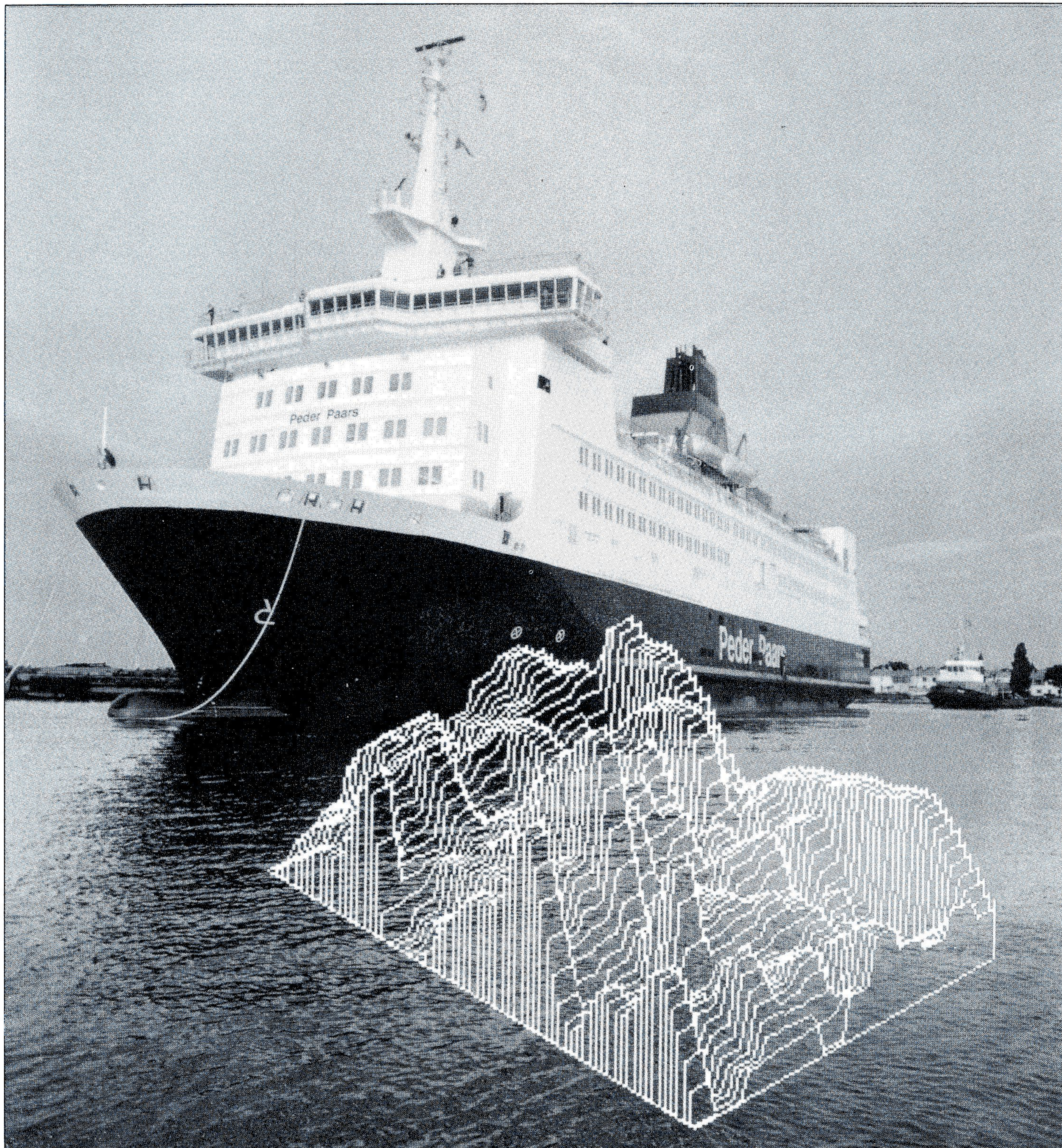




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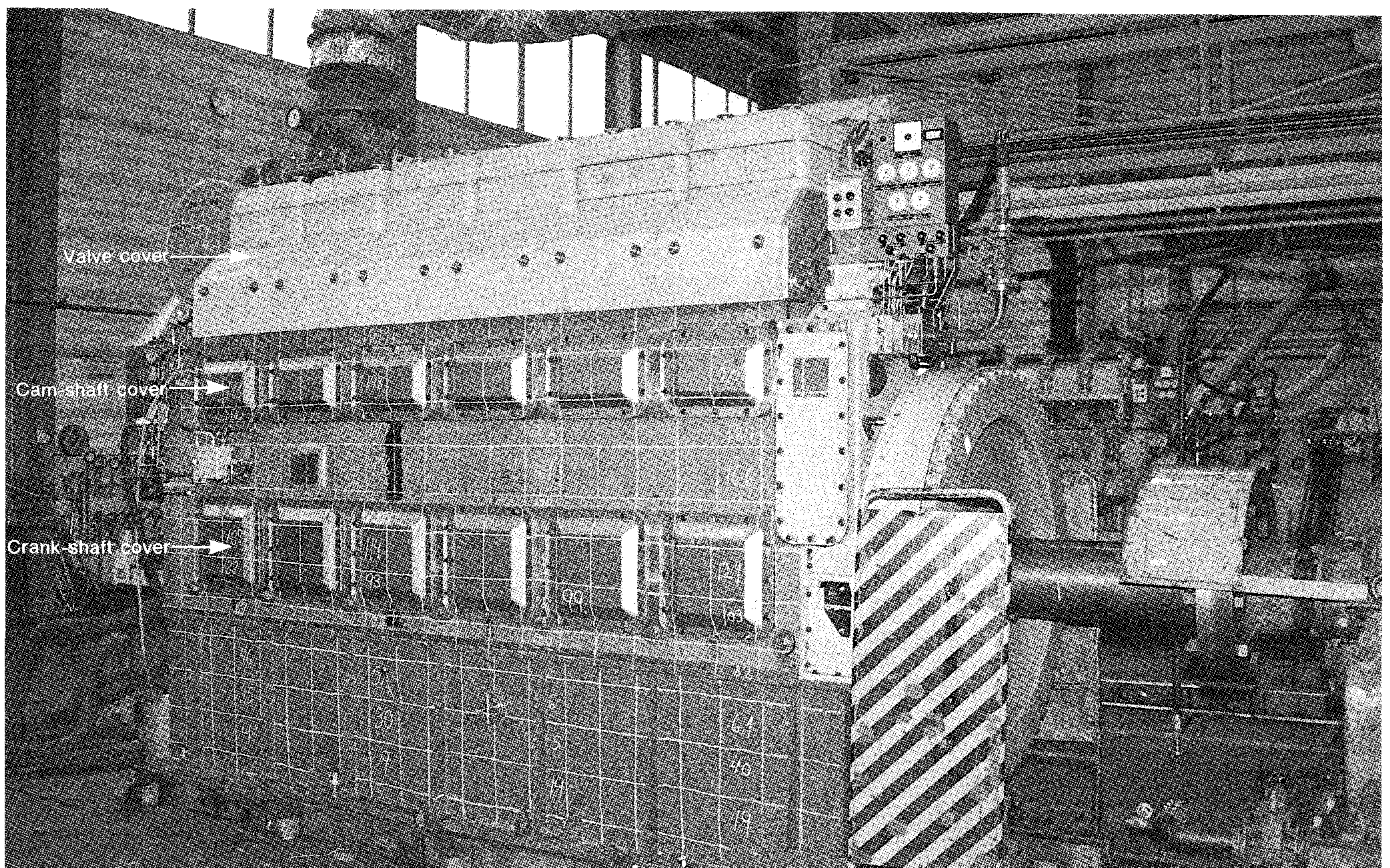
application notes

# Gated Sound-Intensity Measurements on a Diesel Engine



# Gated Sound-Intensity Measurements on a Diesel Engine

by Per Rasmussen and Torben L. Møller  
Brüel & Kjær



## Introduction

In 1984, DSB (Danish Railways) ordered two ships, Peder Paars and Niels Klim, for passenger and motor vehicle transport. These ferries are equipped with four auxiliary engines, each of 1100kW, from M♦A♦N-B & W Diesel (Holeby, Denmark). DSB required that the sound pressure level produced around the engine room must not exceed 100dB(A). The ferries are used intensively, so it must be possible to service one or two engines with the others in normal use, without subjecting personnel to excessive noise levels. Since it was not possible to satisfy this requirement using the construction already in existence, new methods had to be used.

