive field, such a drastic reduction in the amount of data remarkably yields results within 1 dB of the calculation based on the full 270 points. Fig.6 is a typical measured spectrum from the right side of the motor which illustrates just how reactive the sound field was. Fig.6 also shows the averaged value for the same side.

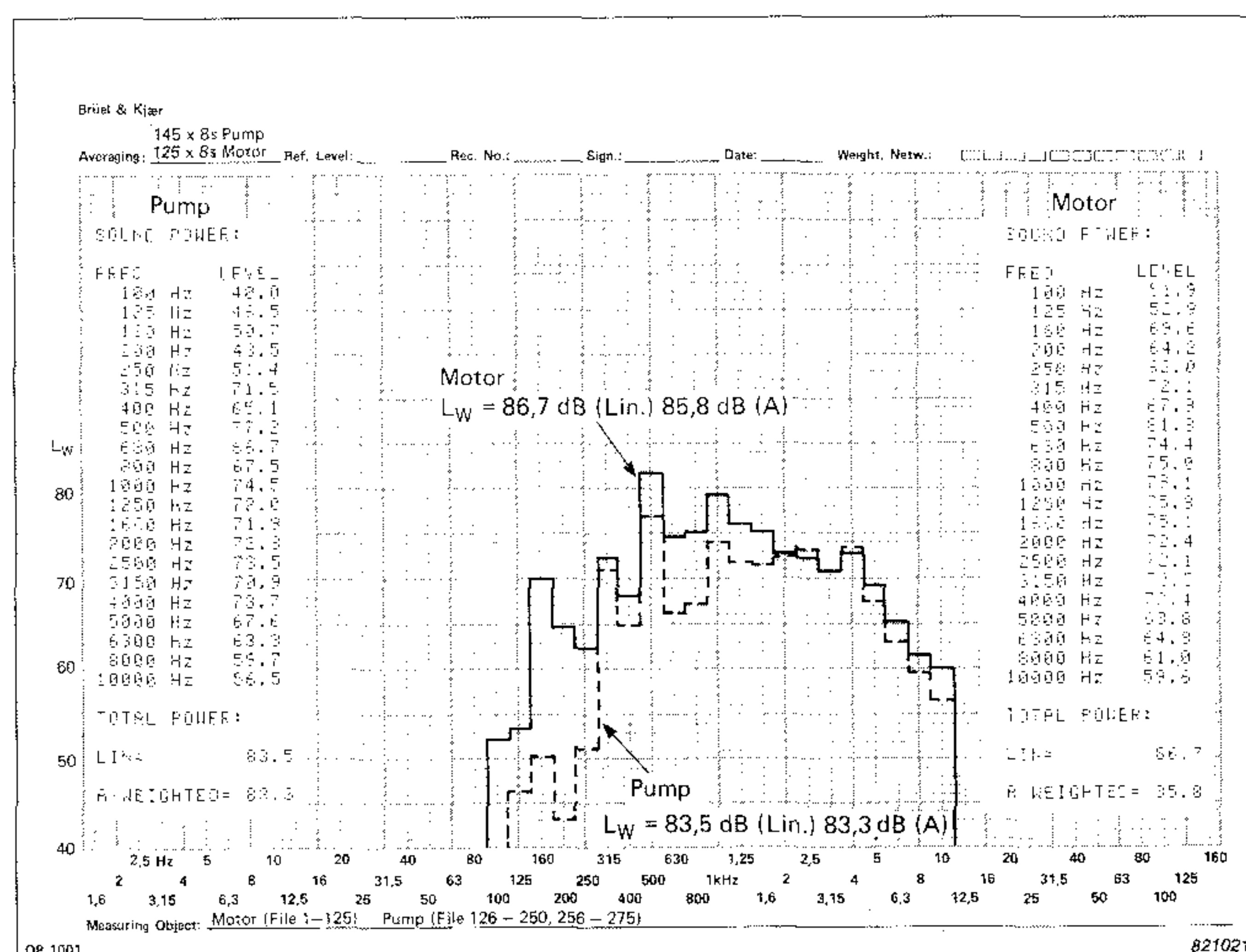


Fig. 4. Power spectra for motor and pump

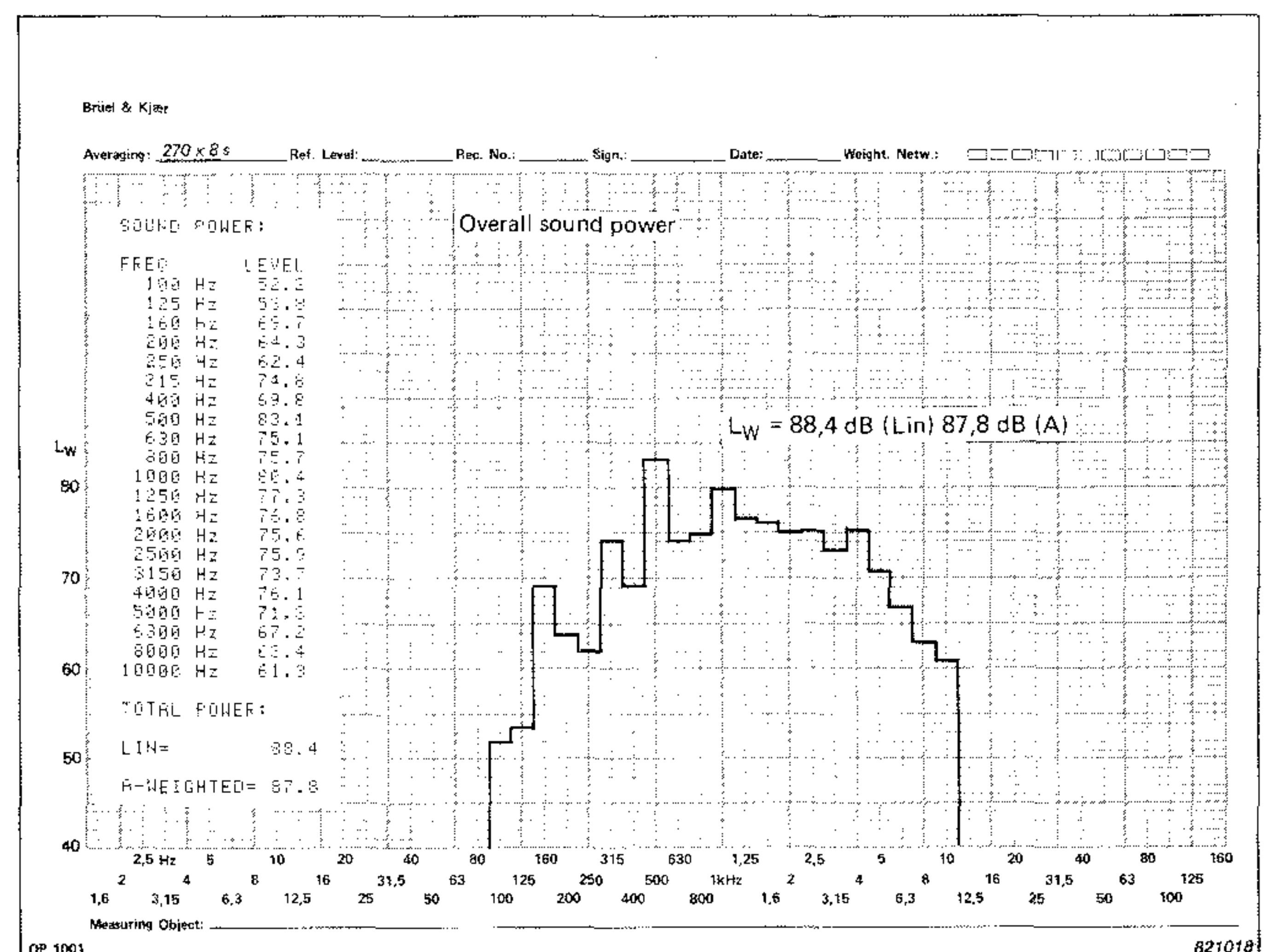


Fig. 5. Overall power spectrum for motor/pump assembly

L_W	Intensity		Pressure
	dB(Lin)	dB(A)	dB(A)
Motor	86,7	85,8	—
Pump	83,5	83,3	—
Difference	3,2	2,5	—
Motor & Pump	88,4	87,8	88

Table 1. Sound power results based on sound intensity and sound pressure measurements

Averaged intensity

To obtain more detailed information on the individual sides, the 25 intensity spectra for each side were summed to yield 1 spectrum (Figs. 7 & 8). From these spectra, it was seen that the net flow of energy at 500 Hz, 1 kHz and 1,6 kHz (3rd, 6th and 9th har-

monic of the pulsation frequency) and at the frequencies between 4 kHz and 10 kHz was towards the pump (that side of the pump adjacent to the motor). This also indicates that the motor is radiating more noise than the pump.

