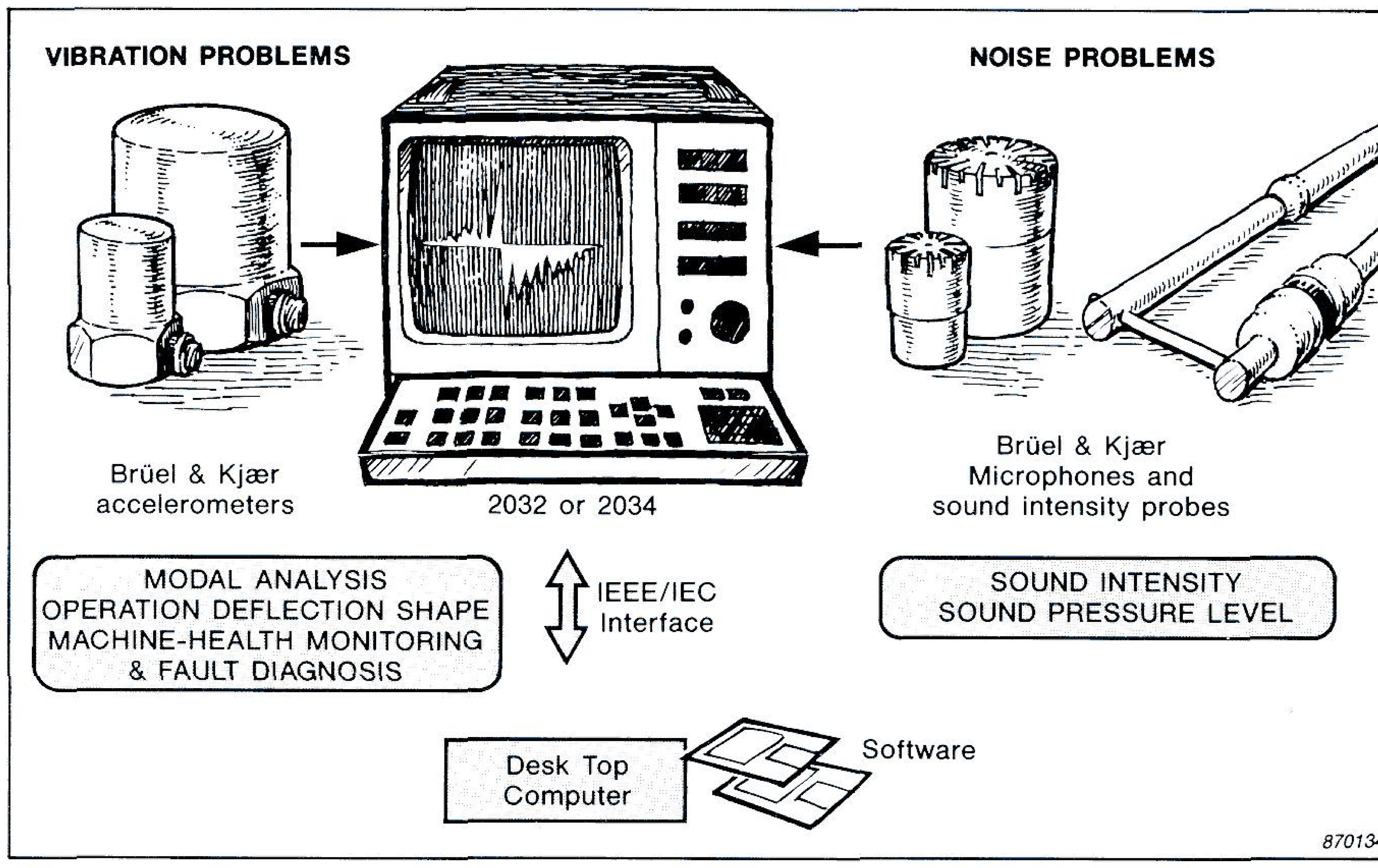
Brüel & Kjær application notes

Sound intensity and modal analysis

Noise and vibration problems are causes of great concern in modern day engineering. Sound intensity measurements and modal analysis are two powerful techniques with which we can work towards a more quiet, comfortable, safe and economical industry and environment. Instruments capable of making just *one* of these types of measurement are very useful. Instruments capable of *both* - the Brüel & Kjær Dual Channel Signal Analyzers Types 2032 and 2034 - are invaluable.

Software packages, running on a personal computer, are also available. These can enhance the documentation and analysis capabilities of the analyzers.