It was decided by all parties involved that the basic design of the engines should not be changed. Also, the engines need to be easily accessible for maintenance and inspection. These considerations limited the possible solutions to the problem. Also, lack of space made it impractical to reduce noise levels by enclosing the engines. Therefore, it was decided that the best way of reducing the noise was to damp those parts of the engine contributing most to the total noise level.

The problem-solving procedure may be summarized as follows:

- The most important noise source areas of the engine are located by making an intensity mapping of the engine surface
- The nature of the noise, i.e. how it develops in time, is studied using gated intensity
- Based on the experience gained from the two measurements above, a noise control treatment is implemented
- The sound power radiated by the engine is measured using intensity. The result of the measurement is compared to a similar measurement on the untreated engine. This gives us information on the effectiveness of the treatment
- Finally, the sound pressure level in the engine room is measured, and it is concluded that a satisfactory reduction in this level has been obtained

## Source Location Procedure

The problem of finding out which parts of the engine should be damped to give the best results was solved in collaboration with the Danish Acoustical Institute, and with IKAS A/S who designed and supplied the noise-deadening materials used for damping. First, a map was made of the sound intensity over the surface of the engine. To do this, the surface was divided up into a grid of  $16 \times 16$  cm squares, marked on the surface, and sound intensity was measured for each area defined by the grid. This mapping helped to rank the separate sound sources within the engine, so that attempts at noise reduction could be concentrated on the most powerful sources. The photograph above and Fig. 1 show the three major noise sources: valve covers, cam-shaft covers and crank-shaft covers. The noise from these parts was then analyzed in detail, to decide what type of noise-reduction technique should be used.

## Gated Intensity

With the intensity technique, the noise power from different parts of an engine can be measured with minimal influence from other noise sources, even in high background noise. However, a normal frequency analysis (e.g.  $1/3$ -octave bands) using the sound-intensity technique does not help us to determine whether the noise is stationary throughout the engine's work-cycle (as for example with a resonance). Nor does it tell us whether the noise is caused by a single process within the work-cycle (for example combustion pressure or valves closing). This is because comparatively long averaging times are used, and en-

