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DP/ID/SER.A/899
10 September 1987
English

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POLLUTION CONTROL RESEARCH INSTITUTE HARDWAR (U.P.)

DP/IND/83/008

INDIA

Technical report: Acoustic design studies on enclosures for noise control*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Mr. Y. K. Kumar, Engineer
and Dr. M. G. Prasad, Director, Noise and Vibration Control Laboratory

Backstopping officer: ^. P. Maltezou, Chemical Industries Branch

United Nations Industrial Development Organization
Vienna

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ACKNOWLEDGEMENTS

The author would like to thank Dr. M.G. Prasad of the Department of Mechanical Engineering at Stevens Institute of Technology for his support and helpful suggestions throughout the project. The author also wishes to thank Dr. F.M. Kessler of FMK Technology for his helpful discussions during the project. The author wishes to acknowledge the support recevied by the Department of Mechanical Engineering at Stevens Institute of Technology and the Carl Duisberg Society (CDS International) in New York during their period of stay at Stevens. The author would like to express thanks to the Pollution Control Research Institute for sponsoring of this training program under the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION and the UNITED NATIONS DEVELOPMENT PROGRAMME.

CONTENTS

ACOUSTIC DESIGN STUDIES ON ENCLOSURES FOR NOISE CONTROL

1.0 INTRODUCTION:

Noise Control is the technology of obtaining an acceptable noise environment, at a receiver, consistent with economic and operational considerations. It is a well known fact that the field of noise control centers around the so called SOURCE-PATH-RECEIVER concept (fig. 1). The noise (physically speaking, sound) generated at the source traverses (propegates) along a path before it reaches the receiver. This (seemingly simple) concept is very complex due to the interdependence of the three elements. The noise control techniques may be classified into three categories:

* Noise Reduction at the Source
* Noise Control along the Transmission Path
* Use of Protective Measures at the Receiver

The choice of a method or combination of methods depends on the amount of noise reduction required and economic and operational considerations.

2.0 ENCLOSURES

The best choice, if the economic and operational conditions permit, is to control noise at the source itself. In the case