Sound intensity measurement and modal analysis, as well as sound pressure measurements and operational deflection shape measurements, are powerful techniques in the world of noise and vibration control. A Dual Channel Analyzer Type 2032 or 2034 can perform all these measurements.

Introduction

Modern industry and our environment are plagued with noise and vibration problems giving rise to annoyance, reduced comfort, fatigue, and also health and safety hazards. Noise and vibration are very closely related, since noise is in fact caused by dynamic forces in solids, transformed into pressure variations in air.

Successful noise and vibration control techniques are essential. A Dual Channel Analyzer Type 2032 or 2034 is the perfect tool for the job. Both acoustics and vibration problems can be diagnosed because:

- Brüel & Kjær microphones can be used in acoustics and Brüel & Kjær Delta Shear® accelerometers can be used in vibration. The analyzers have both microphone and accelerometer inputs. External accelerometer preamplifiers and microphone power supplies are unnecessary.
- Among a host of built-in functions are auto and cross spectra, sound intensity and frequency response functions. In acoustic applications the analyzers can display absolute values (Pa and W/m^2) and relative values (dB). In vibration the analyzer displays spectra of acceleration, velocity and displacement, accelerance, mobility and compliance in both engineering units and relative values (dB).
- The IEC 625-1/IEEE 488 digital interface can be used for controlling the measurement and for extra post-processing of the data.

In short, the user has a completely self-contained instrument for solving both noise and vibration problems in a fast and optimum manner.

Acoustic measurements

Sound pressure measurements

Whenever we need to study the effect of a noise problem and to judge whether or not the observed levels are within acceptable limits, we measure the sound pressure level. The analyzers perform sound pressure measurements. We simply calibrate the system by keying in the microphone sensitivity and the reference sound pressure (20 μPa). The measurement can be made with A-weighted- or linear-analysis. In single channel operation, and using a Hanning weighting, the 2032 has a real-time bandwidth of 16,6 kHz. In dual-channel mode this is 5,4 kHz. The 2034 has a slightly reduced real-time bandwidth. The analyzers each use high resolution 800-line narrow-band analysis, thus ensuring the easy identification of pure tones. Synthesis of 1/1 and 1/3 octave spectra is achieved using the software packages BZ 7006 or WW 9078.

Sound intensity measurements

We use sound intensity measurements to investigate the cause of noise problems and identify noise sources. Sound intensity is a built-in feature of both the 2032 and 2034. Simple calibration is achieved via the Universal Parameter Field. The only additional requirement is a Sound Intensity Probe Type 3519 or 3520. Post processing of the intensity spectra is possible with the WW 9078 software giving the following:

In-situ sound power determination. This technique is attractive because we do not need a special test chamber and there is no influence from the background noise. Narrow band as well as 1/3 octave-band sound power spectra can be calculated.

Noise source ranking. This compares the contributions to the total sound power radiated from a noise source such as a car engine for example. We can make the tests in-situ.

Source location (using intensity mapping). When presented in a 3-D visualization, contour plot or a set of numbers, we can describe the sound field generated by a source.

Vibration measurements

We normally make vibration measurements by using accelerometers as the vibration transducer. We calibrate by selecting ms^{-2}, or g, in the measurement unit field and keying in the accelerometer sensitivity in the Calibration Field. The acceleration spectrum is displayed using the Autospectrum Channel A. If we require absolute acceleration values in engineering units we select absolute units in the Display Unit Field. Velocity and displacement spectra are available via the Integration-Differentiation Field. Comparison of spectra from the analyzers is possible using the software package WT 9124. The package WT 9121 produces 3-D plots of the behaviour of spectra as a function of time.

Operational Deflection Shapes

In a similar way to sound intensity mapping, measurement of operational deflection shapes determines the vibration pattern of structures vibrating *under operating conditions*. The simplest way to do this is to mount a reference accelerometer in a fixed position and mount another accelerometer at further points and directions on the structure. We measure the vibration ratio and phase between the two accelerometers by using the frequency response function. The operational deflection at any frequency represents the absolute deflection of the structure due to a specific forcing function. The documentation of such a measurement can consist of tabulated numeric values, but it is often more informative to show slow-motion animations, or hard copy from the graphics plotter Type 2319, of deflection shapes. These show how parts move in relation to each other. The software package WT 9100, or WT 9101, is available to do this.

