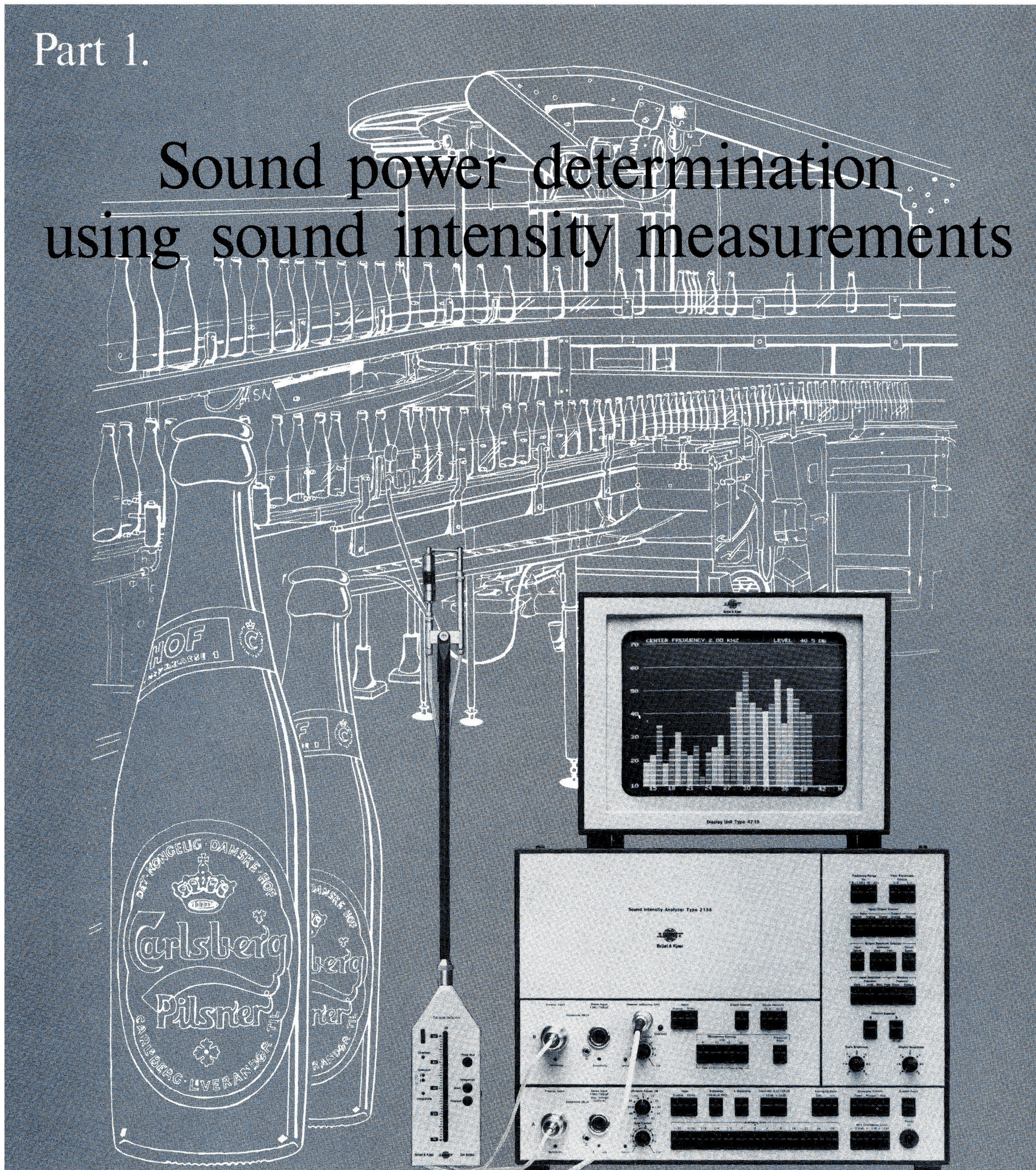




### Part 1.

# Sound power determination using sound intensity measurements



# Sound power determination using sound intensity measurements.

## Part I.

by S.Gade, H.Wulff & K.B.Ginn  
with the collaboration of  
Carlsberg Forskningscenter

### Introduction

The aims of these measurements were to:

1. Measure the amount of noise generated from a labelling machine operating at full speed. The measurements were performed *in situ* in the tapping hall of a brewery where a high level of background noise was present.
2. Verify whether at the operator's position, the sound pressure level due to the labelling machine was below the 85 dB(A) as specified by the manufacturer of the machine.
2. Measurements may be performed in the near- as well as the far-field. Near-field measurements improve signal to noise ratio and are therefore often preferred despite the fact that more measurement points should be employed than in the corresponding far-field measurement.
3. In common with the sound pressure, free-field method, the intensity measurements have to be performed on a hypothetical surface enclosing only the source of interest, however the intensity method places no restrictions on the shape and size of this measurement surface.
4. Measurements 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.