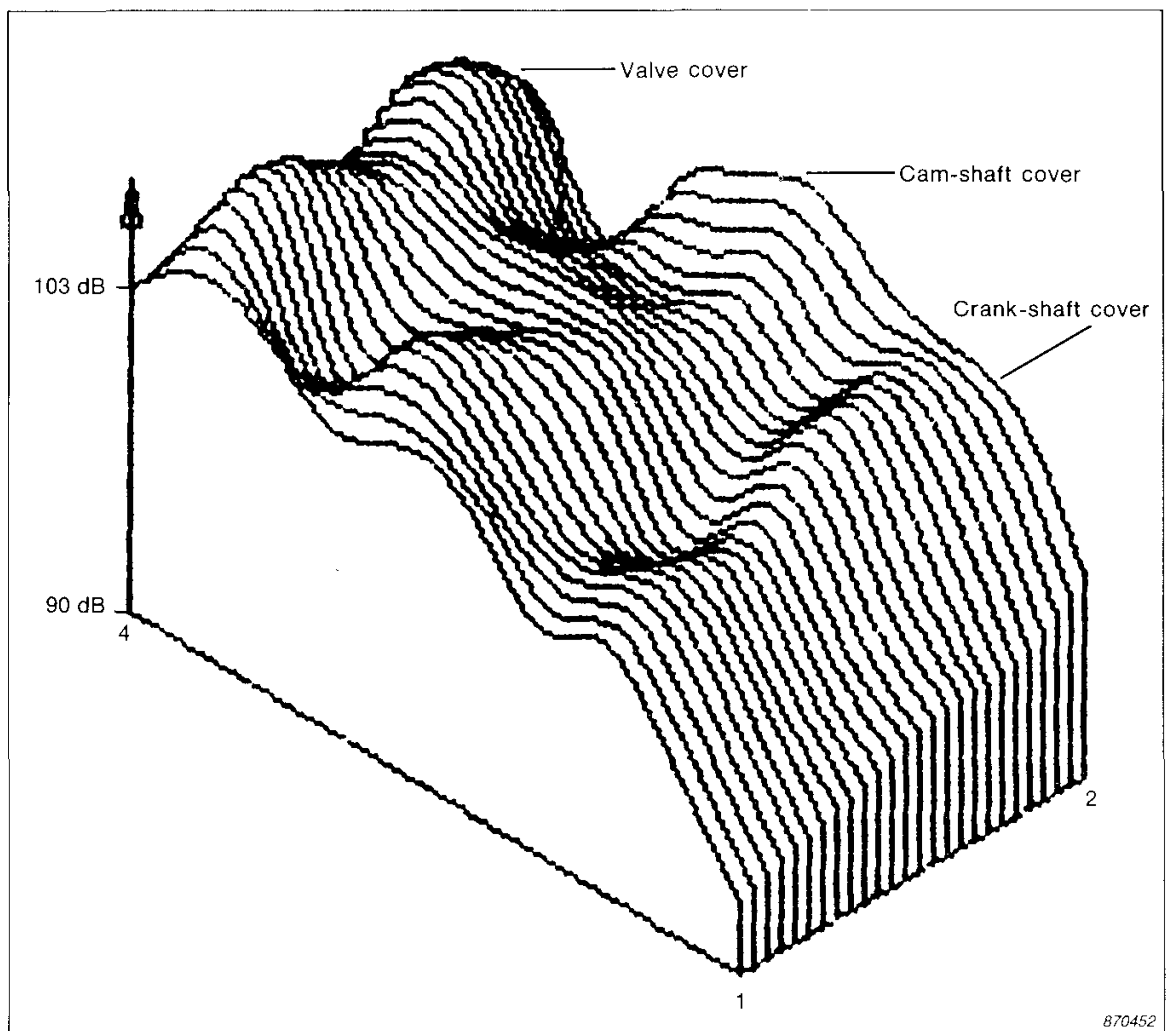


Fig. 1. A-weighted sound intensity (250 – 6300 Hz) measured over the engine surface with 12 mm spacer: corner 4, top; corner 1, bottom. The level for the crank-shaft cover is  $\sim 99$  dB, the cam-shaft cover  $\sim 104$  dB, and the valve cover  $\sim 106$  dB

ergy from short impulsive sources often disappears in the more constant, lower level of sound from other sources.

Gated intensity overcomes this problem. It gives a third dimension to measurements – time. By starting and stopping averaging at different points

in the machine's work-cycle, we can study the development of the intensity spectrum with time. The time-selectivity is achieved by marking a trigger point on a rotating axis, for example the crank shaft. A photoelectric tachometer probe is then used to start averaging after a delay time,  $t_d$ , and stop averaging after  $t_w$ . See Fig. 2.