Modal analysis

Most noise and vibration problems are associated with operational dynamic forces exciting one or more resonances of a structure. When the forcing frequencies are similar to the resonance frequencies of the structure we can expect problems. The goal of a modal analysis is to determine the inherent dynamic properties of a structure and to ultimately create a mathematical dynamic model. For the modes in the frequency range of interest we need the modal parameters - modal frequency, modal damping and mode shape. We can find these from mobility measurements. There are two ways to make the measurement using the analyzers. We can use a vibration exciter to apply a measurable force to a fixed position and measure the vibration response in various positions. Alternativley, we can measure the vibration at one point and apply the measureable force at the other points using an impact hammer. Modal analysis on practical structures often becomes so comprehensive, in terms of number-crunching and measurement management, that an external computer is required to handle the data, extract the modal parameters and document the results. Again, the results can be displayed using a computer animated display of the mode shapes. WT 9100 and 9101 software packages do this.

Conclusion

Dual Channel Analyzers Types 2032 and 2034 are perfect tools in helping to solve both noise *and* vibration problems. The analyzer forms the heart of the measurement and analysis system. The only additional equipment needed are the transducers and maybe a personal computer to enhance the analysis and documentation of results.

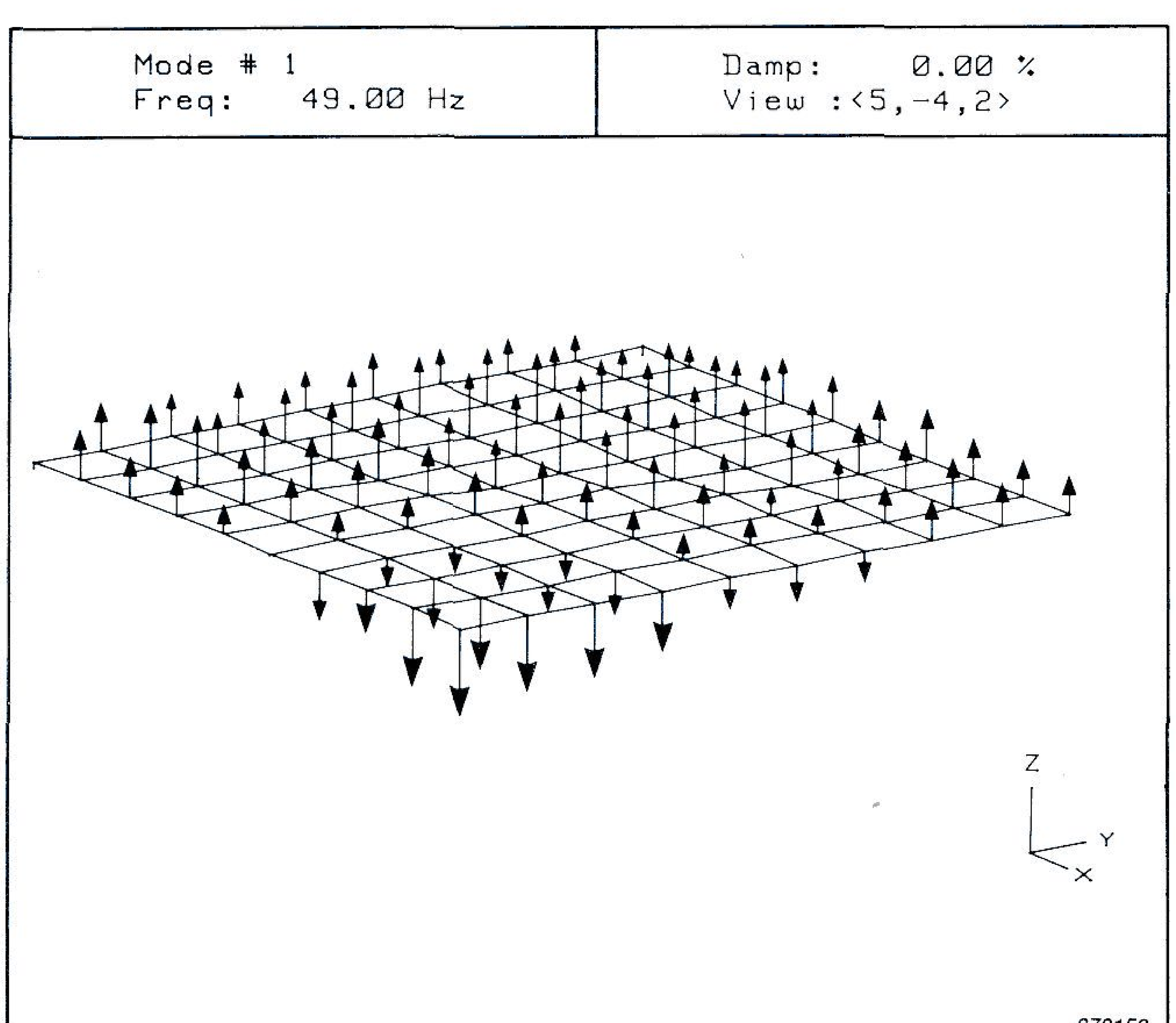


Fig.1. The operational deflection shape of part of the housing on a factory machine during normal operation. A 2034 and software package WT 9100 were used for this.