### Description of the labelling machine and the test conditions

The dimensions of the machine were 225 cm long by 260 cm wide by 190 cm high. At full speed the machine labelled 34500 bottles per hour. The noise due to the transportation of the bottles to and from the machine could not of course be "switched off".

In these circumstances, "traditional", sound pressure measurements to determine the sound power of the machine were of no avail as the noise of the machine could not be dissociated from the high level of background noise.

However sound intensity measurements were able to determine sound power of the machine under normal working conditions. The advantages of the intensity method over the pressure method for sound power determinations are as follows:

1. No restrictions upon the room where the measurements are performed.

### 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 (four sides and a top). On each of the four vertical sides, 24 measurement points were defined yielding 96 points in all, each point representing an area of 0,25 m<sup>2</sup>. To facilitate the positioning of the measurement

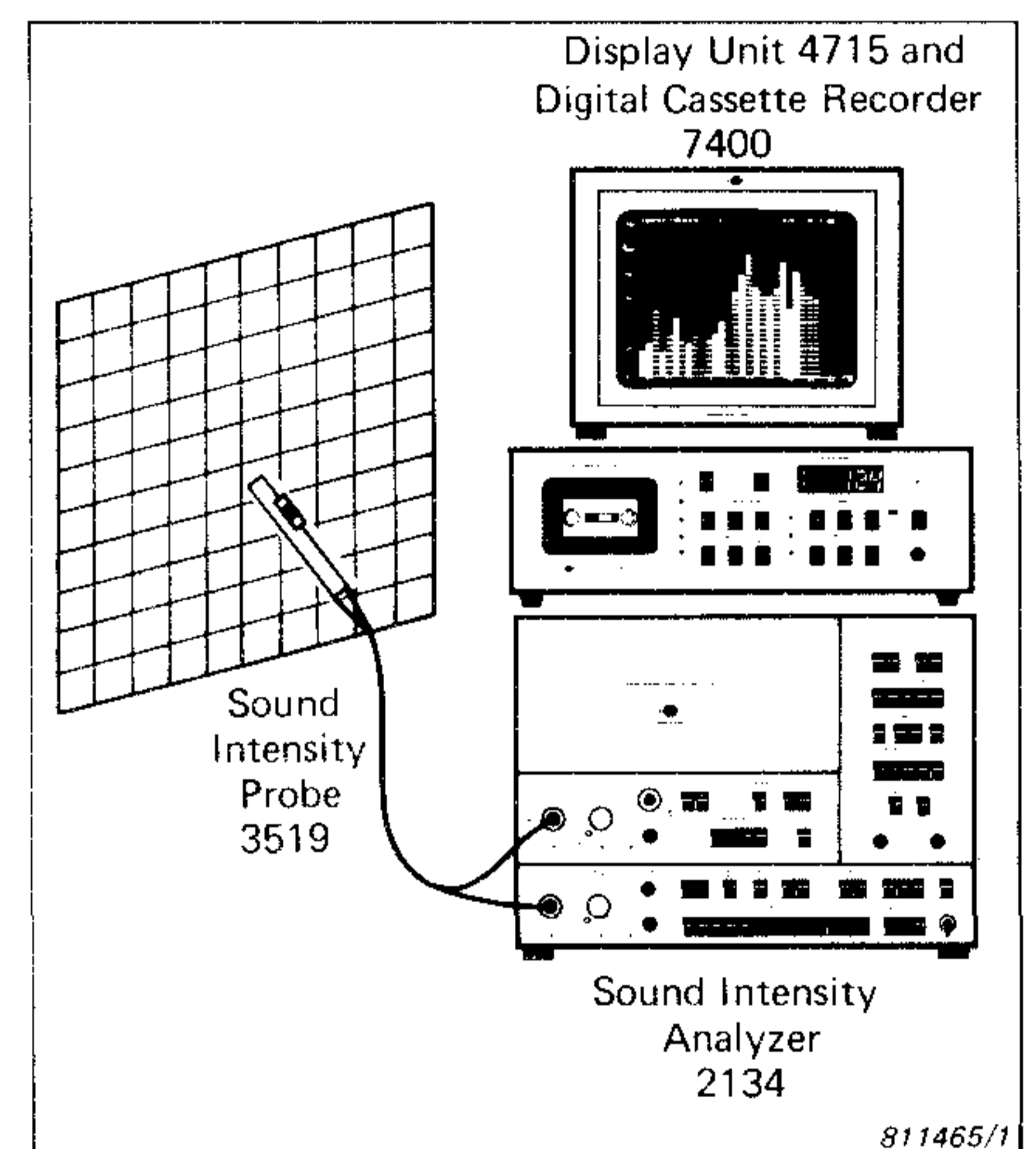


Fig. 1. Instrumentation used for sound intensity measurements in a brewery tapping hall with a schematic representation of a measurement grid

probe at the measurement points, a rectangular frame of dimensions 3 m x 2 m was constructed of aluminium rods. No cross-grid of wire or string was bound to the frame as the operators had to have easy access to the labelling-machine at all times. On the top of the enclosing surface, 9 measurement points were defined, each point representing 1 m<sup>2</sup>.

To measure the sound intensity level spectrum at each of the 105 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  $\pm 1$  dB and up to 10 kHz with an accuracy of +1 to -4 dB. A linear averaging time of 8 s was used yielding a measuring time of 14 minutes for the sound intensity

spectra. Approximately 3 seconds were required to move the probe between measurement points which increased the measuring time to 17 minutes. In addition, sound pressure spectra were measured at the centre of each of the 5 surfaces (one measurement being at the operator's position) and in the centre of the hall 15m away from the labelling machine. After the measurements, the 111 spectra were recalled from the Digital Cassette Recorder onto the Display Screen to ensure that all the results were valid. Broken bottles in the machine and along the conveyor system were common. This led to several machine shut-downs which meant that the total time for performing the measurements was 2 hours.