Notice that the sign of the overall power level at the rear of the pump is "negative" when the linear level is calculated but "positive" when an A-weighting is performed.

Noise reduction

As a result of these measurements, the oil reservoir (which possessed a considerable surface area) was removed from the assembly.

With this action the overall sound power level was reduced by 2,5 dB(A). A further reduction in the noise level may be expected by an improved design of the coupling between the motor and the pump.

Conclusion

Sound intensity measurements enabled the major sound source, the oil reservoir, to be identified under extremely difficult acoustical conditions where conclusions based solely on sound pressure measurements could be directly misleading. This note clearly shows how such measurements can be used to advantage in achieving a significant noise reduction.

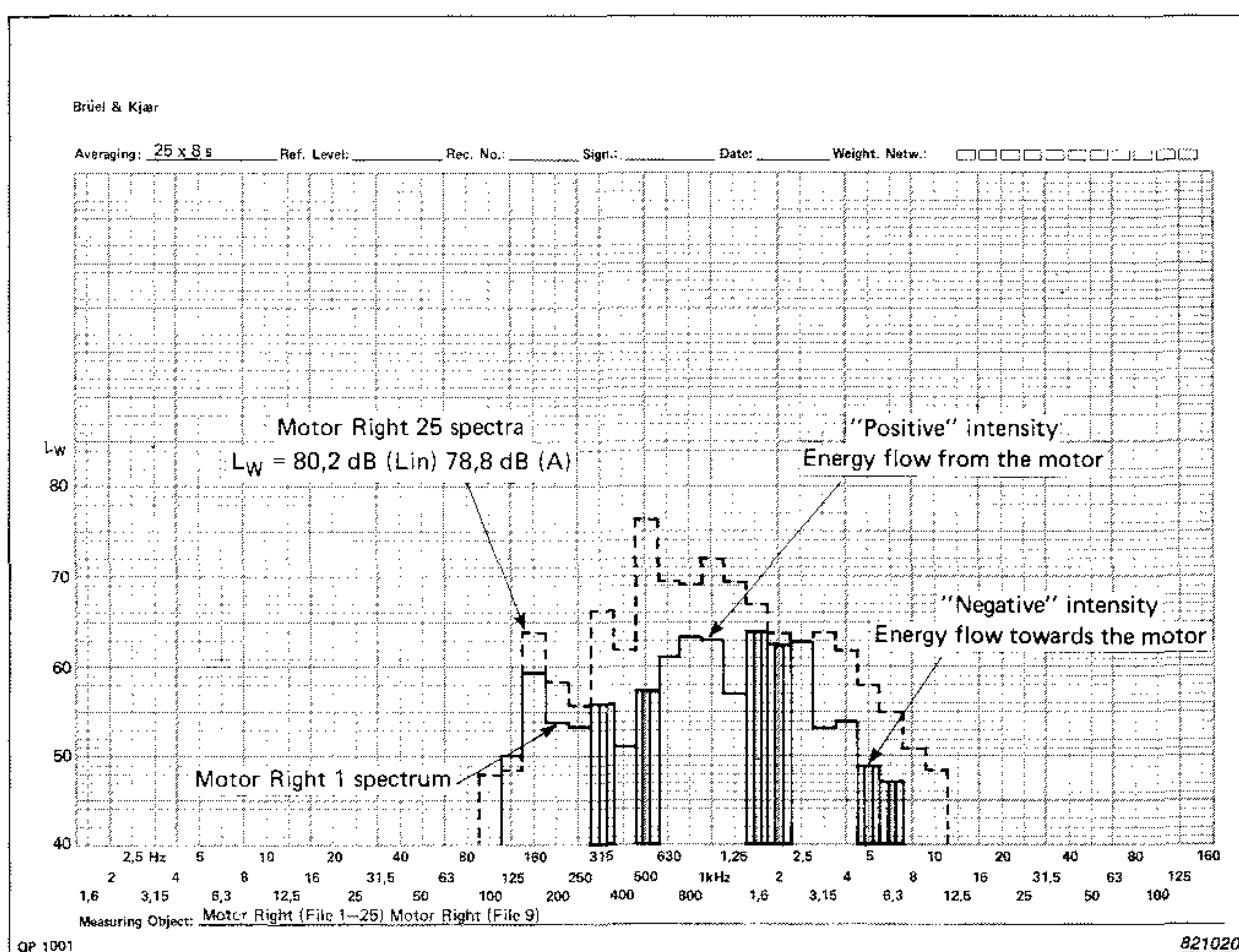


Fig. 6. Typical intensity spectrum on the right hand side of the motor (full line) and overall intensity spectrum on the same side (dashed line)