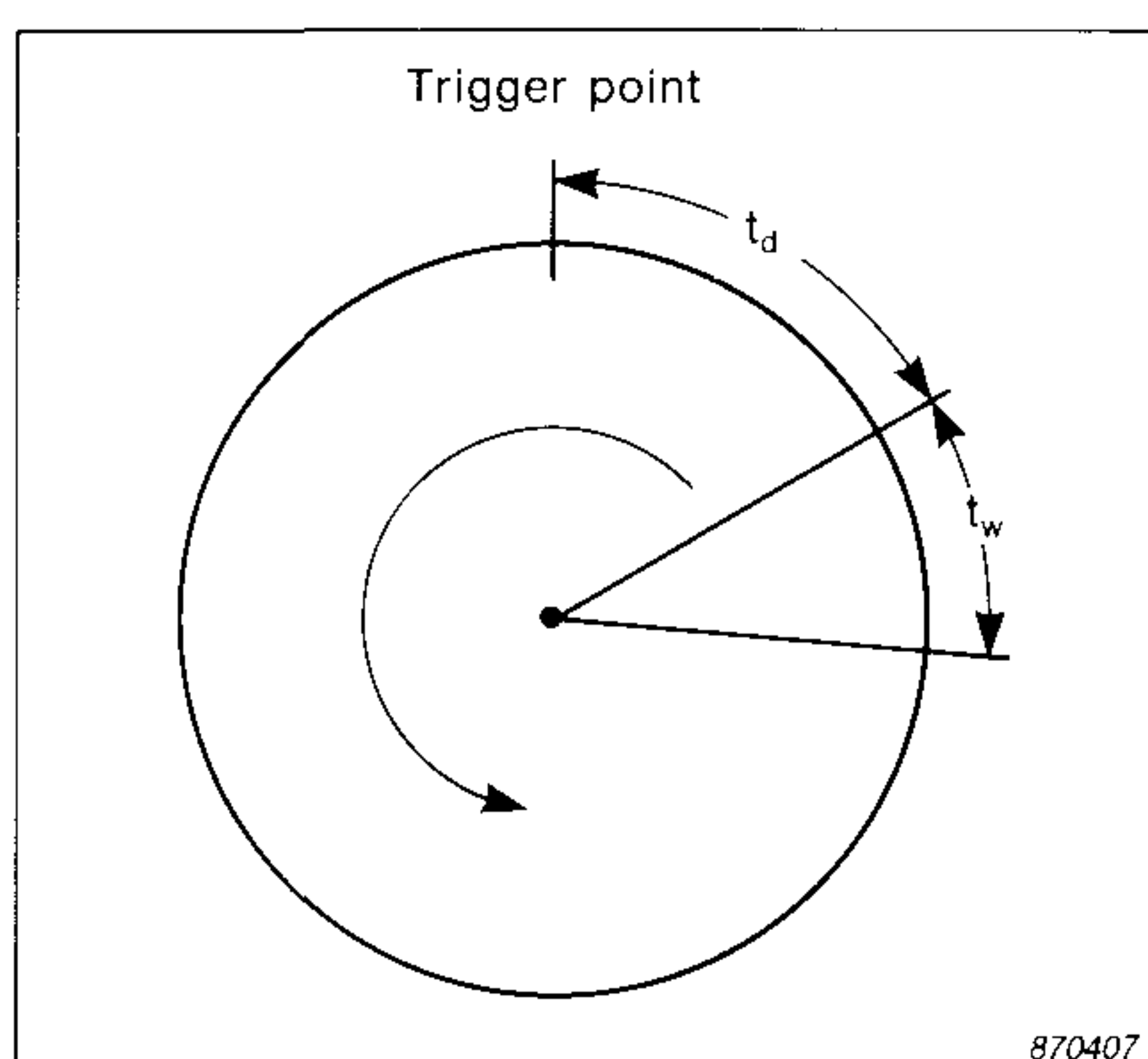


Fig. 2. The measuring cycle:  $t_d$  is the delay time and  $t_w$  is the averaging time (window)

