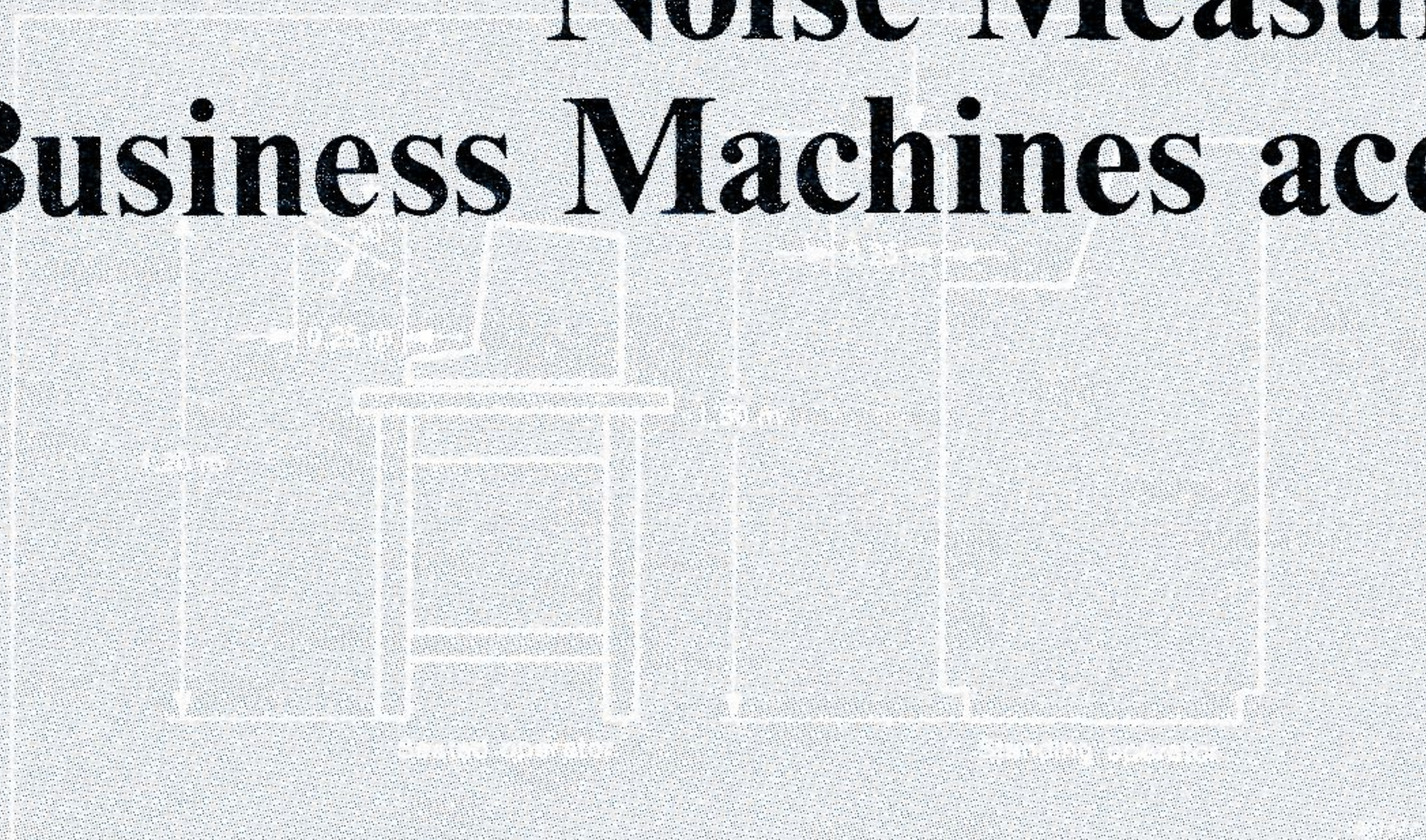


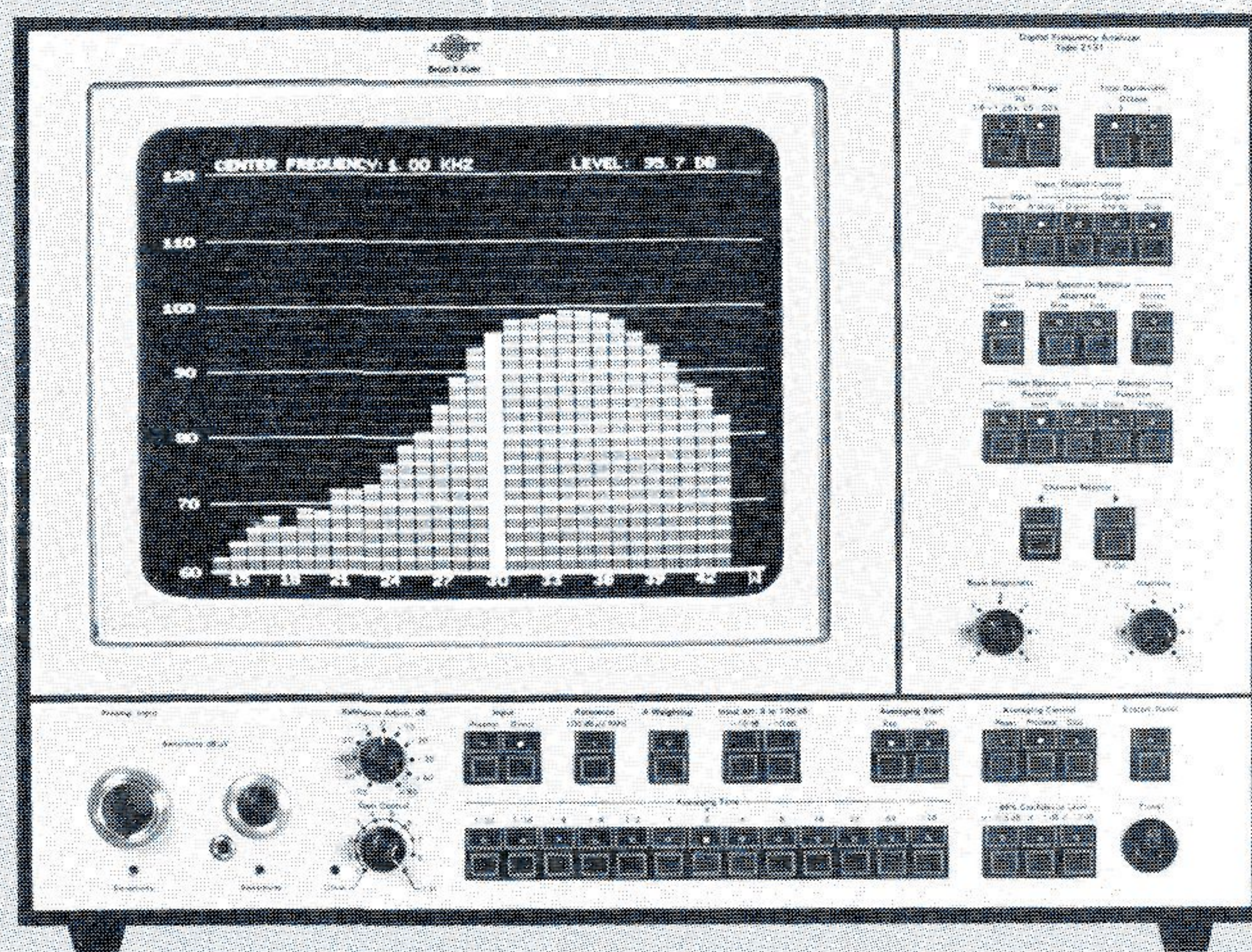
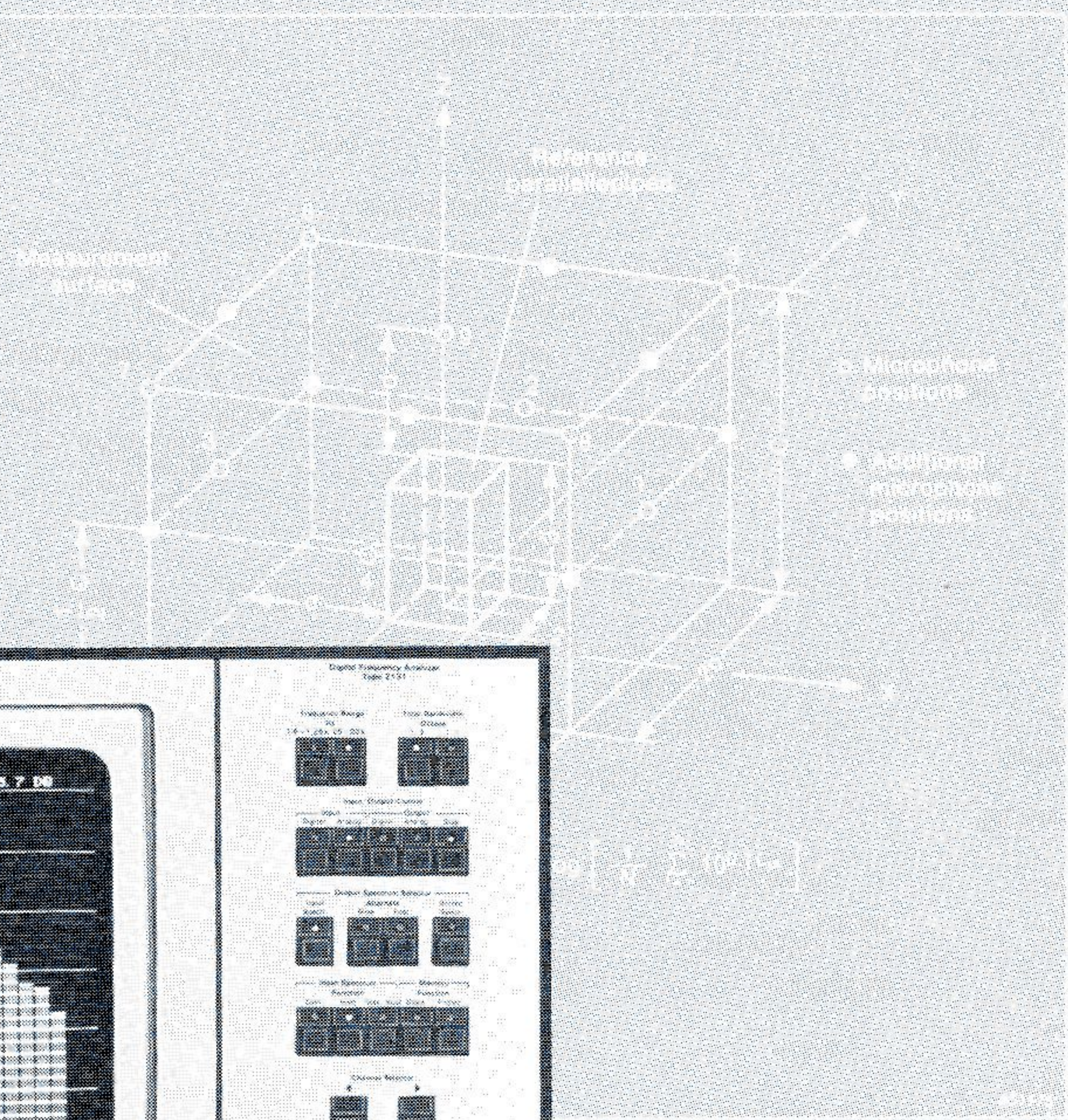
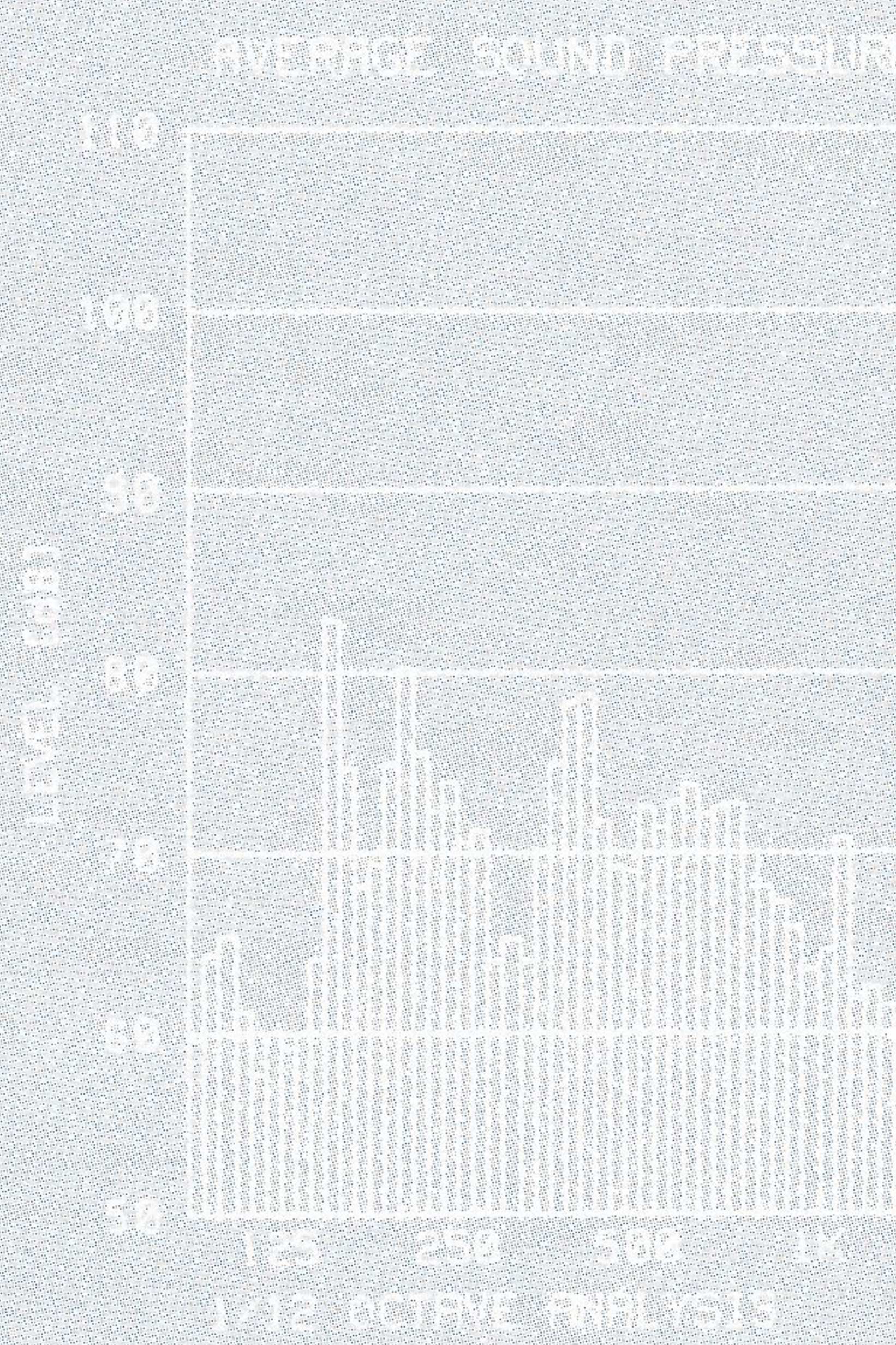