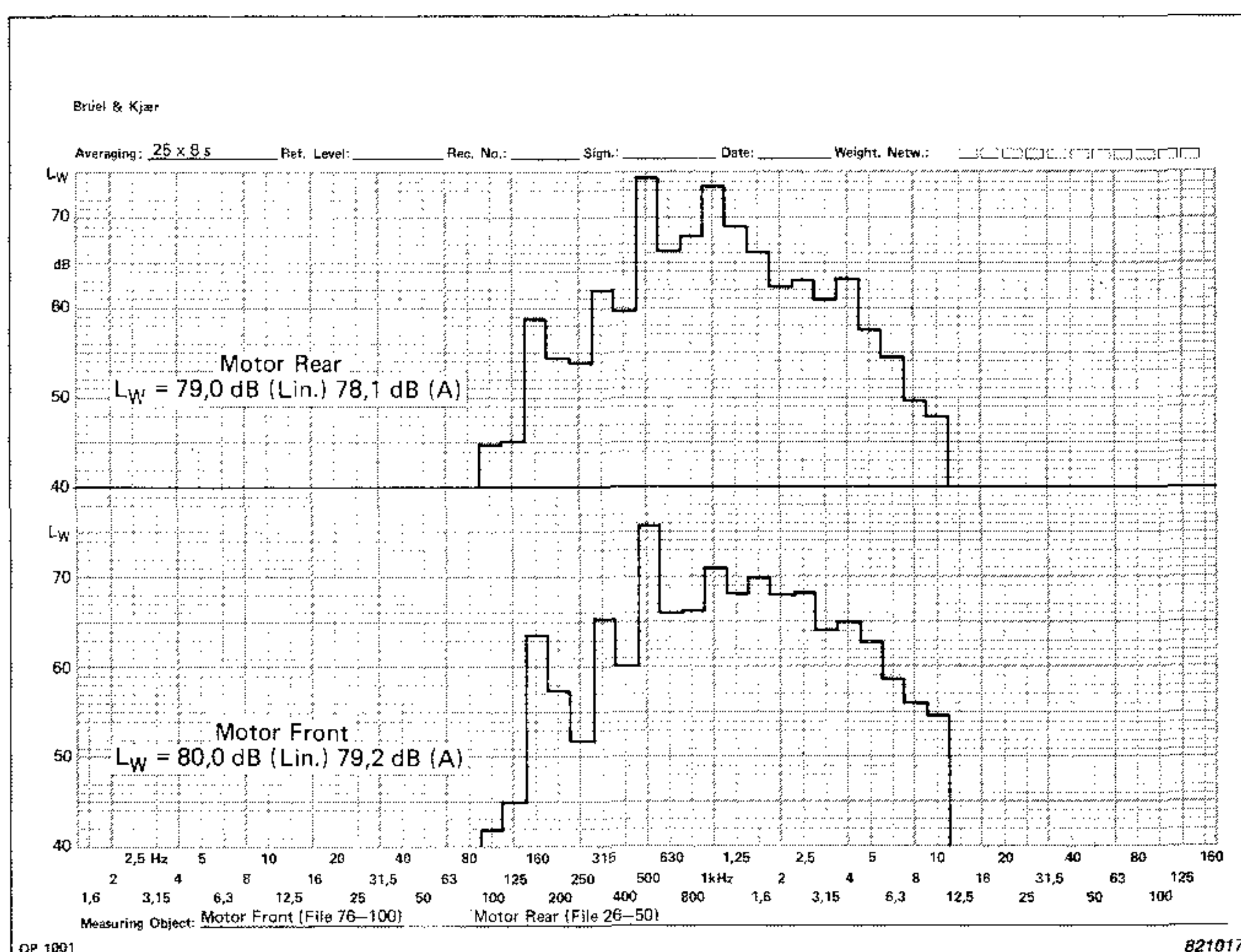


Fig. 7. Intensity spectra for motor rear and front

Sound power dB(A) re 1 pW				
Number of points	Motor	Total	Pump	Number of points
125	85,8	87,8	83,3	150
25	85,9	87,4	82,2	30
25	86,2	88,2	84,0	30
20	86,3	88,2	83,7	24
Max. difference	0,5	0,4	-1,1	