### Results of sound power determination

The sound power determined from sound pressure level measurements,

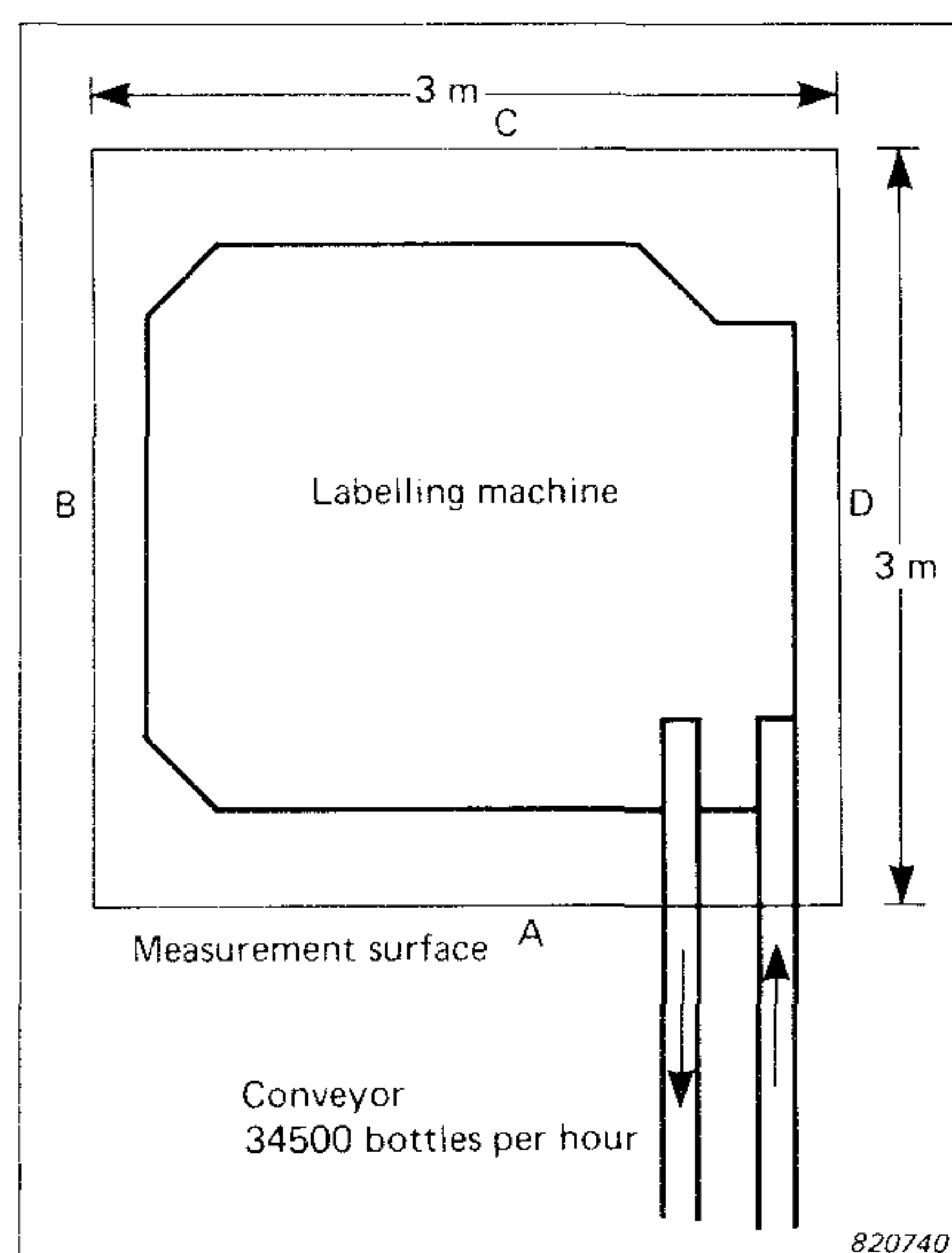


Fig. 2. Plan view of the labelling machine showing the measurement surfaces and the position of the bottle conveyor

$L_w$	dB Lin	dB(A)
$L_w(p)$	105,3	103,7
$L_w(I)$	99,8	97,5
Difference	5,5	6,2

820048

Table 1. Sound power as determined from sound pressure,  $L_w(p)$ , and from sound intensity,  $L_w(I)$ , measurements

without any room corrections,  $L_w(p)$ , and from sound intensity measurements,  $L_w(I)$ , are shown in Fig.3 and summarized in Table 1. The corrected value  $L_p = (87,2 - 6,2) \text{ dB(A)} = 81,0 \text{ dB(A)}$  verifies the manufacturer's specifications for the sound pressure level at the operator's position.

### Average intensity

To obtain an overall view, the 24

intensity spectra for each side were averaged to yield one spectrum for each side. From these spectra, it was seen that the net flow of energy between 5kHz and 10kHz was towards the labelling machine on the side where the bottles entered and left the machine. This was expected as the rattling bottles on the conveyor produced a lot of noise especially at high frequencies.