Software Package WW 9041 for Noise Measurements on Business Machines according to ECMA 74



985 ID/MEAS. NO. 2
OP. MODE:
SERIAL NO. 1

NUMBER OF PDS: 4 NUMBER OF SCANS: 1



Software Package WW 9041 for Noise Measurements on Business Machines according to ECMA 74

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Roger Upton, B.Sc., Brüel & Kjær, Denmark

1. Introduction

Software Package WW 9041 allows noise measurements on business machines according to ECMA 74, Measurement of Airborne Noise Emitted by Computers and Business Equipment. It includes programs for determination of sound power and for measurement of sound pressure at the operator and bystander positions. The programs are written in BASIC 4.0, and can operate in an HP 200/300 series computer. They are stored on a 5 1/4 or 3 1/2 inch disc. The programs also make use of a data disc for storage and retrieval of results.

The programs can be used for semi-automatic or automatic measurements. For semi-automatic measurements, the following instruments are required:

1. The Digital Frequency Analyzer Type 2131, or the Sound Intensity Analyzing System Type 3360
2. Modifications WH 0490/WI 1624 to the Type 2131 or Type 3360
3. A Microphone and Preamplifier, (e.g. Type 4165 with Type 2639)

For automatic measurements, the following instruments are required:

1. The Digital Frequency Analyzer Type 2131, or the Sound Intensity Analyzing System Type 3360
2. Modifications WH 0490/WI 1624 to the Type 2131 or Type 3360
3. 1 to 4 Multiplexers Type 2811
4. 1 to 32 Microphones and Preamplifiers, (e.g. Type 4165 with Type 2639).

Since the determination of sound power follows ISO 3744, (ANSI equivalent, ANSI S1.34), a Reference Sound Source Type 4204 might also be required for measurement of the room correction factor K.

The sound power determination is according to ECMA 74 and ISO 3744, from sound pressure measurements in an essentially free field over a reflecting plane. The sound pressure levels are determined according to ECMA 74 and ISO 6081. The test for impulsive noise uses the modifications WH 0490/WI 1624 to the 2131 or 3360, and follows ECMA 74, as does the pure tone determination, which uses the 1/12 octave mode of the 2131 or 3360. All measurements are according to the September 1981 draft of ECMA 74, except the pure tone determination, which follows the September 1982 amendment.

The programs can also be operated with an unmodified 2131 or 3360. All of the measurements described above can be carried out, except the impulsive noise test.

2. Sound Power Determination

The sound power levels are determined from 1/3 octave sound pressure measurements at a number of microphone positions on a measurement surface in an essentially free field over a reflecting plane. Two measurement surfaces are allowed, namely the par-

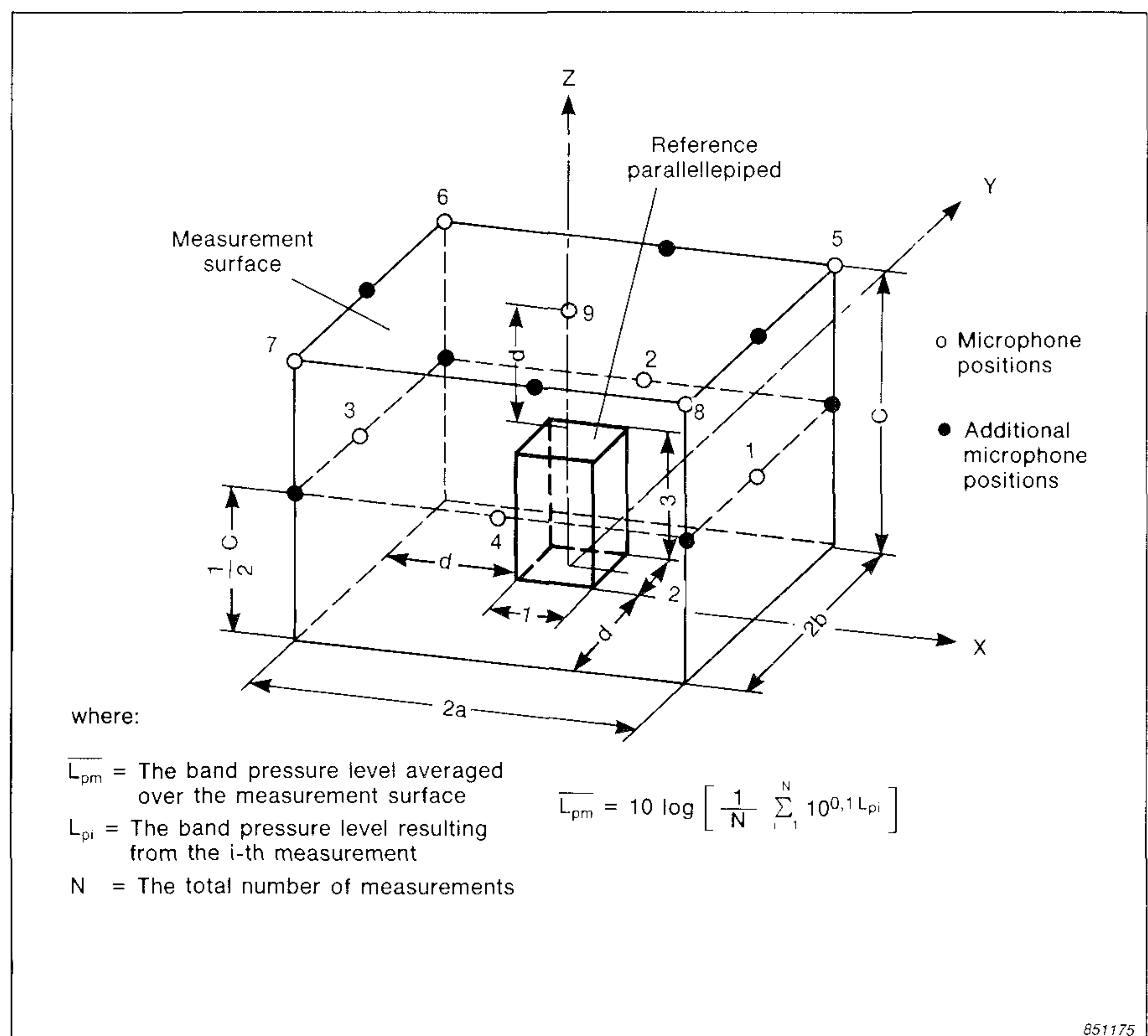


Fig. 1. Microphone positions for the parallelepiped, or "shoe-box"