Table 2. Sound power calculations using a reduced amount of data. The maximum difference is the difference between the level for the full number of points and the level for the reduced number of points

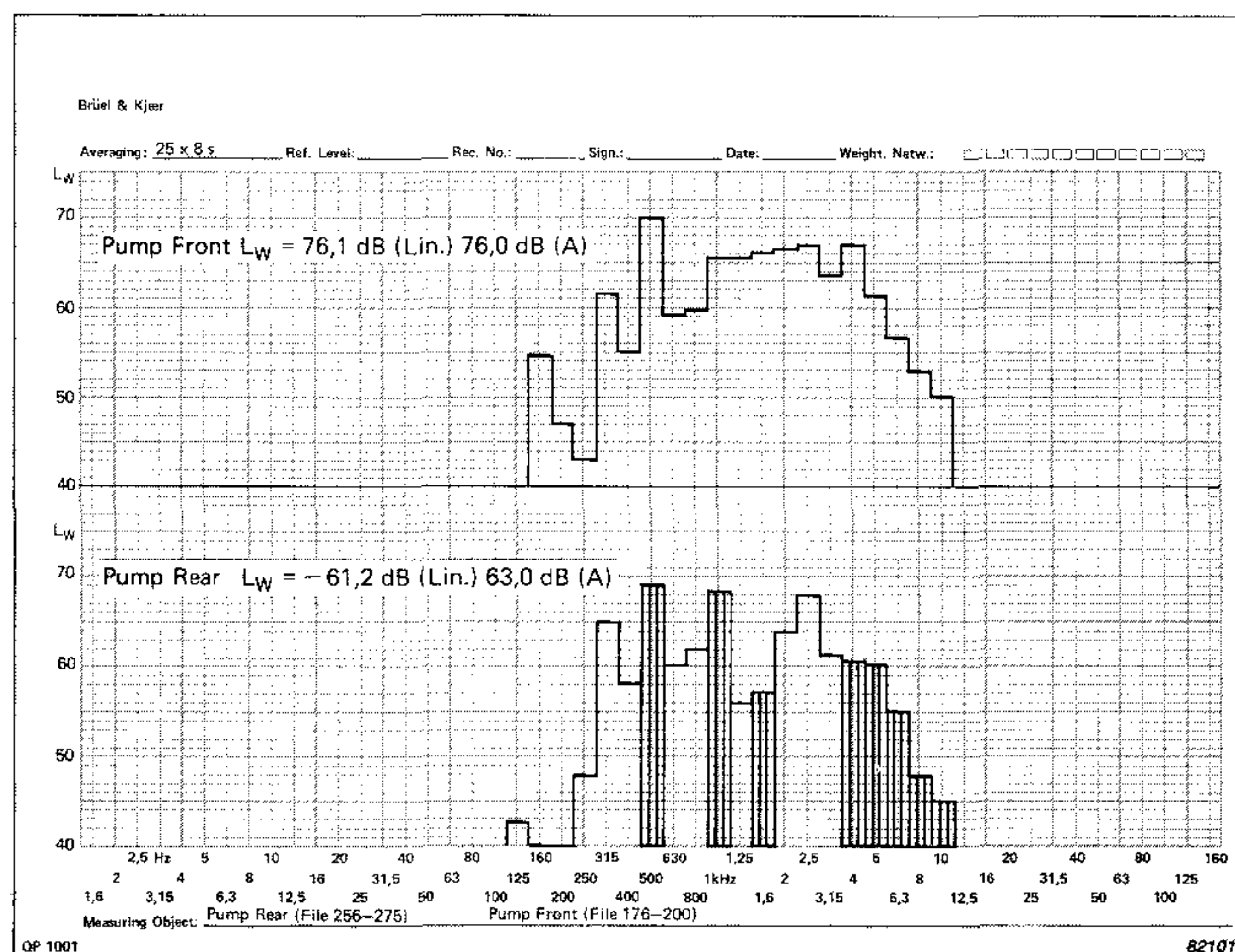


Fig. 8. Intensity spectra for pump front and rear