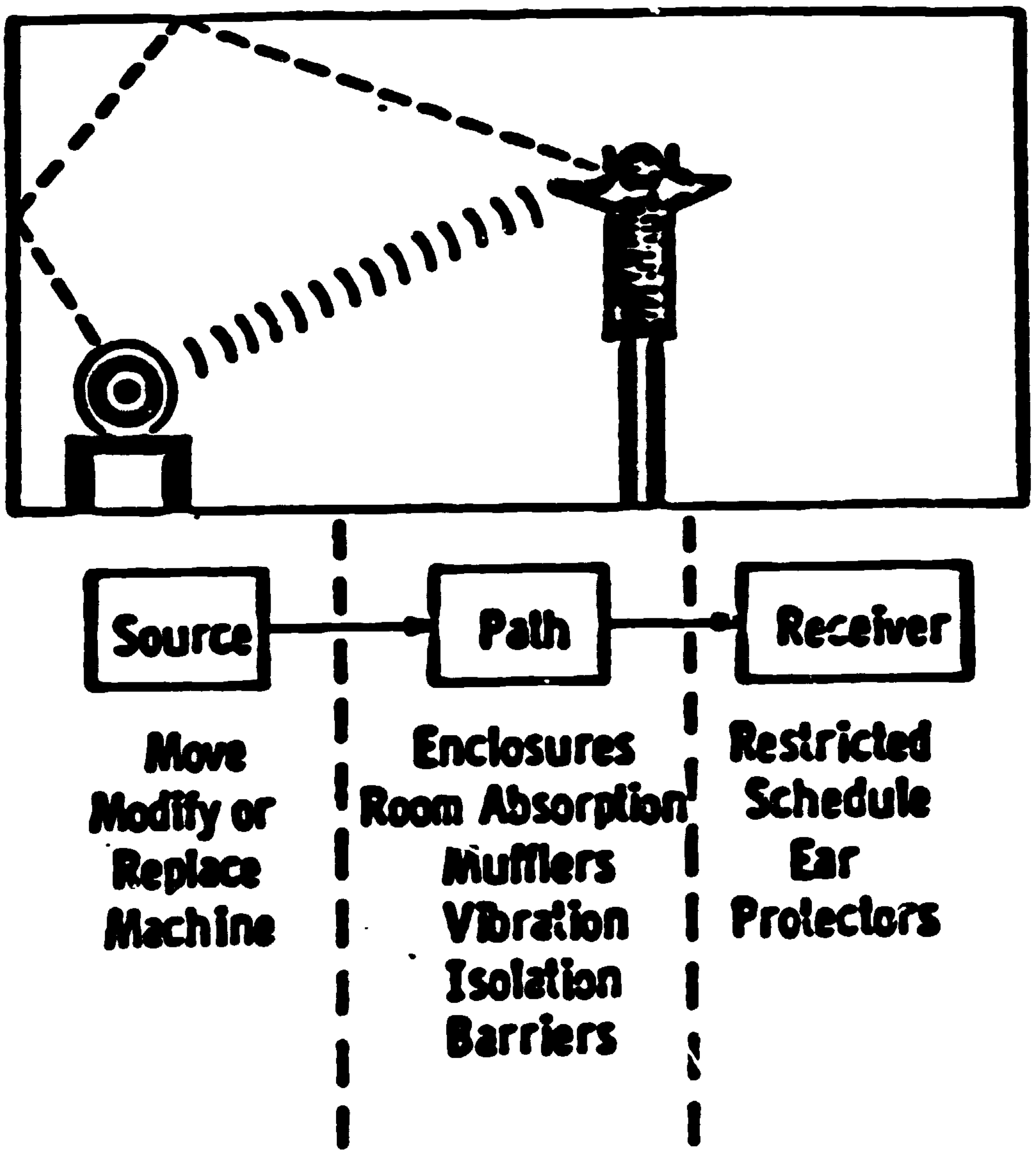

Fig. 1 SOURCE - PATH - RECEIVER

Various Noise Control Techniques

where reduction of noise at the source is impractical, one of the most powerful alternative method is to enclose the source, which is one of the methods of modifying the transmission path. Though this enclosing seems to be causing some nuisance associated with the loss of visibility, accessibility and maintenance, a well designed enclosure adds very much to personnel safety in terms of noise reduction.

There are two basic types of enclosures, total and partial. When the nature of machine operation prohibits the use of a total enclosure, it is sometimes possible to control noise with a partial enclosure. Although the noise reduction that can be obtained with partial enclosures is limited to 12 to 15 dB, these are sometimes very useful to separate and protect the employees from the exposure to noise source.

The parameters which charaterize the performance of an enclosure are:

- Transmission Loss (TL), dB
- Noise Reduction (NR), dB
- Insertion Loss (IL), dB

2.1 <u>TRANSMISSION LOSS</u> (TL)

The TL is defined as ten times the logarittum of the ratio of the sound intensity incident upon a panel (I_i) to that transmitted by the panel (I_t).

$$TL = 10 \log_{10} (I_i/I_t) dB \qquad (1)$$

It can also be shown to be there is no error in this line

$$TL = 10 \log_{10} ((1/t)dB \qquad (2)$$

where t is the transmission coefficient of the walls.

At very low frequencies, TL is controlled primarily by the wall shiftness. In general, the stiffer the wall the better is the TL. As the frequency is increased, in a particular range, the TL is controlled by various resonant frequencies of the wall. In this region the TL depends on the damping of the wall.

At frequencies higher than the resonant frequencies, the TL is controlled by mass and is given approximately by the expression (known as mass law).

$$TL = (20 \log F + 20 \log W-47)dB \qquad (3)$$

where f = frequency (H_3)

and W = surface density (kg/m^2/cm(thickness))

2.2 NOISE REDUCTION (NR)

The NR of an enclosure is the difference between the sound pressure levels, inside and outside the walls of the enclosure. Thus,

$$NR = (L_{pi} - L_{po})dB \qquad (4)$$

It can be shown that the relationship between NR and TL is given by the expression.

$$NR = TL - 10 \log_{10}(1/4 + Sw/R)\ dB \qquad (5)$$

where Sw = exposed area of enclosur (m^2) and insertion loss (IL) is the most useful from the user point of view. However, it is not always easy/possible to remove an enclosure and in some cases there may be considerable time gap between "with" and "without" measurements. In these cases the IL either can not be measured or there may be possible errors.

3.0 DESIGN AND FABRICATION GUIDELINES

The design of enclosures is very complicated and time consuming in the sense that there are many factors to be considered if it is to prove satisfactory from both acoustical and production points of view. But the input parameters at such required for the design are the dimensions of the machine/source to be enclosed, the TL or NR required and the frequency characteristics of the machine/source. The guidelines for the design are discussed in the subsequent sections.