851175

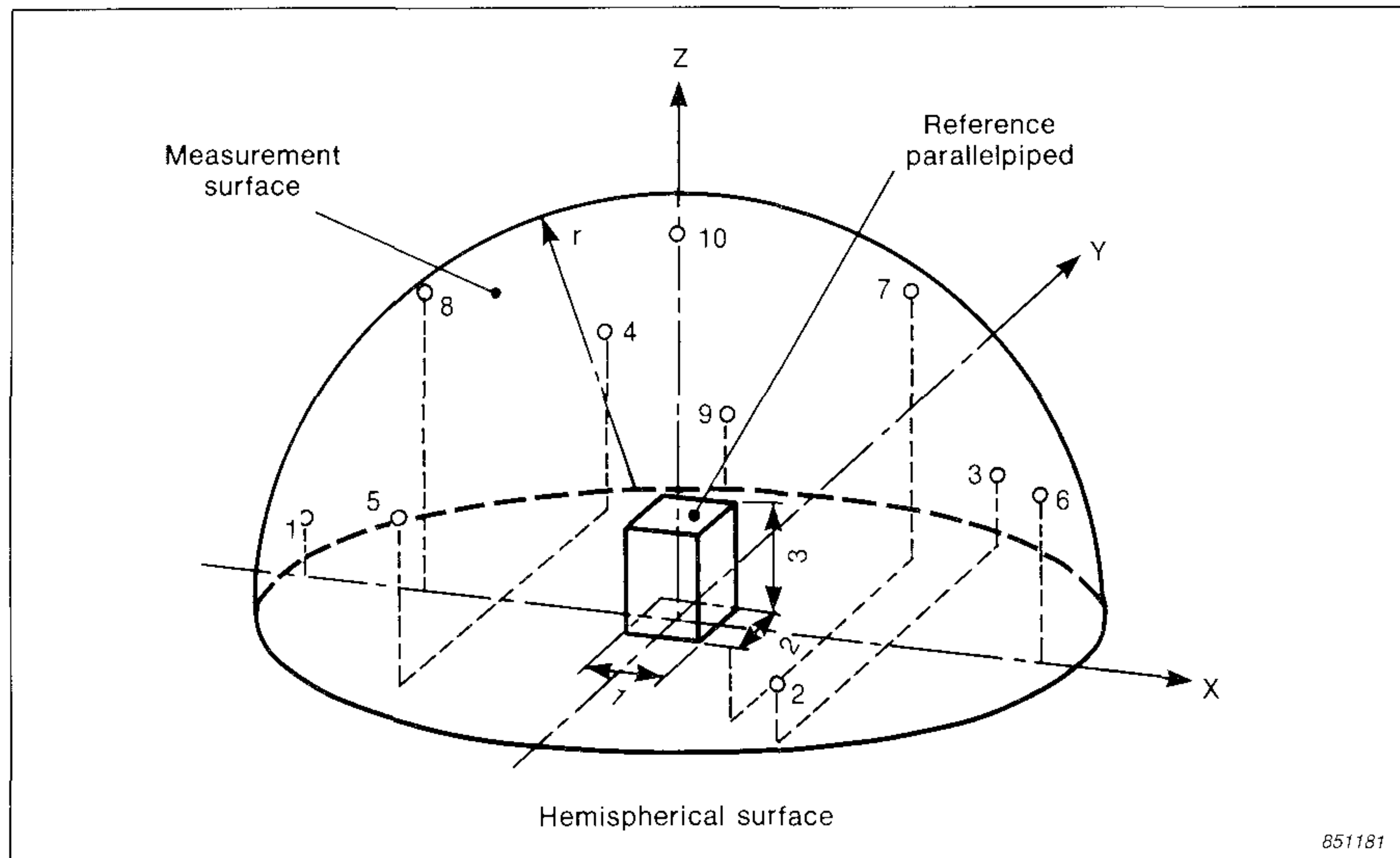


Fig. 2. Microphone positions for the hemisphere

allelepiped, or "shoe-box", and the hemisphere, shown in Figs.1 and 2 respectively. Of these two surfaces, ECMA 74 states that the parallelepiped is preferred, and that the hemisphere can only be used for measurements on small noise sources.

The measurements can be performed in a semi-automatic or automatic mode. The semi-automatic mode is intended for use with systems using only one microphone. A pause is introduced between each sound pressure measurement to enable the microphone to be moved to the next microphone position. The automatic mode is for use with multiplexed microphone systems, whereby the program automatically scans around all microphone positions. The scan can either be continuous, or a pause can be introduced between each sound pressure measurement at each microphone position, should it be necessary to make adjustments to the device under test. For instance, for printers printing onto single sheets of paper, it will be necessary to insert a new sheet of paper for each sound pressure measurement at each microphone position.

Up to 32 microphone positions can be scanned, either semi-automatically or automatically, with a linear averaging time of up to 128 seconds at each microphone position. When an averaging time of 128 seconds is insufficient, it may be extended by repeating the measurement at each microphone position, with up to 10 repetitions being possible. In addition, up to 10 complete scans can be carried out around the selected microphone positions. All of the measured spectra are stored on the data disc for later retrieval.

In addition to the source scan, a background noise scan is required. In both semi-automatic and automatic measurements, the background noise at each microphone position is measured as a separate scan prior to the source scan.

The background noise scan is stored on the program disc, and provided the number of microphone positions remains unchanged, it can be used for multiple measurements of sound power. If the number of microphone positions is changed, however, (or the background noise conditions change), a new background noise scan must be

Difference in dB between sound pressure level measured with equipment operating and background noise alone	Correction in dB to be subtracted from sound pressure level measured with equipment operating to obtain sound pressure level due to equipment alone
< 6	measurement invalid
6	1,0
7	1,0
8	1,0
9	0,5
10	0,5
> 10	0,0

Table 1. Corrections for background noise according to ECMA 74, Clause 6.7.3.

made. The averaging time used for the background noise scan and the source scan is independently selectable.

The sound pressure spectrum at each microphone position, averaged over the number of scans performed and corrected for background noise according to ECMA 74, (see Table 1), can be displayed on the screen of the computer or printed out on its graphics printer. The measured background noise spectrum for each microphone position can also be displayed or printed. The average sound pressure level, L_{pm} , (corrected for background noise), is calculated for each $1/3$ octave band across all microphone positions, and can be displayed or printed, as can the average background noise level.

The software includes the possibility of entering the environmental or room correction factor, K , (ECMA 74, clause 6.8, and ISO 3744, annex A). This factor describes the amount of noise measured in dB due to unwanted reflections. The correction factor can be entered manually for each $1/3$ octave and the A-weighted channel, or can be measured using the Reference Sound Source Type 4204, which is placed in the test environment in the same position as the source under test, and with the same microphone positions. The correction factors are stored on the program disc, and hence provided that the test environment and microphone positions remain unchanged, they need only be entered or measured once. The maximum range allowed for the room correction factors is 0 to 2 dB.

The surface sound pressure level L_{pf} is the average sound pressure level, corrected for the amount of noise due to unwanted reflections:

$$L_{pf} = L_{pm} - K$$

The sound power level is calculated from the surface sound pressure level according to the equation:

$$L_W = L_{pf} + 10 \log_{10} \left(\frac{S}{1 \text{ m}^2} \right)$$

where S is the surface area of the measurement surface in m^2 . Both the surface sound pressure level and the sound power level can be displayed on the computer's display screen or printed on its graphics printer, as can the room correction factor K .

The display and printout of measured and calculated spectra can be made both in numeric and in graphic form. The A-weighted and $1/3$ octave or $1/1$ octave levels, (calculated from the $1/3$ octave data), are shown. Corrections for background noise or unwanted reflections, (room corrections), are indicated, as are under-range in the

measurements or invalid data due to too high background noise or room correction factors. Examples of printouts are given in Section 7.

The data can also be displayed and printed out without the background noise correction. This allows sound power to be calculated even when the

required background noise conditions have not been met. However, the calculated values will be too high, and cannot be quoted as being measured according to ECMA 74. A warning is given on the display or printout when the background noise correction has not been made.

3. Sound Pressure Measurements at the Operator and Bystander Positions

The operator position for noise measurements on business machines according to ECMA 74 is defined as in Fig.3. The microphone should be oriented such that it has a flat response to sound incident on it from the device under test at an angle of 30° below the horizontal. Where the device under test is not usually operator attended, the noise measurements are made at the bystander position(s). A number of bystander positions can be defined e.g. at the front, sides, and back of the equipment under test. It is left to the manufacturer to decide how many positions are relevant. The bystander positions are defined similarly to the operator position, except that they are now 1 m from the device under test. The sound pressure measurements required at the operator and/or bystander positions are the mean A-weighted sound pressure level, \overline{L}_pA , and where impulsive noise and/or pure tones are audible, an impulsive noise test and/or a pure tone determination.

The scanning of the microphone positions for sound pressure measurements and the data storage is performed as described in Section 2. The sound pressure spectrum at each microphone position, averaged over the number of scans performed and corrected for background noise can be displayed and printed, as can the A-weighted sound pressure level, L_pA . The average sound pressure spectrum, (corrected for background noise), over all the microphone positions is calculated and can be displayed and printed. Also, the measured background noise at each microphone position and the average background noise over all microphones can be displayed and printed.

If the 2131 or 3360 is fitted with the modifications WH 0490/WI 1624, the impulsive noise test according to ECMA 74 is performed at the same time as the sound pressure measure-

ment. The A-weighted impulse rectified sound pressure level, L_{pAI} , averaged on a mean-square basis, is measured. If the difference between L_{pAI}

and L_pA is equal to a greater than 3 dB, the noise is considered to be impulsive, and this is indicated on the display and print-out.