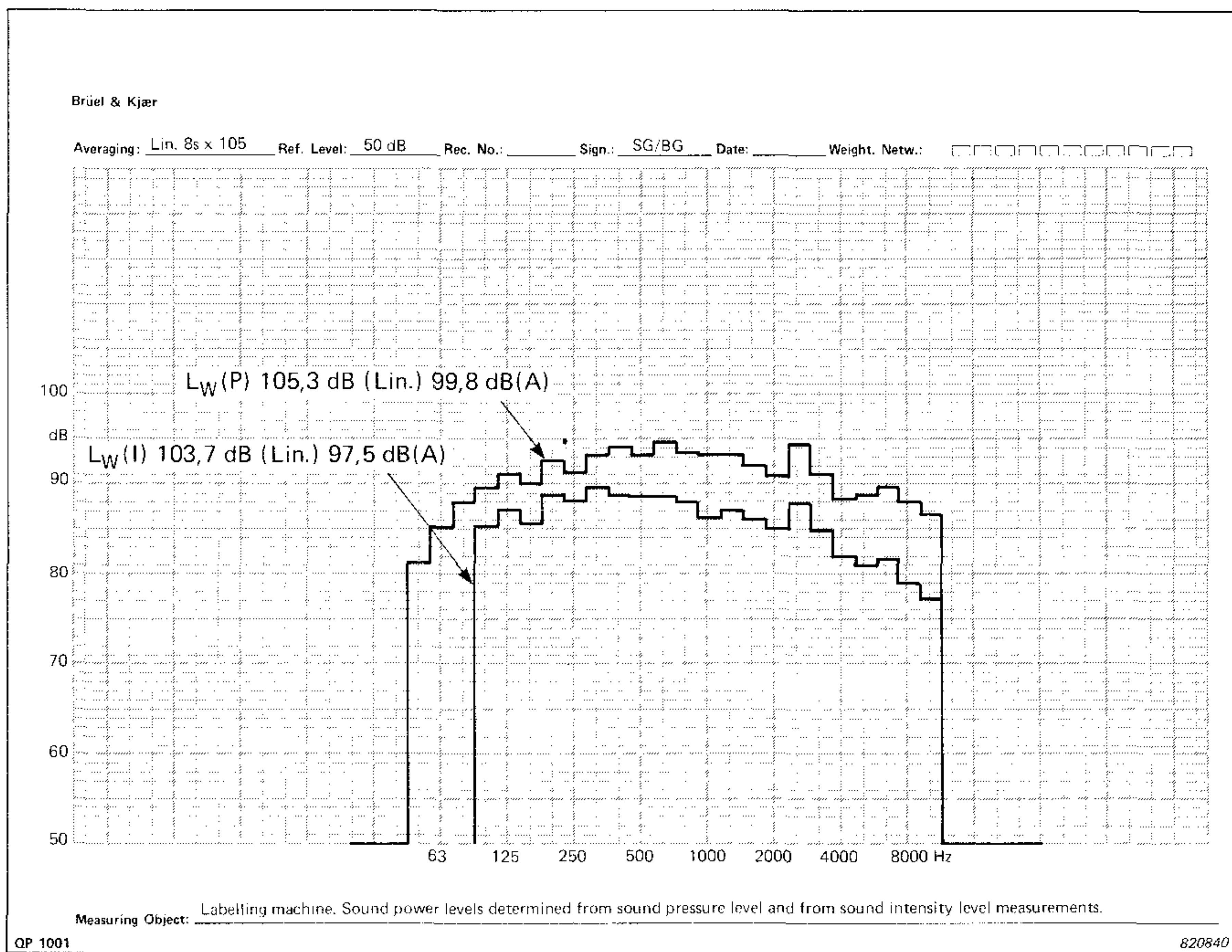


Fig. 3. Sound power levels determined from sound pressure level and from sound intensity level measurements