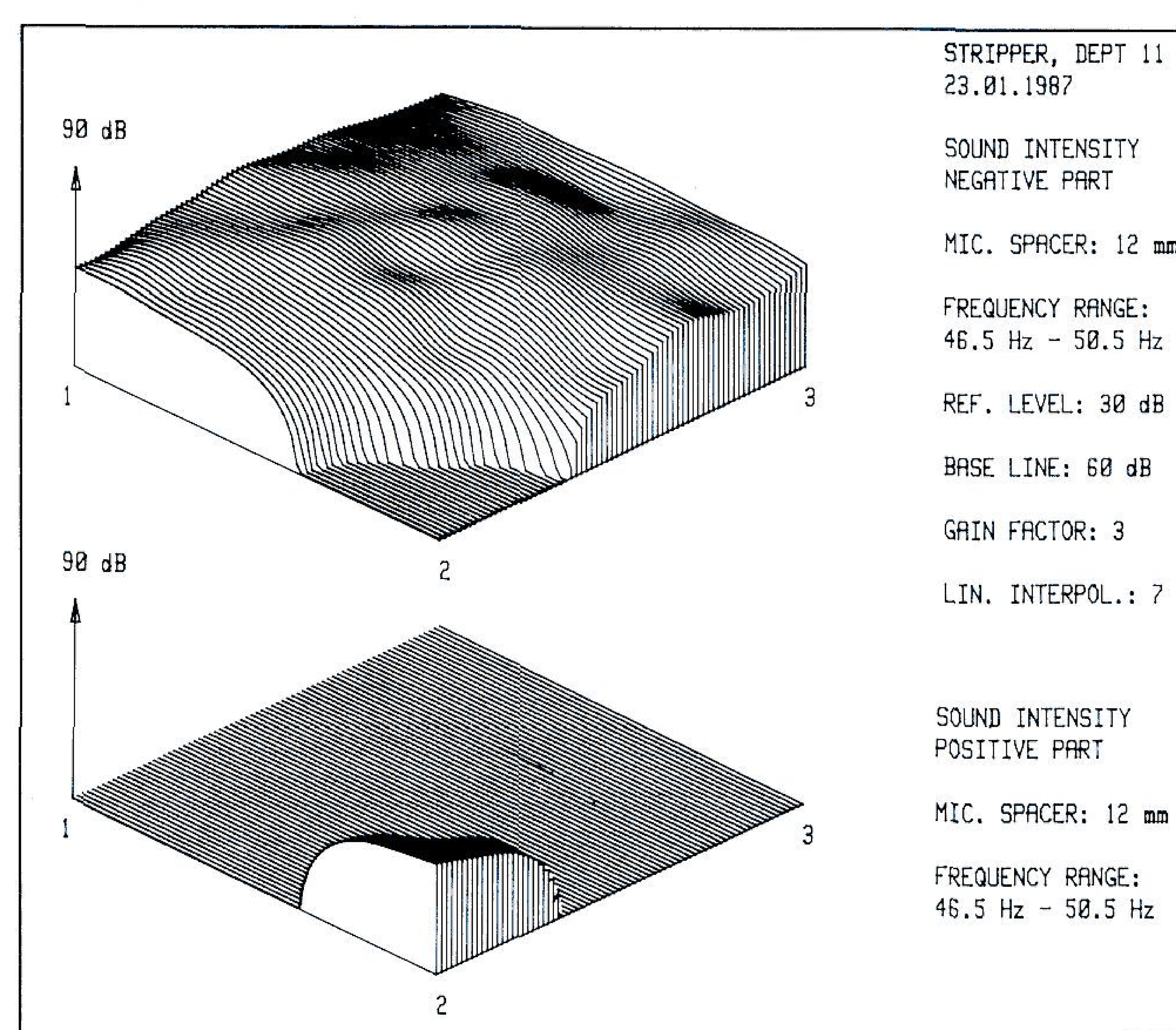


Fig.2. The positive and negative parts of the sound intensity flowing out of the same part of the machine in fig. 1. The similarity of the sound intensity contours to the operational deflection shape indicates a correlation between the two. A 2034 and software package WT 9078 were used.

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