3.1 ENCLOSURE DIMENSIONS AND WALLS

There are no specific thumb rules for calculating the dimensions of an enclosure but most of them are designed such that the machine/source does not occupy more than one-third of the total volume of the enclosure. A suitable volume ratio is to be selected depending on the frequency content of the noise from the machine/source. The low frequency noise reduction increases with decreasing enclosure volume.

The materials used to construct the basic shell must not be imprevious to air flow and the shell must be air tight. Once, the material and the volume of the enclosure are selected as explained above, the wall thickness of the enclosure can be calculated using the expression

$$NR = 20 \log_{10}(1 + 42Et^3/(\rho Co^2 V)) \quad (8)$$

where E = Young's modulus of the material, $(N/M)^2$

t = thickness of the walls, (m)

ρ = density of air, (kg/m^3)

Co = speed of sound at a mean temperature

and V = volume, (m^3)

3.2 ACOUSTICAL LINING

The inner surface of the shell is often lined with sound absorbing material to prevent the reverberant build up. The thickness and density of the lining will depend upon the frequency range over which the greatest noise reduction is required. For example, fig. 2 shows the variation of absorption coefficient of $6 lb/ft^2$ fiberglass as a function of frequency, with material thickness as a parameter. Thus, a proper selection of material and thickness is to be made as per requirement.

3.3 SEALS

If the NR of more then 10dB is required of an enclosure, it must be made air-tight. It must have tight-fitting joints and all cracks and openings tightly sealed in order to reduce leakage of

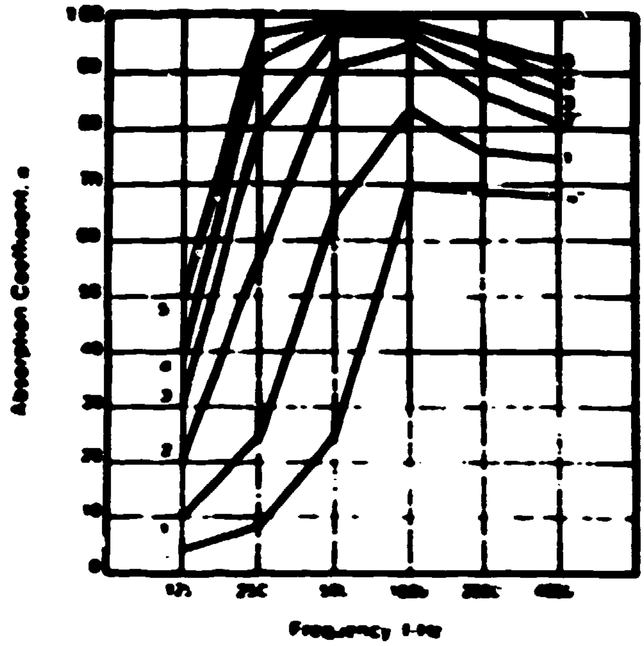

Fig. 2 Variation of Absorption Coefficient of 6 lb/ft³ fiberglas as a function of frequency, with material thickness as a parameter