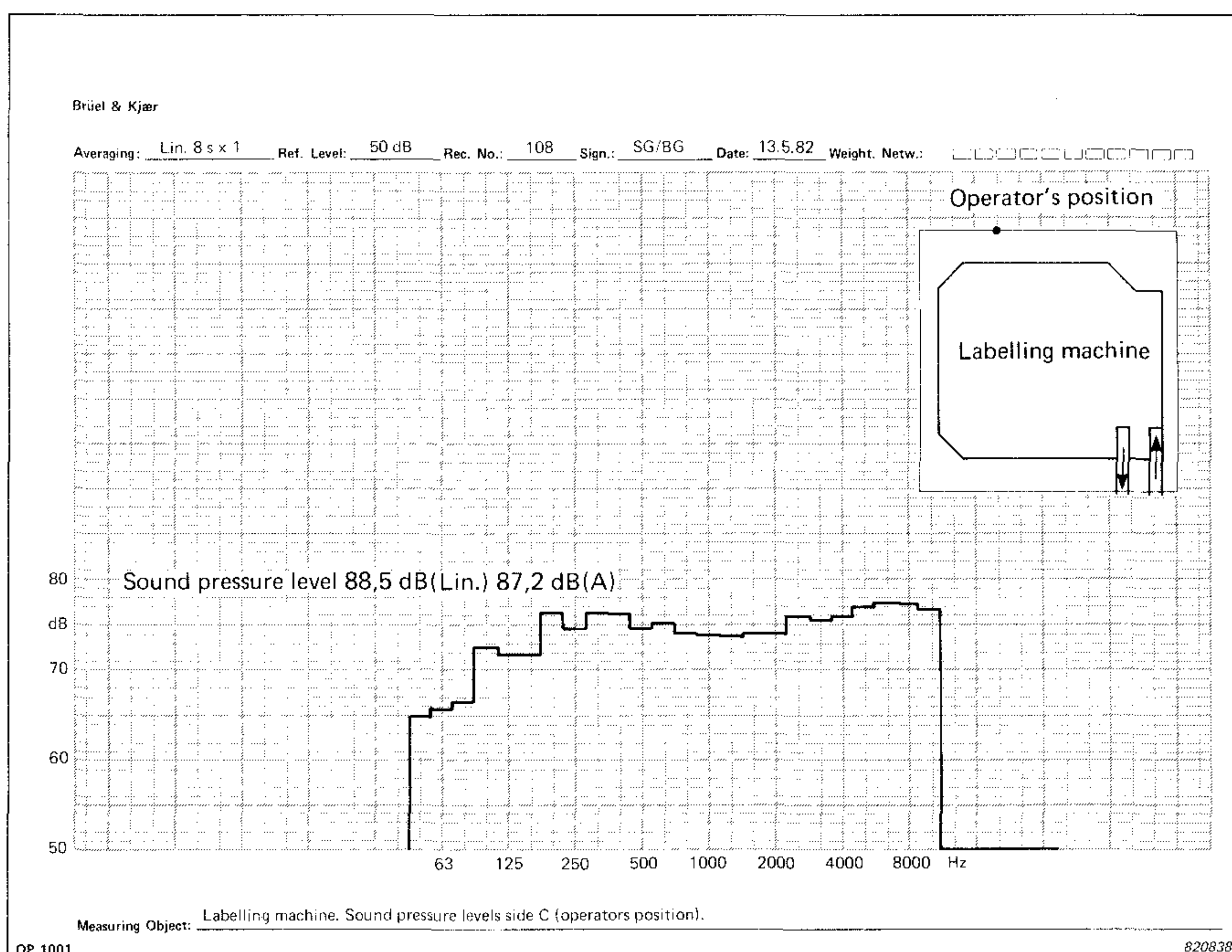


Fig. 4. Sound pressure level at the operator's position

### Intensity maps

For the measurement surface closest to the operator, an iso-intensity map of the overall intensity level was plotted using the instrumentation shown in Fig.6. The numbers around the map are the sound intensity levels to the nearest dB, at the perimeter measurement points. This map shows that the highest intensity level is between 84 dB and 85 dB and is located in the right hand portion of the map area at about 70 cm above the floor. Iso-intensity contours can also be plotted for selected frequencies.

The intensity map indicates that the area of high intensity is located just in front of the operator's usual position. Such a map can help in deciding where best to position the operator or to install an acoustic barrier.