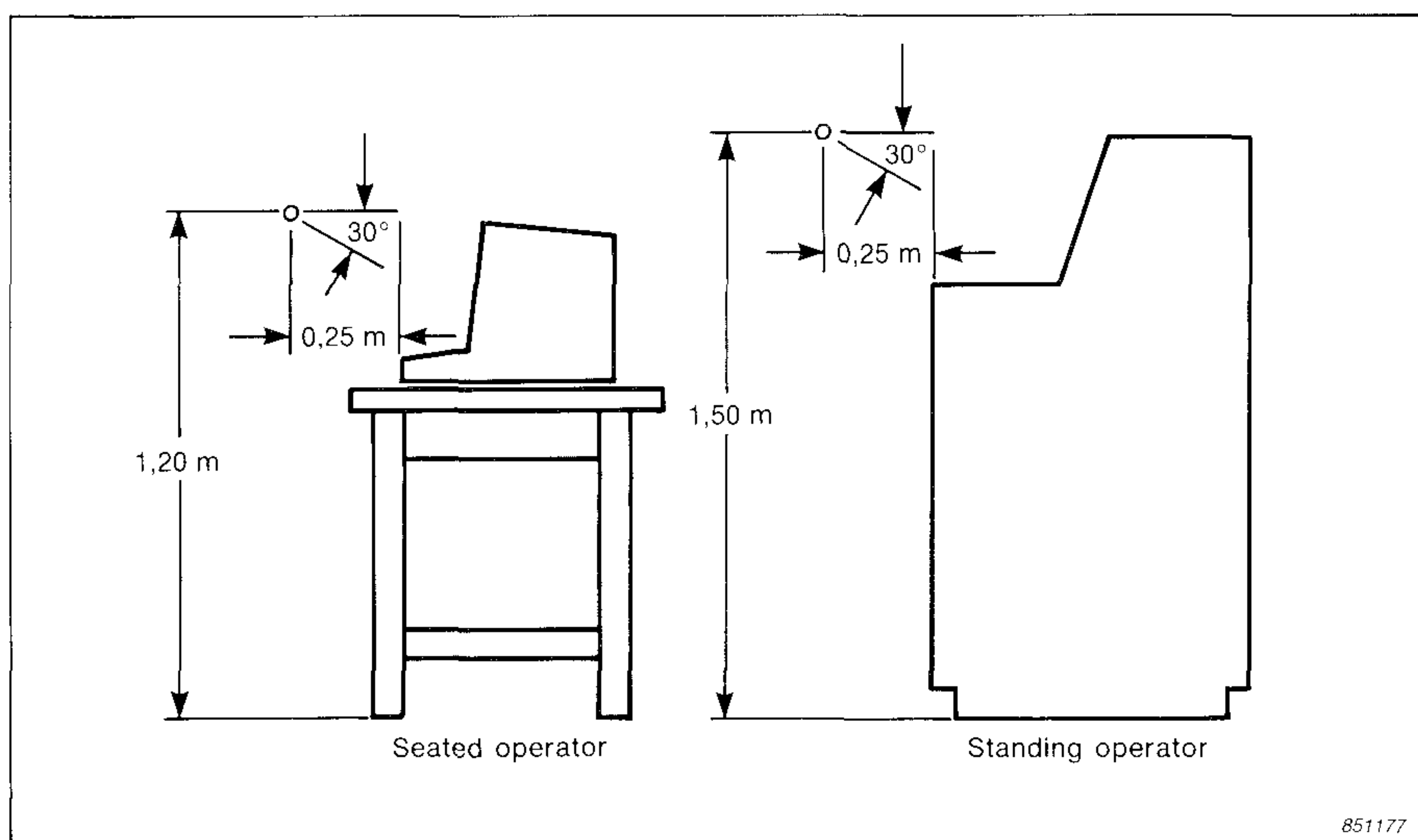


Fig. 3. Examples of the operator position for a seated and standing operator

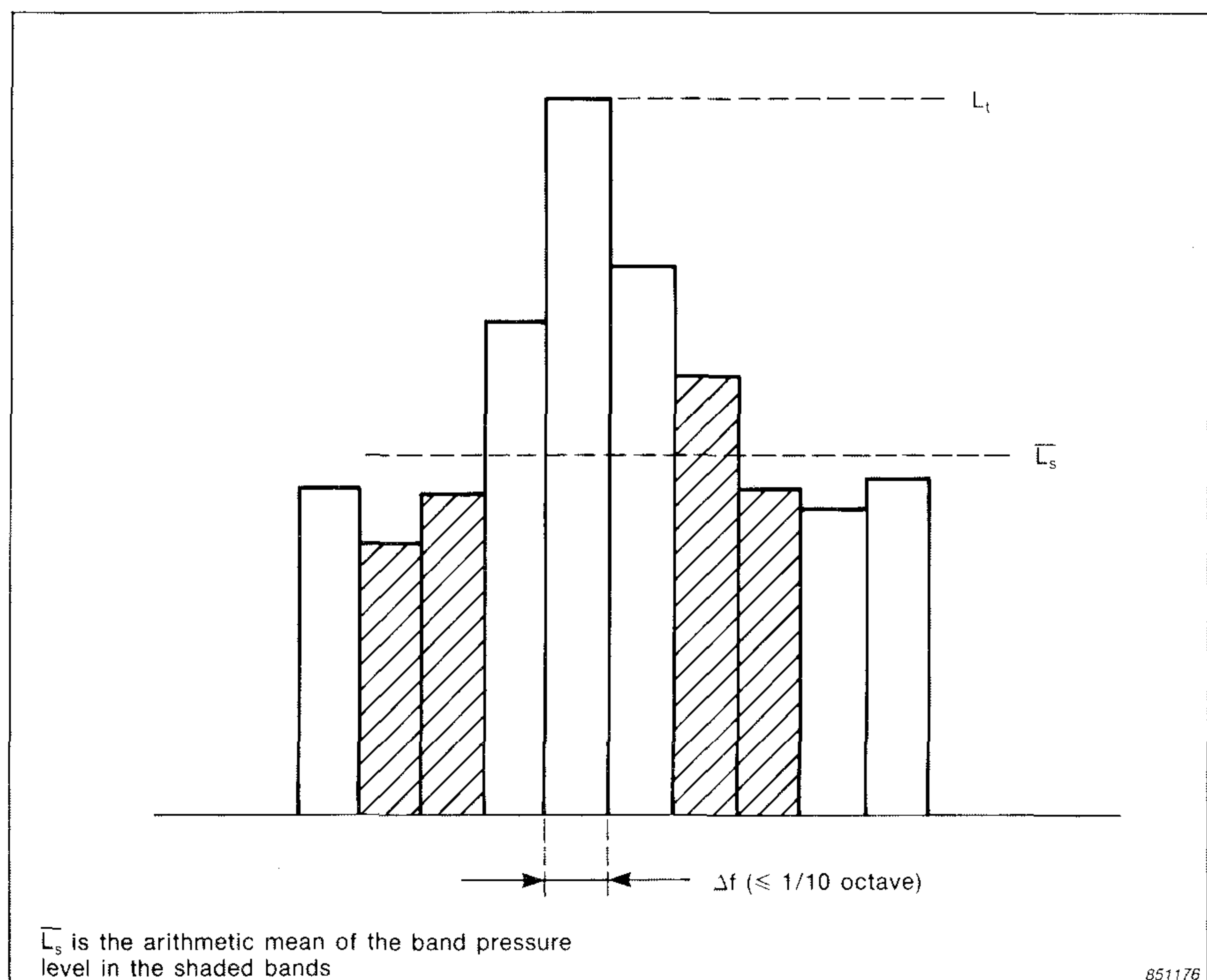


Fig. 4. Determination of $L_t - \overline{L}_s$ in the pure tone determination

The pure tone determination is performed according to the amendment to ECMA 74, September 1982. It uses the $1/12$ octave mode of the 2131 or 3360, which requires a four pass analysis. Hence, the number of scans is limited to 1, and no background noise scan is made. The difference $L_t - \bar{L}_s$ is determined as shown in Fig.4, and a pure tone is detected when:

$$L_t - \bar{L}_s \geq 10 - 10 \log_{10} \left(\frac{\Delta f}{f_c} \right) \text{ dB}$$

where Δf is the bandwidth of the analyzing filter, ($1/12$ octave), and f_c is the Fletcher critical bandwidth. Frequencies where a pure tone has been detected are indicated on the display or print-out of the $1/12$ octave spectrum

and where the analyzer has been modified as described in the previous paragraph, the impulsive noise test is also performed.

Examples of printouts for all of the above measurements are given in Section 7.

4. Set-up of Instruments

The instruments should be set up as shown in Figs.5, 6 or 7. Fig.6 shows 10 microphone channels, which is the minimum required when the hemisphere is used. Where the parallelepiped is used, the minimum number of microphone channels is 9. However, in both cases, additional microphone channels could be required for the operator and/or bystander positions. The microphone channels to be used for the measurements in an automatic scan are selected using the SELECT-INHIBIT switches on the Multiplexer(s) Type 2811. Note, however, that Channel No. 1 on the main multiplexer must always be connected. As mentioned earlier, up to 4 multiplexers and 32 microphone channels can be controlled.

The modification WH 0490/WI 1624 to the 2131 or 3360 are required to perform the impulsive noise test. Where these modifications are included, both WH 0490 channels should be set to A weighting, with a "Fast" time weighting in the first channel and an "impulse" time weighting in the second.

For detailed instructions on the instrument set-up and running the programs, refer to the Instruction Manual for WW 9041.

5. Available Options

WW 9041/WW 1475 – programs on a $5\frac{1}{4}$ inch disc for an HP 9826 or 9836 computer

WW 9041/WH 1476 – programs on a $3\frac{1}{2}$ inch disc for an HP 9816/9817 or a series 300 computer.