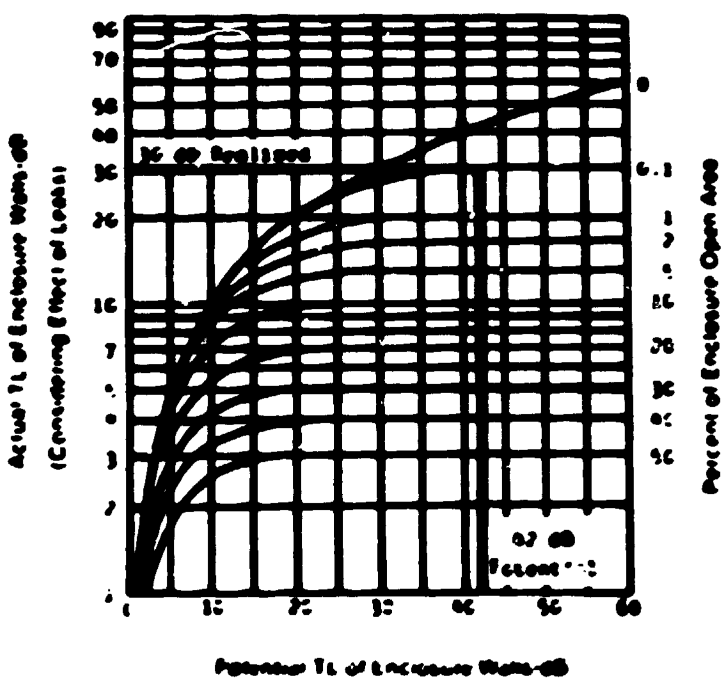

Fig. 3 Effect of leaks on Enclosure Transmission Loss

noise. The base, walls, door and observation window are to be fastened and sealed properly. Fig. 3 shows the effect of leakage on enclosure proformance.

3.4 MOUNTING

The enclosure should be isolated from any vibrating part of the machine. If the machine is mounted on a heavy concrete block or floor, it is usefully satisfactory to fasten the enclosure to the floor. However, if the machine causes the floor to vibrate considerably, either the machine or the enclosure (preferably the machine) should be vibration isolated.

3.5 ACCESS/PROVISION OF UTILITY SERVICES

For convenient access of operation and maintenance the enclosure is to be provided with access doors and removable panels wherever necessary. Use of remotely operated ganges for observation might help in reducing/avoiding the frequent opening and closing of the door. Depending on the requirement, a permanent panel may be provided through which oil, water and electrical lines can be run.

3.6 VENTILATION

One of the most important problems encountered with enclosures is heating due to air-tight environment inside it.

Forced ventilation might be required if the enclosure causes overheating of the machine. If the enclosure is ventilated, the inlet and discharge ducts must be muffled to control the additional noise in ducts.

4.0 PERFORMANCE EVALUATION OF AN ENCLOSURE

As discussed in the previous sections, there are many factors that control the performance of an enclosure. To study some of such factors, quite a few experiments have been conducted recently with a 30.5cm wide, 30.5cm high and varialbe length enclosure made of plexiglas. Three different noise sources have been selected;

* a blender (quite noisy)
* a speaker with random noise signal input
* a blower as small as that used in a hairdryer

The experiments are conducted in anechoic chamber. In almost all the cases, both narrow and octave band analyses of spectra have been carried out. All the narrow band spectrum plots are shown in appendix II. The results in each case are discussed in the subsequent sections.

4.1 BLENDER NOISE

The sound spectra due to a domestic blender for various cases have been measured and compared with the sound spectrum without enclosure. Table 4.1 shows the octave band sound pressure levels for each case. For some of these cases, the sound spectra are plotted (fig. 4). It can be seen that air insertion loss of 15dB is achieved by enclosing the source. This value his increase to 21dB with fiberglass lining inside the enclosure. When the source is mounted on isolators and then enclosed with fibreglass lining inside, there was no considerable increase in the insertion loss of course, the isolators were not designed selected for the purpose. But a well designed vibration mountin helps greatly in increasing the noise reduction.

This set of experiments reveals that a good amount of noise reduction is possible by enclosing the source of noise by a well designed enclosure.

4.2 RANDOM NOISE SOURCE

This set of experiments aims at studying the effect of volume of enclosure on insertion loss. The sound spectra for three different volume ratios (volume of enclosure/volume of the source) have been measured and compared with the spectrum without enclosure (Table 4.2). It can be seen from the plots (fig. 5) that the insertion loss particularly at low frequencies improves with the decrease in volume. However, it is to be emphasized that the ratio must not be less than 3.

4.3 SMALL BLOWER

Fig. 6 shows the spectra due to a small blower without and with enclosure. Though there is reduction of noise, it was

TABLE 4-1. BLENDER NOISE

Condition	SOUND PRESSURE LEVELS, dB									
	Lin	A-wt	125	250	500	1K	2K	4K	8K	16K
1. WITH OUT ENCLOSURE	74	74	47	56	65	67	67	67	67	61
2. WITH ENCLOSURE	59	57	51	51	49	47	50	52	49	41
3. ISOLATORS	72	72	46	54	63	65	65	65	66	69
4. ISOLATOR + ENCLOSURE	53	53	43	50	47	44	46	47	45	38
5. ENCLOSURE WITH FIB. GLASS	53	45	48	48	46	43	39	38	37	31
6. ENCLOSURE + FIB. GLASS + ISOLATION	53	47	44	52	43	38	35	34	33	28