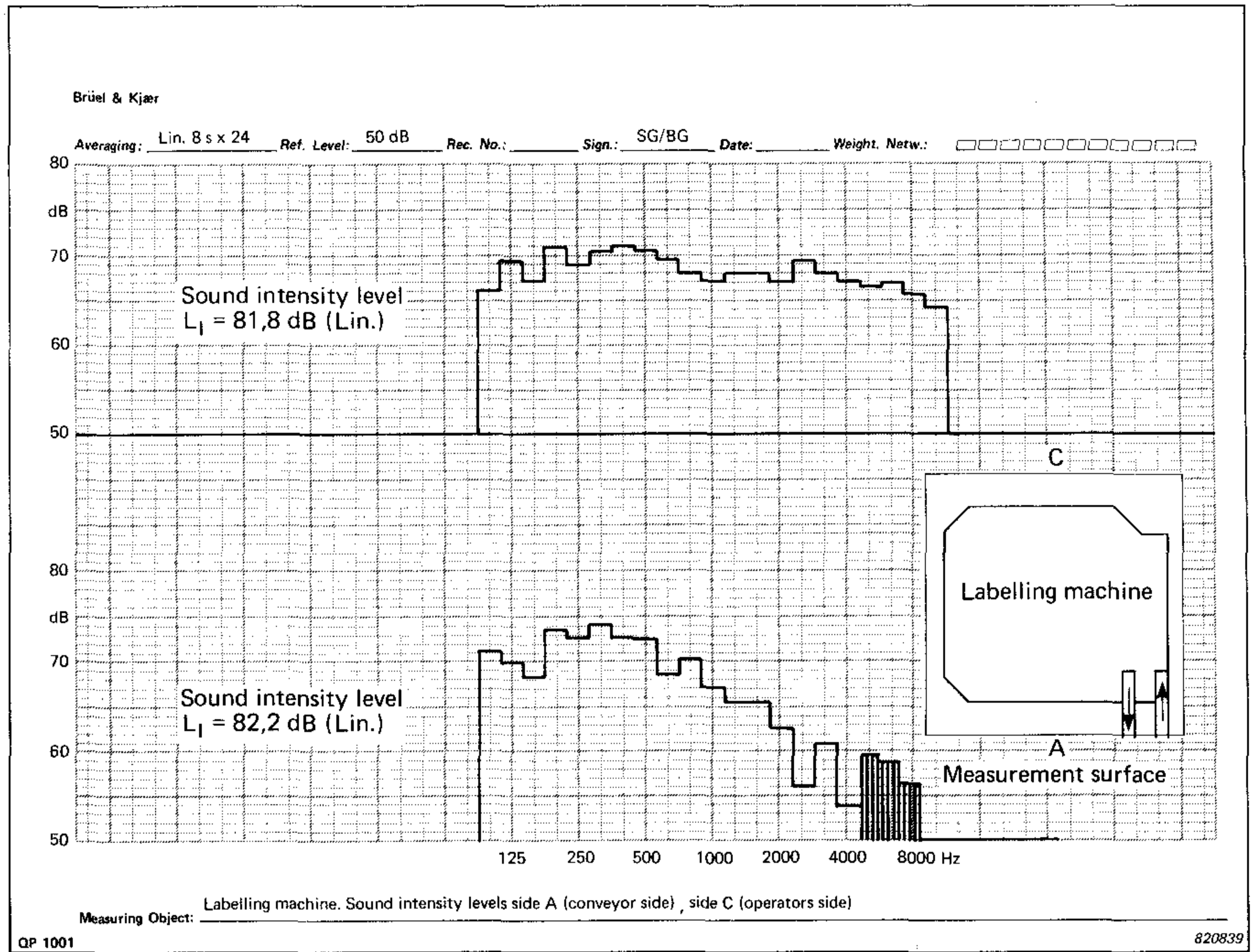


Fig. 5. Sound intensity levels averaged over 24 measurement points on side A (conveyor side) and on side C (operator's side)

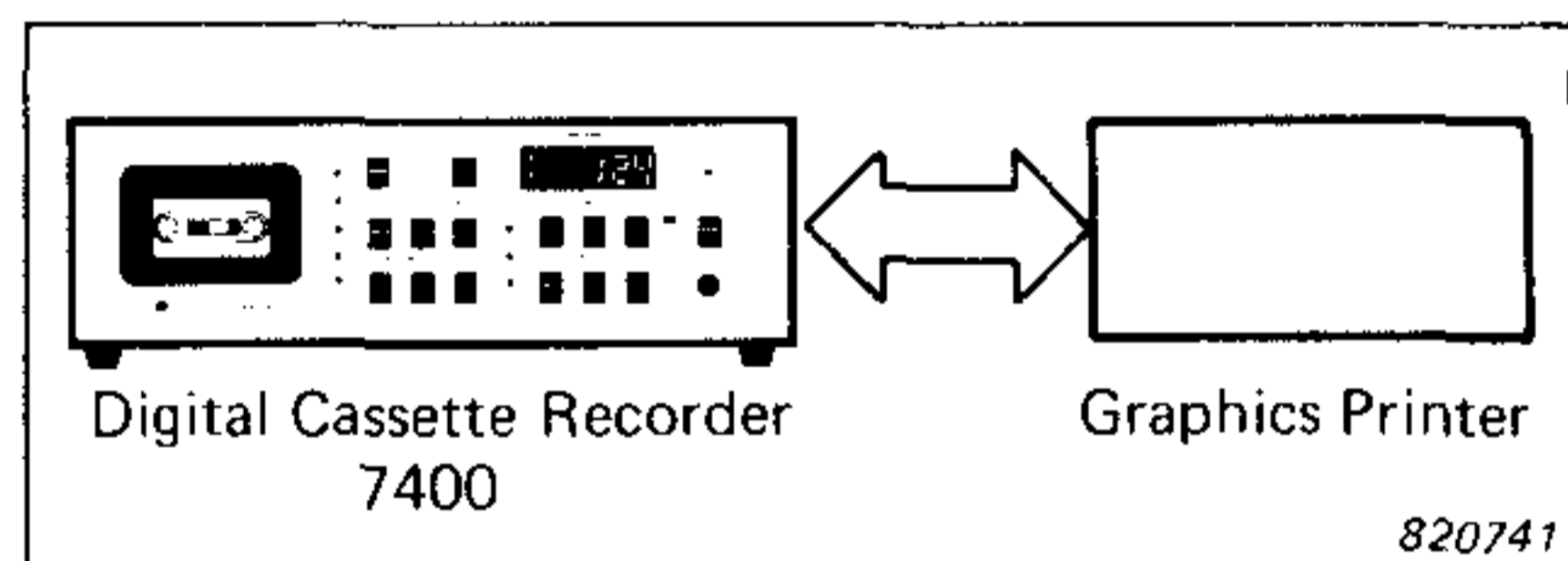


Fig. 6. Instrumentation used for plotting intensity maps

### Conclusion

During recent years, sound intensity measurements have become established as a valid and precise method for determining sound power levels of noise sources. The advantages of the sound intensity

method over the sound pressure method are clearly demonstrated when performing measurements *in situ* where sound intensity permits measurement even in the presence of high levels of background noise.