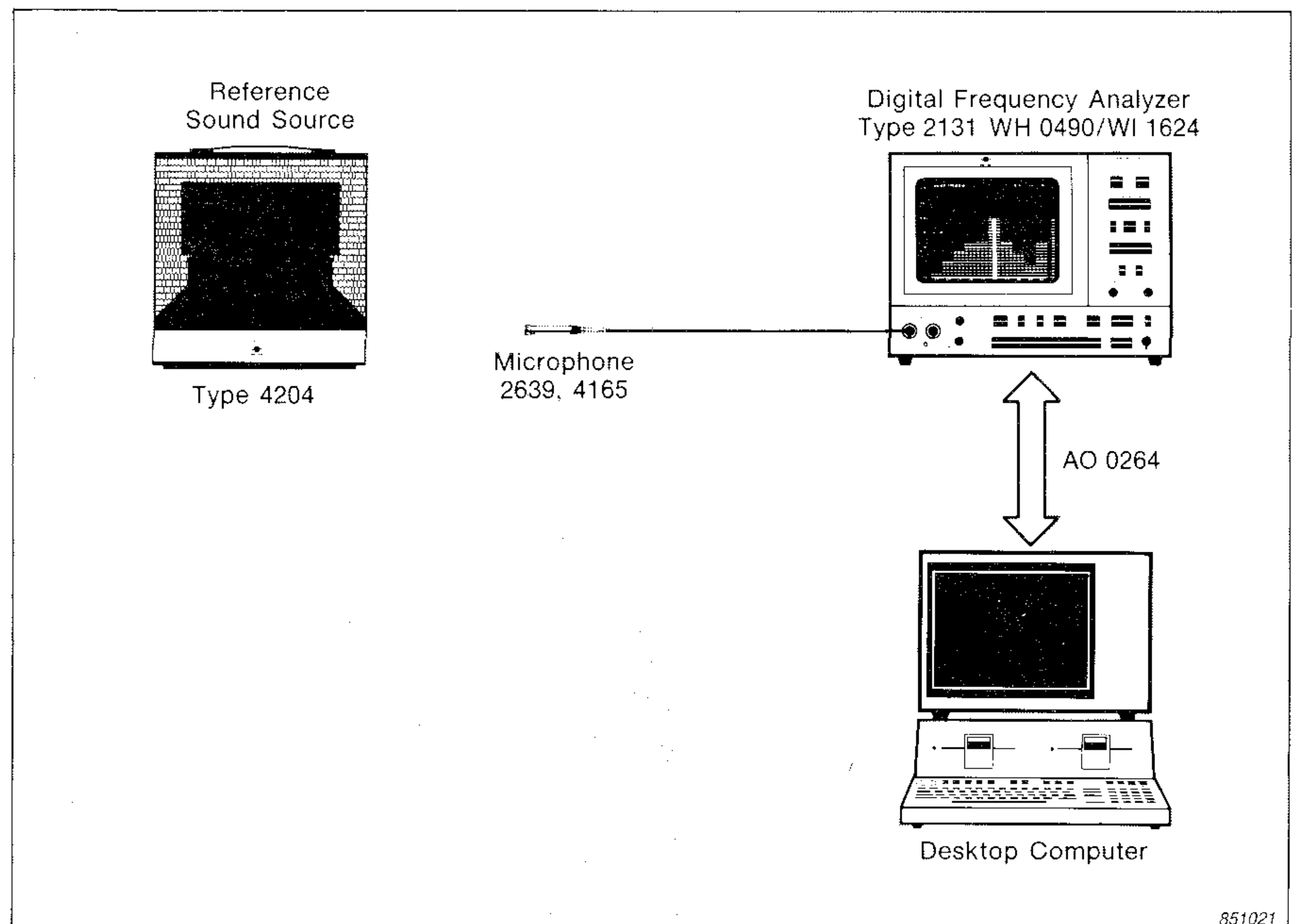


Fig. 5. Set-up of instruments for semi-automatic measurements

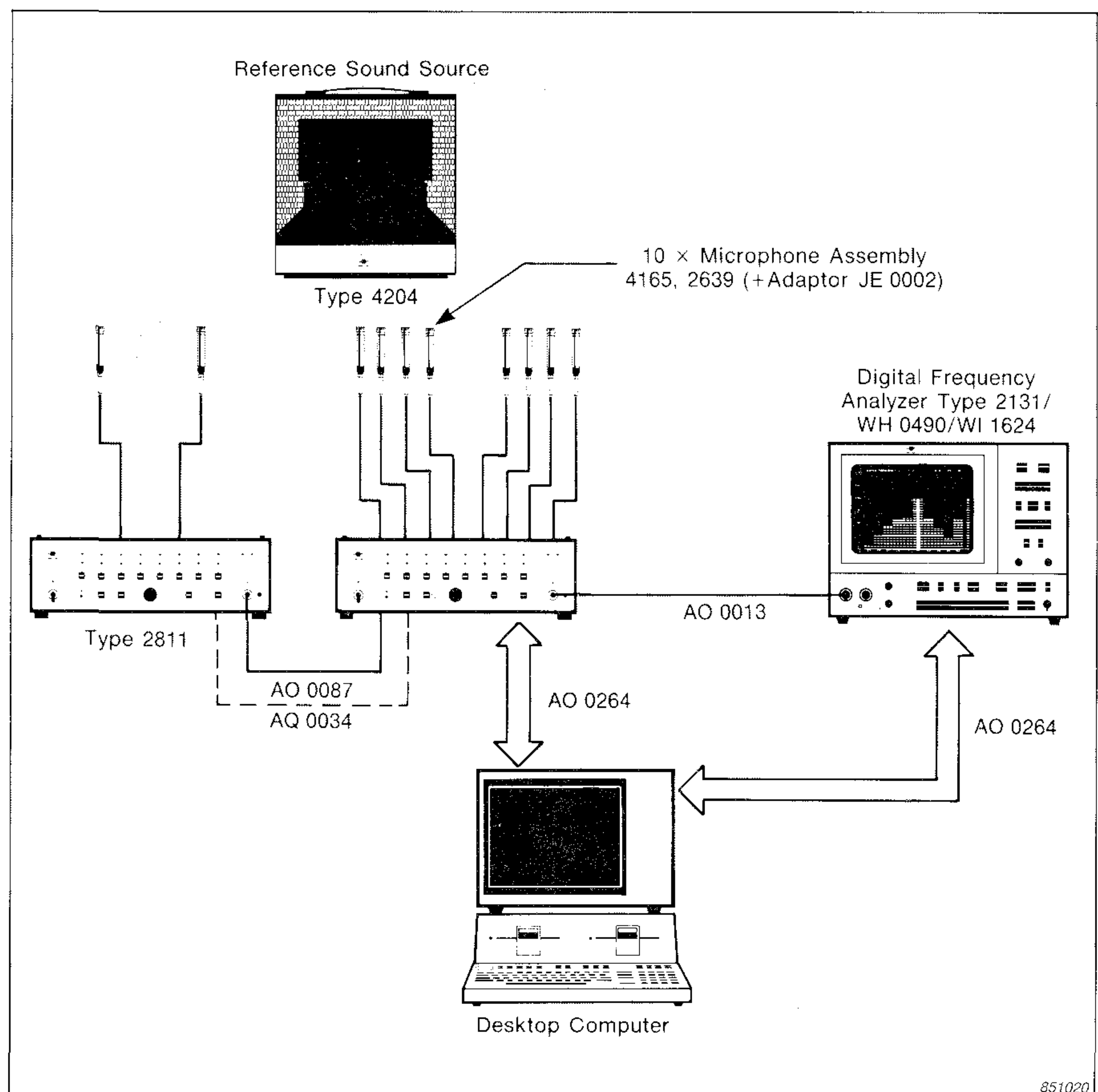


Fig. 6. Set-up of instruments for automatic measurements

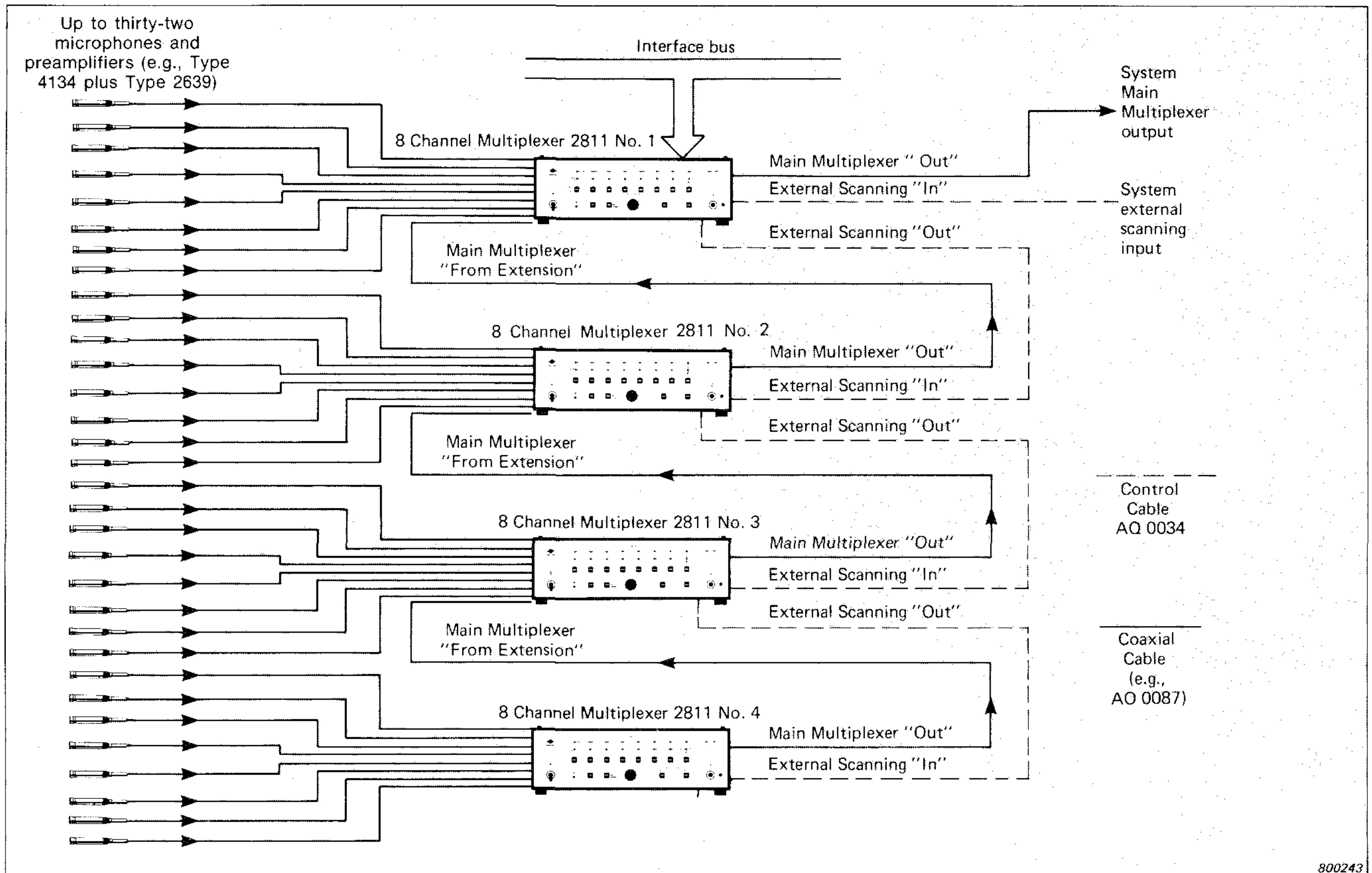


Fig. 7. Use of more than one multiplexer in the set-up

6. Example of a Complete System for measurement according to ECMA 74

1 × 2131/WH 0490/WI 1624	Digital Frequency Analyzer with options WH 0490 and WI 1624
2 × 2811	8 Channel Multiplexer
9 × 2639	Microphone Preamplifier
9 × 4165	Condenser Microphone
1 × 4204	Reference Sound Source
1 × AO 0133	BNC to BNC Cable (0,6 m)
1 × AO 0127	BNC to B & K Cable (1,2 m)
1 × AQ 0034	Control Cable
1 × AO 0194	IEC – IEC Interface Cable (2 m)
1 × AO 0264	IEC – IEEE Interface Cable (2 m)
1 × HP 98580 A, opt. 008	Series 300 Computer with 1 Mbyte and Basic 4.0 (includes 98546 A Display Compatibility interface)
1 × HP 9122 D	Double-sided 3 ¹ / ₂ inch Dual Disc Drive
1 × HP 2225 A	Graphics Printer
1 × WW 9041/WH 1476	Software Package on 3 ¹ / ₂ inch discs

T00847GB0

Table 2.