TABLE 4-2 SPEAKER WITH RANDOM NOISE INPUT

Condition	SOUND PRESSURE LEVELS, dB									
	Lin	A-wt	125	250	500	1K	2K	4K	8K	16K
1. WITHOUT ENCLOSURE	85	82	76	81	79	74	74	73	74	71
2. WITH ENCLOSURE (VOL. RATIO [illegible])	70	64	65	67	56	56	55	56	55	50
3. WITH ENCLOSURE (VOL. RATIO 3)	68	62	63	65	56	55	54	54	52	47
4. WITH ENCLOSURE (VOL. RATIO 6)	65	60	61	61	55	52	51	52	52	45

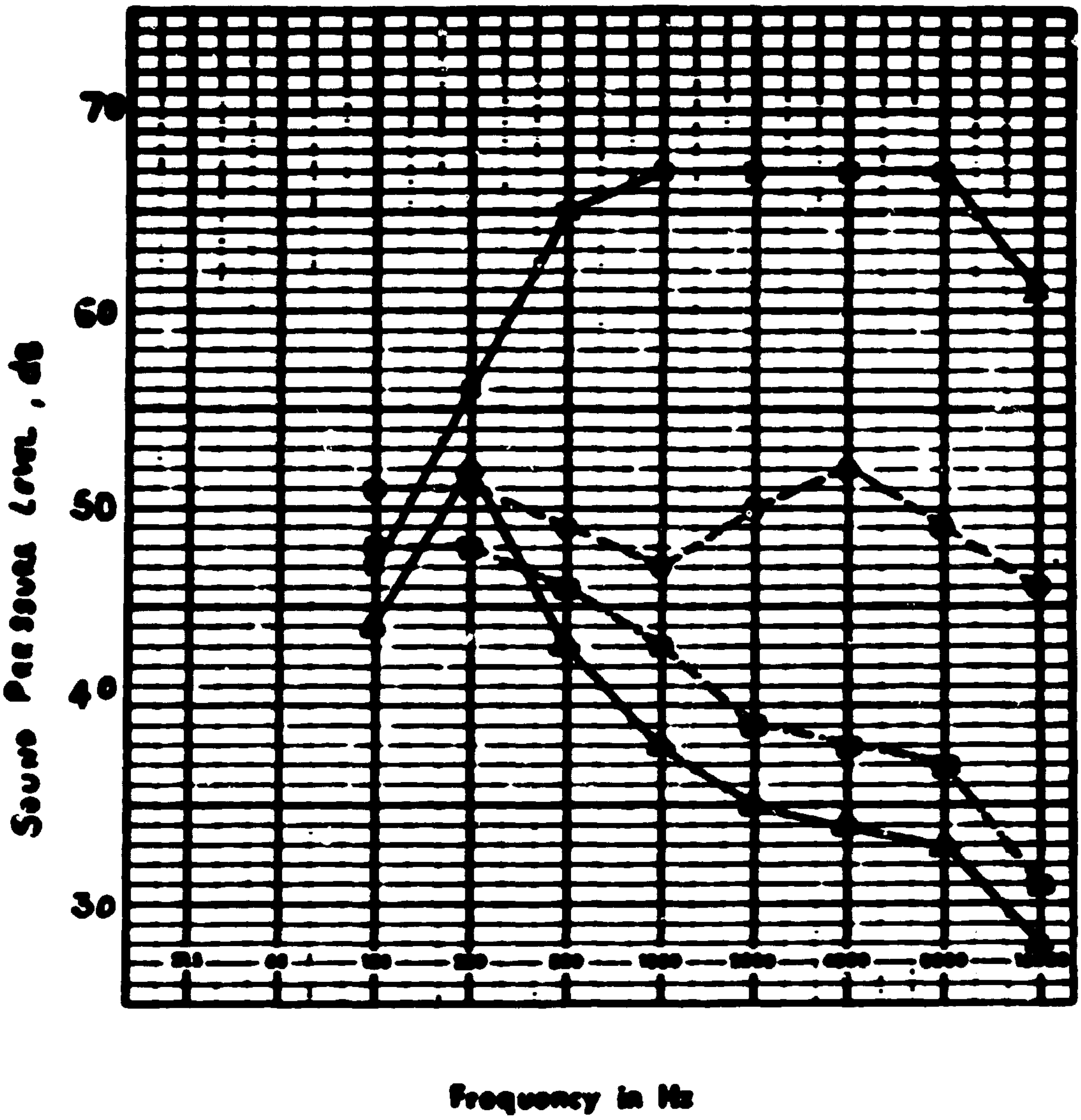