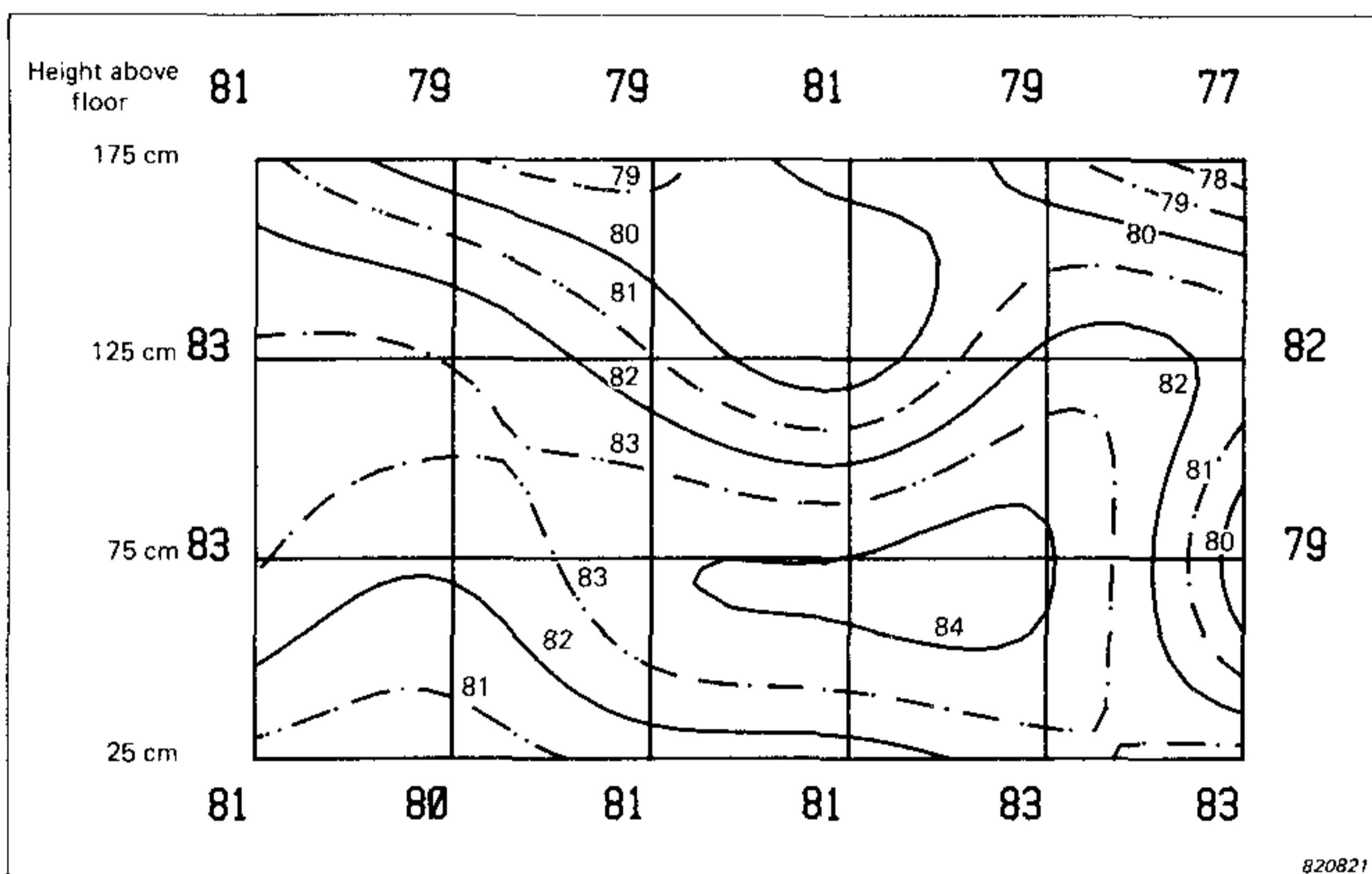


Fig. 7. Sound intensity map of the total sound intensity levels over the 24 measurement points on side C

81.3	79.2	78.7	80.6	79.4	77.1
83.1	82.9	81.1	79.5	82.3	81.5
83.1	82.2	83.8	84.0	84.1	79.3
80.7	80.5	81.3	81.5	82.7	83.4

Fig. 8. An alternative representation of the total sound intensity levels over the 24 measurement points on side C. Each sound intensity level is associated with an area of 0,25m<sup>2</sup>



**Brüel & Kjær Instruments, Inc.**

185 Forest Street, Marlborough, Massachusetts 01752 / (617) 481-7000 TWX 710/347-1187