7. Examples of Printouts

```

SOUND POWER MEASUREMENT
OPERATOR: E.M.
DATE: 1/2 1985          ID/MEAS.NO: 1
-----
MACH.TYPE: LINE PRINTER  OP.MODE: NORMAL
MODEL NO.: 7506A        SERIAL NO.: 723567
COMMENTS:
TEMP.: 19 C    PRESS.: 98.6 kPA    R.H.: 45 %
-----
NUMBER OF POS.: 9        NUMBER OF SCANS: 1
AVERAGING TIME: 16 s    TOTAL AREA: 12.00 m^2
LOWEST FREQ.: 100 Hz    HIGHEST FREQ.: 10000 Hz
    
```

A-WEIGHTED SOUND PRESSURE

POS	LpA
1	62.8 dB
2	62.8 dB
3	63.5 dB
4	64.0 dB
5	61.9 dB
6	62.1 dB
7	63.7 dB
8	61.1 dB
9	62.3 dB

AVERAGE SOUND PRESSURE

ID/MEAS.NO: 1

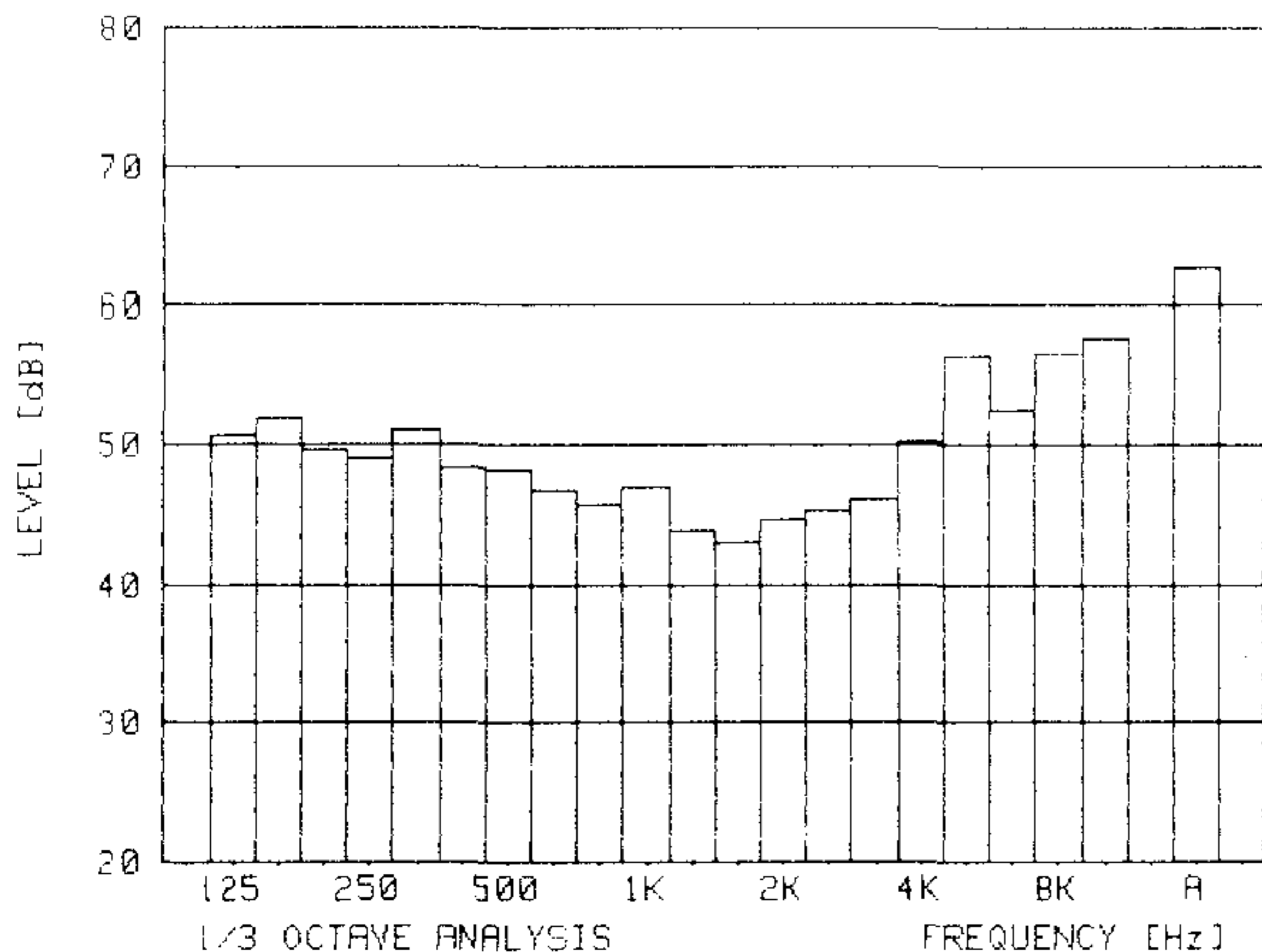
FREQ.	LEVEL
100 Hz	****
125 Hz	50.6 dB *
160 Hz	52.0 dB *
200 Hz	49.7 dB *
250 Hz	49.0 dB
315 Hz	51.0 dB *
400 Hz	48.4 dB
500 Hz	48.2 dB
630 Hz	46.8 dB
800 Hz	45.6 dB
1000 Hz	46.9 dB
1250 Hz	43.9 dB
1600 Hz	43.1 dB
2000 Hz	44.6 dB
2500 Hz	45.3 dB
3150 Hz	46.1 dB
4000 Hz	50.2 dB
5000 Hz	56.4 dB
6300 Hz	52.5 dB
8000 Hz	56.6 dB
10000 Hz	57.5 dB

A-wht. 62.8 dB

*) Bkgr-corr.

AVERAGE SOUND PRESSURE

ID/MEAS. NO: 1



SOUND PRESSURE (POS. 1)

ID/MEAS.NO: 1

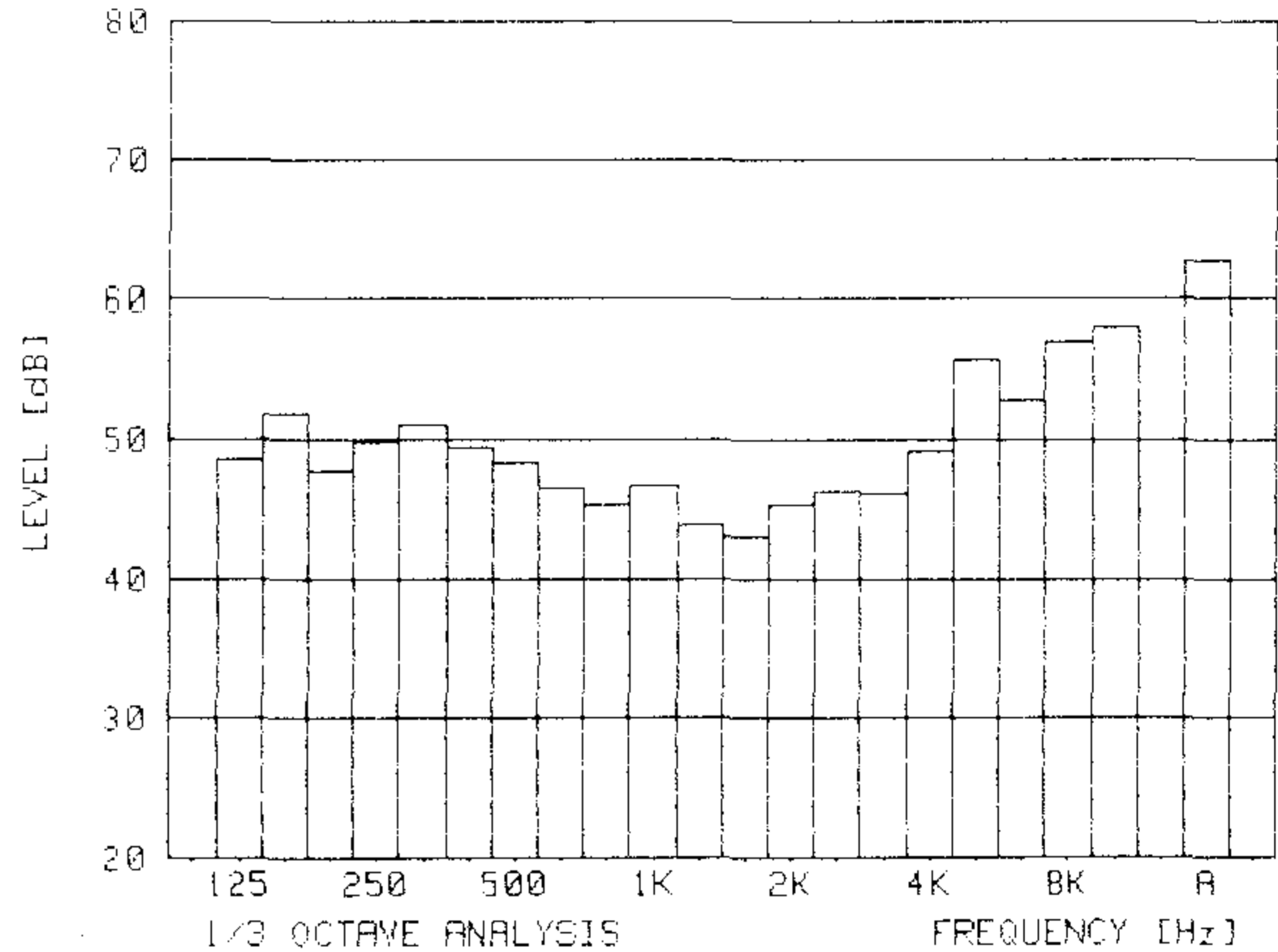
FREQ.	LEVEL
100 Hz	****
125 Hz	48.5 dB *
160 Hz	51.9 dB *
200 Hz	47.7 dB *
250 Hz	49.8 dB
315 Hz	51.0 dB *
400 Hz	49.4 dB
500 Hz	48.4 dB
630 Hz	46.6 dB
800 Hz	45.2 dB
1000 Hz	46.7 dB
1250 Hz	43.8 dB
1600 Hz	43.1 dB
2000 Hz	45.2 dB
2500 Hz	46.3 dB
3150 Hz	46.1 dB
4000 Hz	49.2 dB
5000 Hz	55.8 dB
6300 Hz	53.0 dB
8000 Hz	57.1 dB
10000 Hz	58.0 dB

A-wht. 62.8 dB

*) Bkgr-corr.