Fig. 4 BLENDER NOISE: VARIOUS CASES

* WITHOUT ENCLOSURE

O WITH ENCLOSURE

□ ENCLOSURE WITH FIB.GLASS LINING

▲ ON VIBRATION ISOLATORS + ENCLOSURE WITH LINING

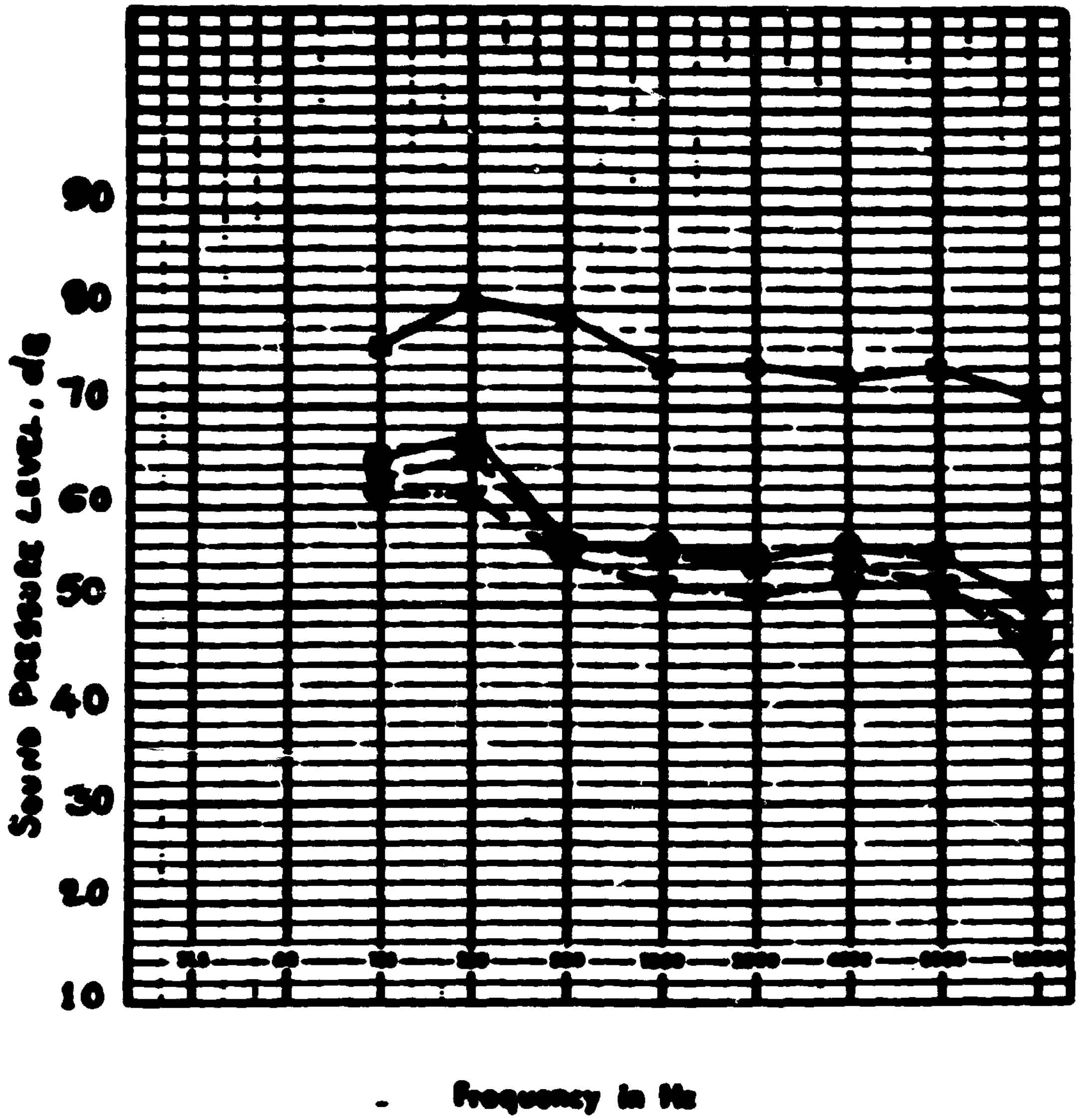

Fig 5 Random Noise Source - Effect of Volume of the Enclosure

- Spectrum Without Enclosure
- ● Enclosure Volume = 11 × Source Volume
- □ Enclosure Volume = 8 × Source Volume
- ▼ Enclosure Volume = 6 × Source Volume