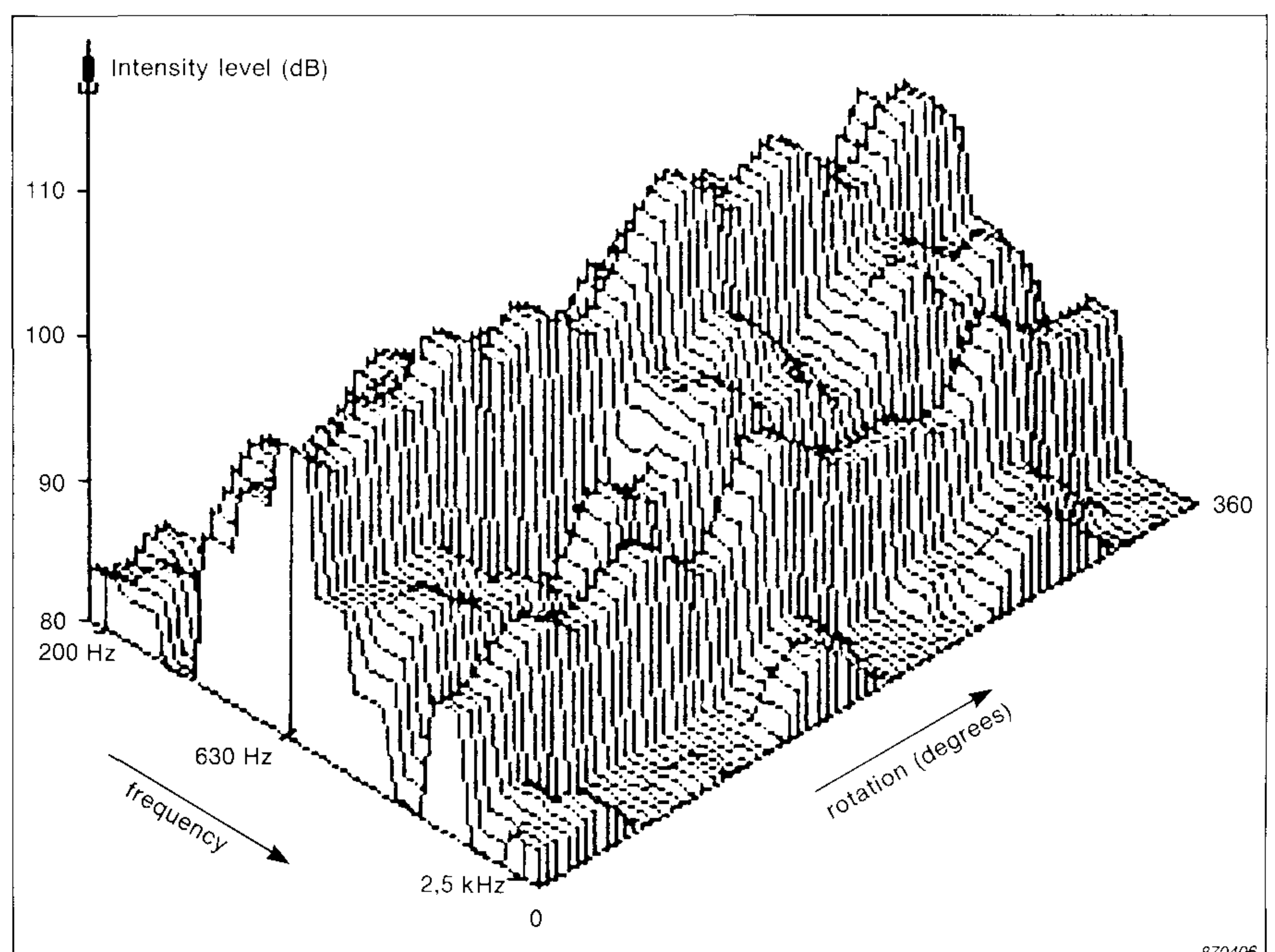


Fig. 3. 3D plot produced from gated-intensity measurements on the cam-shaft cover

Different points of the work-cycle are chosen by varying the delay time.

The results of gated intensity measurements on the cam-shaft cover, one of the dominating sources, are illustrated in Fig. 3. The diagram shows that the highest sound intensity level is measured in the 630 Hz  $\frac{1}{3}$ -octave band, so it is this component we want to concentrate our efforts on. Further, we see that the level is relatively constant throughout the work-cycle of the machine. This implies that the cam-shaft cover resonates at 630 Hz when the engine is running. Therefore, damping material was mounted on this plate to hinder the resonance.

## Instrumentation

The measurement setup is shown in Fig. 4. The long-distance Photoelectric Tachometer Probe MM 0024 is used to trigger the rest of the apparatus. In order to be able to select a particular moment during the work-cycle, the trigger signal is fed through the Control Unit WB 0845 to the Sound Intensity Analyzing System Type 3360. From there it is fed over the interface to the computer. This sends a signal back to the 3360 to start and stop averaging at the required times,  $t_d$  and  $t_d + t_w$ . The computer uses software provided with the Control Unit WB 0845.

## Results

The different noise sources were given a variety of treatments, and the results were evaluated for each case by measuring the reduction of radiated sound power from each source. The most effective treatment was then selected for each of the major sources.

The results of sound-power measurements before and after damping of the cam-shaft cover are shown in Fig. 5. Similar results were also obtained for valve and crank-shaft covers. A final control measurement of sound pressure level after damping showed that the maximum noise level in the engine room had been reduced from 103 dB(A) to 97,2 dB(A), easily satisfying DSB's requirements.