SOUND PRESSURE (POS. 1)

ID/MEAS. NO: 1



ROOM CORRECTION FACTORS

FREQ.	LEVEL
100 Hz	1.7 dB
125 Hz	1.8 dB
160 Hz	1.6 dB
200 Hz	1.4 dB
250 Hz	1.2 dB
315 Hz	1.0 dB
400 Hz	.9 dB
500 Hz	.8 dB
630 Hz	.5 dB
800 Hz	.8 dB
1000 Hz	.7 dB
1250 Hz	.6 dB
1600 Hz	.6 dB
2000 Hz	.5 dB
2500 Hz	.3 dB
3150 Hz	.1 dB
4000 Hz	0.0 dB
5000 Hz	0.0 dB
6300 Hz	.7 dB
8000 Hz	.4 dB
10000 Hz	.6 dB

A-wht. .5 dB

SURFACE SOUND PRESSURE

ID/MEAS.NO: 1

FREQ.	LEVEL
100 Hz	****
125 Hz #	48.8 dB *
160 Hz #	50.4 dB *
200 Hz #	48.3 dB *
250 Hz #	47.8 dB
315 Hz #	50.0 dB *
400 Hz #	47.5 dB
500 Hz #	47.4 dB
630 Hz #	46.3 dB
800 Hz #	44.9 dB
1000 Hz #	46.2 dB
1250 Hz #	43.3 dB
1600 Hz #	42.5 dB
2000 Hz #	44.1 dB
2500 Hz #	45.0 dB
3150 Hz #	46.0 dB
4000 Hz	50.2 dB
5000 Hz	56.4 dB
6300 Hz #	51.8 dB
8000 Hz #	56.2 dB
10000 Hz #	56.9 dB
A-wht. #	62.3 dB

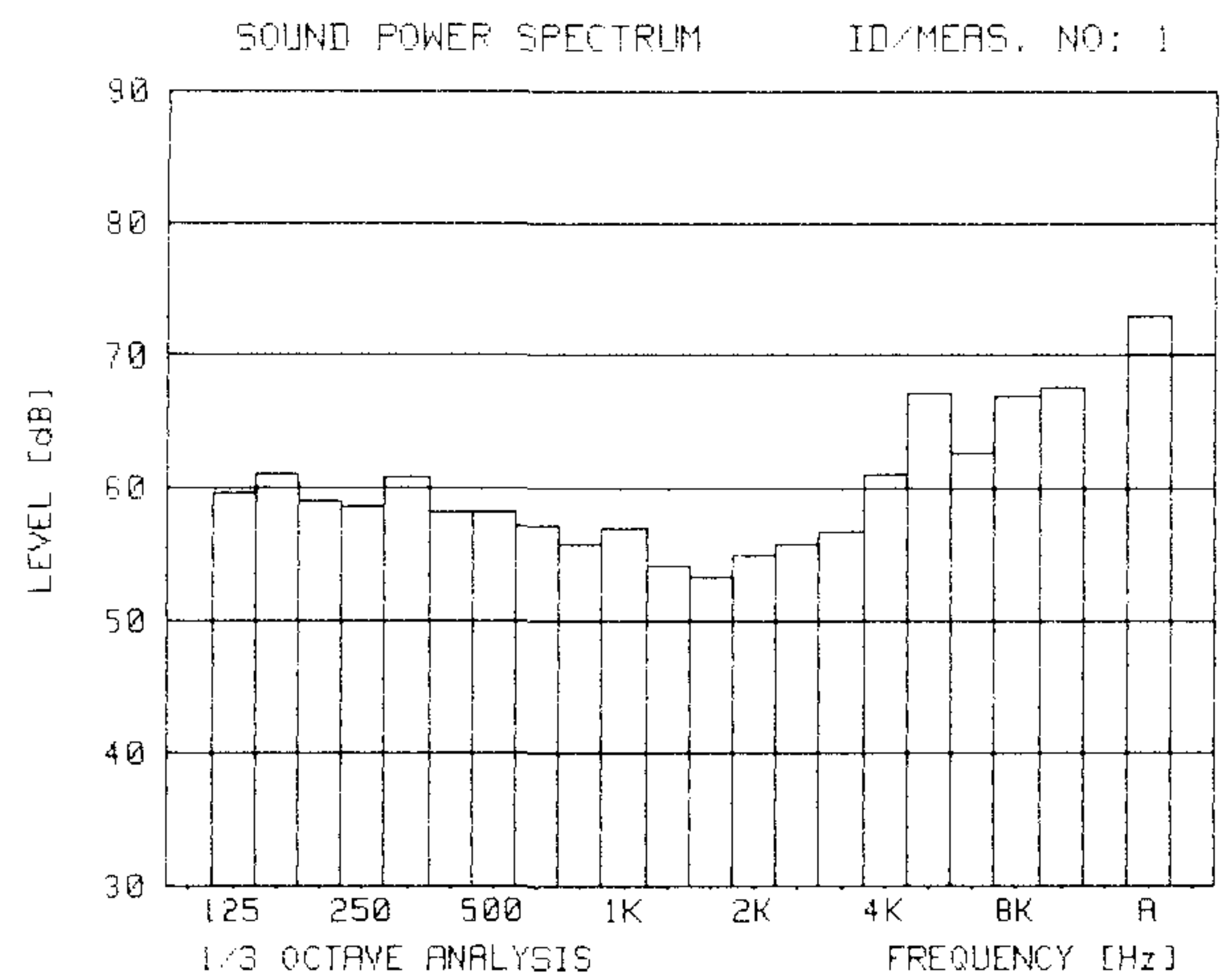
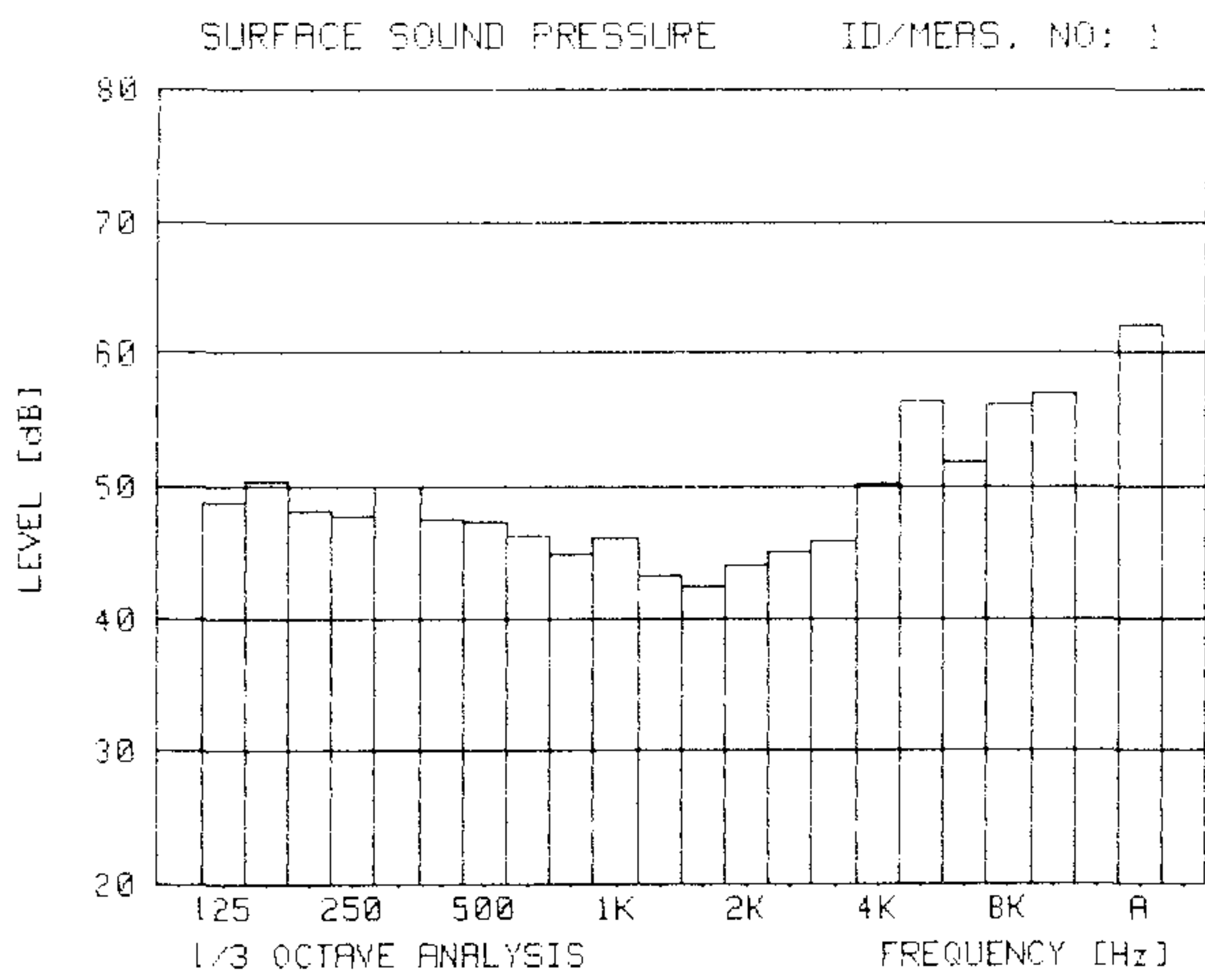
*) Bkgr-corr.
#) Room-corr.

SOUND POWER SPECTRUM

ID/MEAS.NO: 1

FREQ.	LEVEL
100 Hz	****
125 Hz #	59.6 dB *
160 Hz #	61.1 dB *
200 Hz #	59.0 dB *
250 Hz #	58.6 dB
315 Hz #	60.8 dB *
400 Hz #	58.3 dB
500 Hz #	58.2 dB
630 Hz #	57.1 dB
800 Hz #	55.6 dB
1000 Hz #	56.9 dB
1250 Hz #	54.1 dB
1600 Hz #	53.2 dB
2000 Hz #	54.9 dB
2500 Hz #	55.8 dB
3150 Hz #	56.7 dB
4000 Hz	61.0 dB
5000 Hz	67.2 dB
6300 Hz #	62.6 dB
8000 Hz #	67.0 dB
10000 Hz #	67.7 dB
A-wht. #	73.0 dB

*) Bkgr-corr.
#) Room-corr.



```

SOUND PRESSURE MEASUREMENT
OPERATOR: E.M.
DATE: 1/2 1985          ID/MEAS.NO: 1
-----
MACH.TYPE: LINE PRINTER  OP.MODE: NORMAL
MODEL NO.: 7506A        SERIAL NO.: 723567
COMMENTS: BYSTANDER POSITIONS
TEMP.: 19 C          PRESS.: 98.6 kPA      R.H.: 45 %
-----
NUMBER OF POS.: 4          NUMBER OF SCANS: 1
AVERAGING TIME: 16 s
LOWEST FREQ.: 100 Hz      HIGHEST FREQ.: 10000 Hz

```

SOUND PRESSURE (POS. 1)