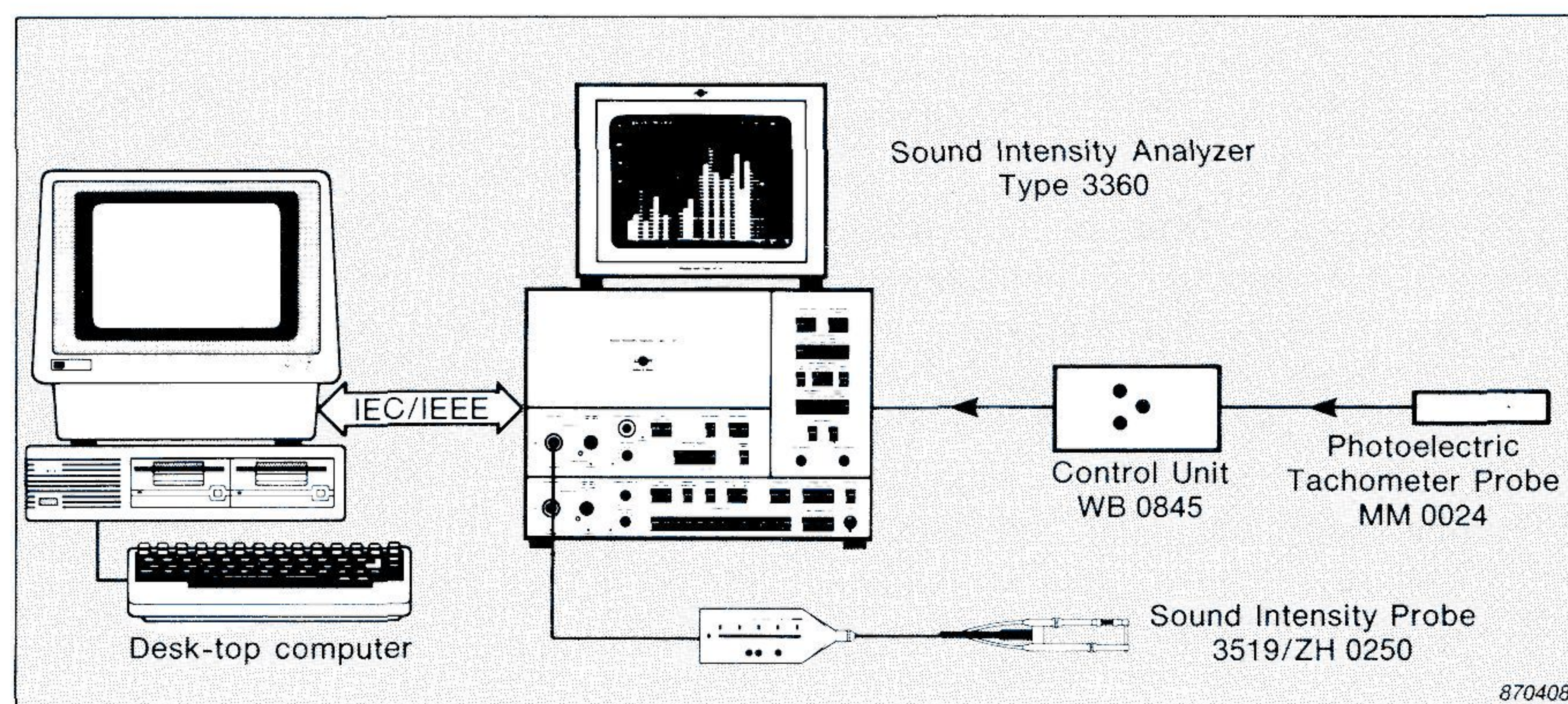


Fig. 4. The measurement setup

Sound Intensity Analyzing System Type 3360 comprises:

Sound Intensity Analyzer Type 2134  
Display Unit Type 4715  
Sound Intensity Probe Type 3519  
Remote Indicating Unit ZH 0250

This system forms a digital frequency analyzer measuring sound intensity and sound pressure levels in octave or  $\frac{1}{3}$ -octave bands over a frequency range of 3,2 Hz to 10 kHz ( $\frac{1}{3}$ -octave intensity) and 1,6 Hz to 20 kHz ( $\frac{1}{3}$ -octave pres-

sure). Results are displayed in real time on the screen of the 4715, and the direction of the sound intensity vector is indicated.

Control Unit WB 0845 adapts the Type 3360 for gated-intensity measurements. Software for computer control of the 3360 is included with the control unit. An Extension Unit WH 1692 for mounting inside the 2134 is also included.