ID/MEAS.NO: 1

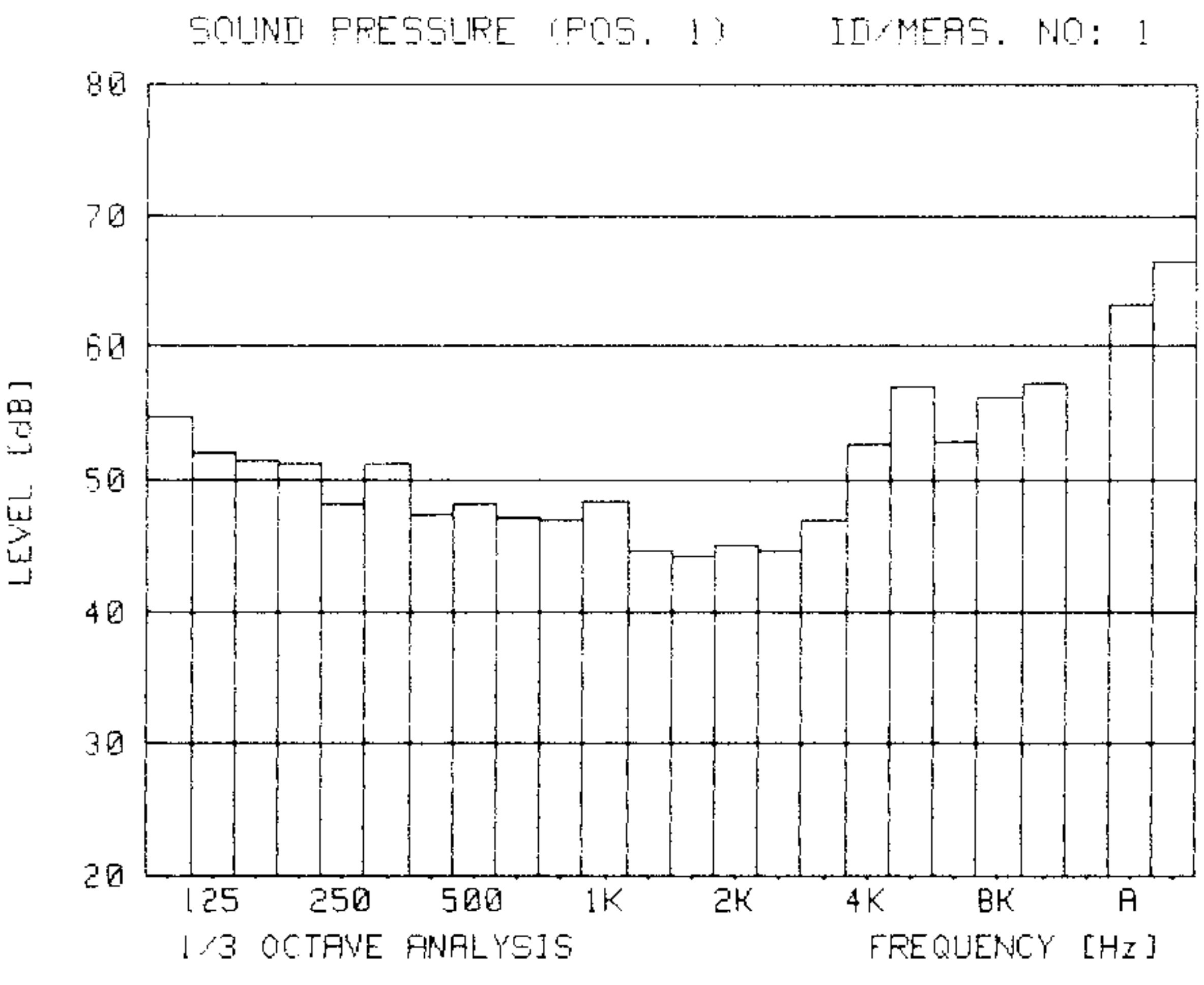
FREQ.	LEVEL
100 Hz	54.8 dB *
125 Hz	52.1 dB *
160 Hz	51.4 dB *
200 Hz	51.2 dB
250 Hz	48.2 dB
315 Hz	51.2 dB
400 Hz	47.4 dB
500 Hz	48.2 dB
630 Hz	47.2 dB
800 Hz	46.9 dB
1000 Hz	48.3 dB
1250 Hz	44.6 dB
1600 Hz	44.3 dB
2000 Hz	45.0 dB
2500 Hz	44.7 dB
3150 Hz	46.9 dB
4000 Hz	52.6 dB
5000 Hz	57.0 dB
6300 Hz	53.0 dB
8000 Hz	56.2 dB
10000 Hz	57.3 dB
LpA	63.2 dB
LpAI #	66.4 dB

#) IMPULSIVE
*) Bkgr-corr.

A-WEIGHTED SOUND PRESSURE LEVELS

POS	LpA	LpAI
1 #	63.2 dB	66.4 dB
2	62.2 dB	64.9 dB
3 #	63.8 dB	67.2 dB
4	62.8 dB	65.6 dB

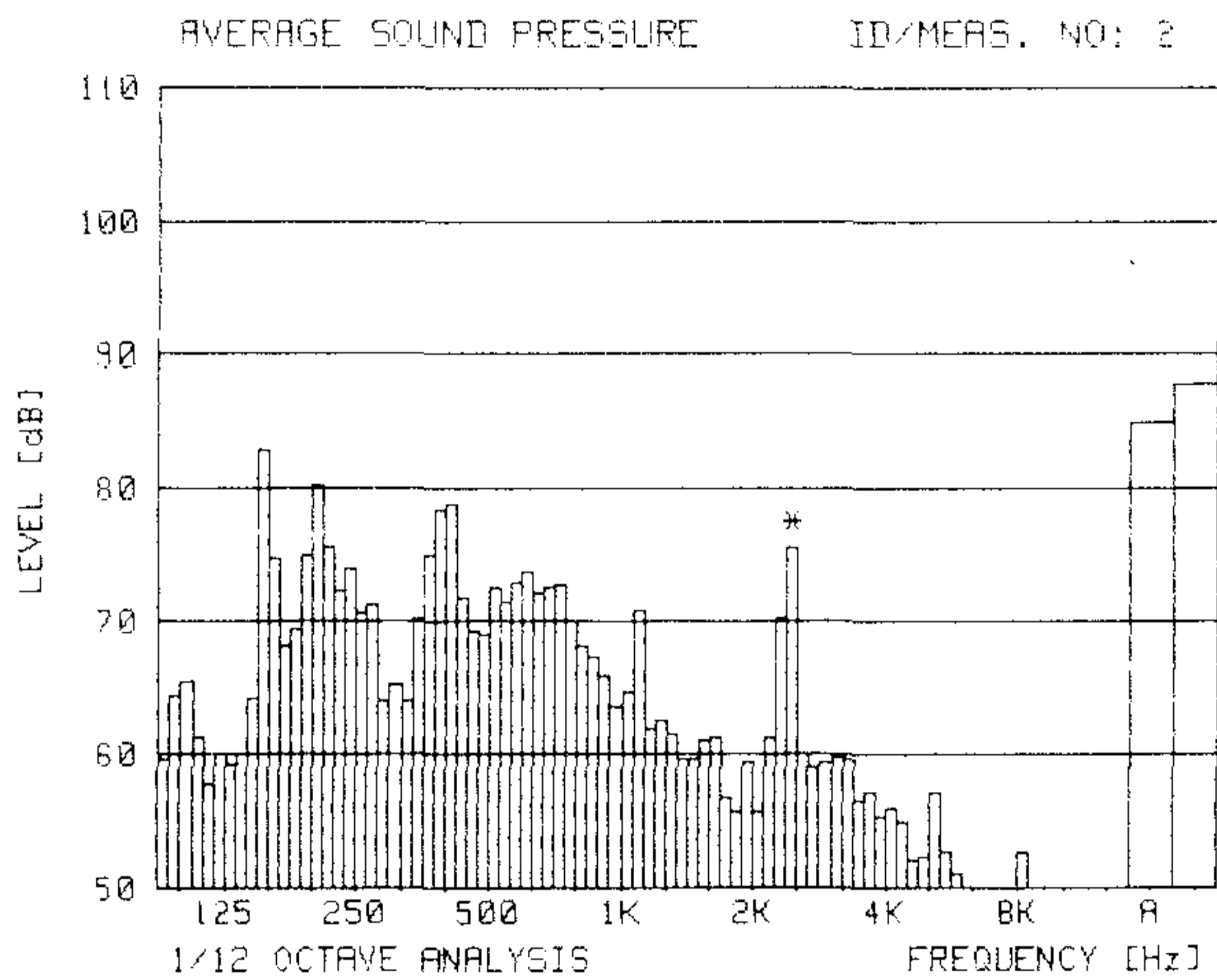
#) IMPULSIVE



```

PURE TONE MEASUREMENT
OPERATOR: E.M.
DATE: 1/2 1985          ID/MEAS.NO: 2
-----
MACH. TYPE:           OP. MODE:
MODEL NO.:           SERIAL NO.:
COMMENTS:
TEMP.:              PRESS.:              R.H.:
-----
NUMBER OF POS.: 4      NUMBER OF SCANS: 1
AVERAGING TIME: 8 s
LOWEST FREQ.: 100 Hz  HIGHEST FREQ.: 10000 Hz
    
```

FREQ.	LEVEL	FREQ.	LEVEL
92 Hz	59.7 dB	1029 Hz	64.5 dB
97 Hz	64.4 dB	1090 Hz	70.8 dB
103 Hz	65.4 dB	1155 Hz	61.9 dB
109 Hz	61.3 dB	1223 Hz	62.6 dB
115 Hz	57.9 dB	1296 Hz	61.5 dB
122 Hz	60.0 dB	1372 Hz	59.7 dB
130 Hz	59.2 dB	1454 Hz	59.6 dB
137 Hz	60.1 dB	1540 Hz	61.2 dB
145 Hz	64.1 dB	1631 Hz	61.4 dB
154 Hz	82.8 dB	1728 Hz	56.7 dB
163 Hz	74.6 dB	1830 Hz	55.8 dB
173 Hz	68.0 dB	1939 Hz	59.5 dB
183 Hz	69.4 dB	2054 Hz	55.8 dB
194 Hz	74.9 dB	2175 Hz	61.3 dB
205 Hz	80.3 dB	2304 Hz	70.2 dB
218 Hz	75.5 dB	2441 Hz *	75.4 dB
230 Hz	72.2 dB	2585 Hz	60.1 dB
244 Hz	73.8 dB	2738 Hz	59.1 dB
259 Hz	70.5 dB	2901 Hz	59.4 dB
274 Hz	71.1 dB	3073 Hz	59.9 dB
290 Hz	63.9 dB	3255 Hz	59.7 dB
307 Hz	65.3 dB	3447 Hz	56.6 dB
325 Hz	64.0 dB	3652 Hz	57.1 dB
345 Hz	70.1 dB	3868 Hz	55.4 dB
365 Hz	74.9 dB	4097 Hz	55.9 dB
387 Hz	78.3 dB	4340 Hz	54.9 dB
410 Hz	78.8 dB	4597 Hz	52.1 dB
434 Hz	71.5 dB	4870 Hz	52.3 dB
460 Hz	69.1 dB	5158 Hz	57.1 dB
487 Hz	68.9 dB	5464 Hz	52.7 dB
516 Hz	72.5 dB	5788 Hz	51.0 dB
546 Hz	71.4 dB	6131 Hz	50.0 dB
579 Hz	72.8 dB	6494 Hz	<<<<
613 Hz	73.7 dB	6879 Hz	<<<<
649 Hz	72.1 dB	7286 Hz	<<<<
688 Hz	72.5 dB	7718 Hz	<<<<
729 Hz	72.6 dB	8175 Hz	52.6 dB
772 Hz	70.0 dB	8660 Hz	50.0 dB
818 Hz	68.1 dB	9173 Hz	<<<<
866 Hz	67.2 dB	9716 Hz	<<<<
917 Hz	65.8 dB	10292 Hz	<<<<
972 Hz	63.5 dB	10902 Hz	<<<<
LpA	85.0 dB		
LpA1	87.8 dB		



*) PURE TONES

Brüel & Kjær 

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