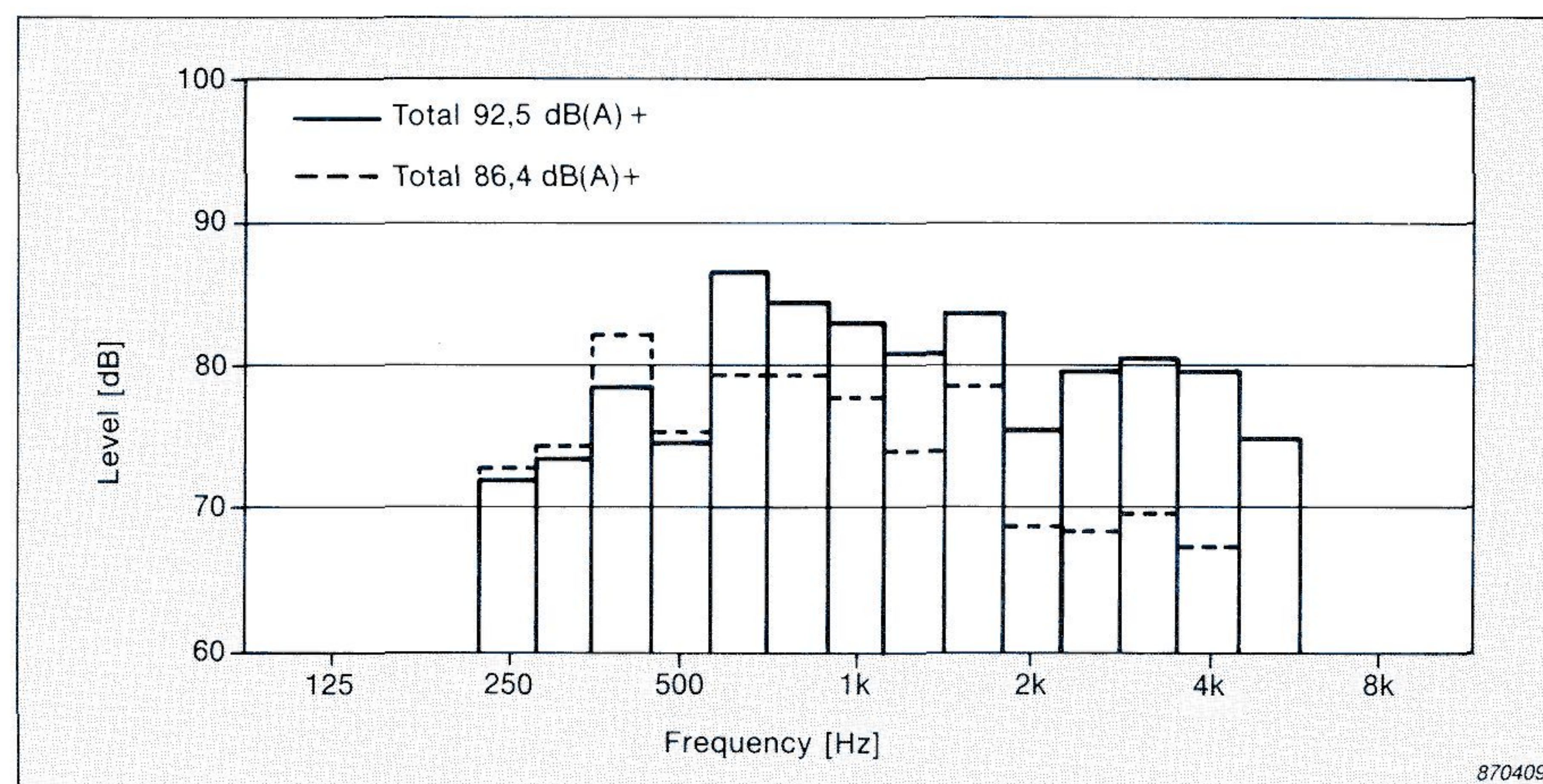


Fig. 5. Sound power spectrum of the cam-shaft cover before (full curve) and after (dashed curve) modification

## Conclusion

As can be seen from the measurement results, gated intensity is a powerful technique when applied to rotating (or translational) machinery. This is especially true when combined with ordinary sound intensity measure-

ments. Gated sound intensity makes it possible to determine the effects of separate processes in a work-cycle in a way which is not possible using more traditional methods.

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