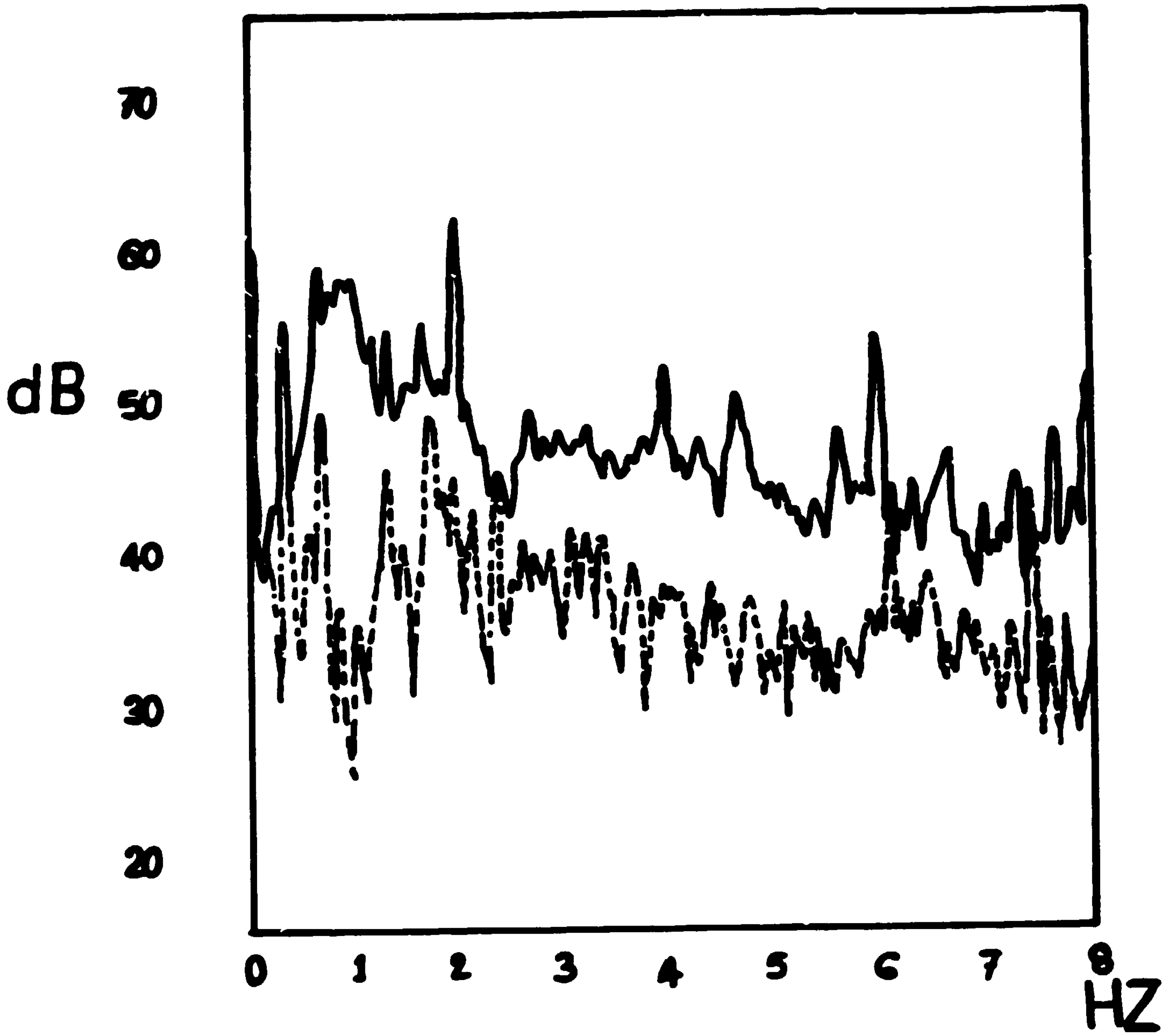

Fig. 6 Small Blower Noise

——— without enclosure

- - - - with enclosure

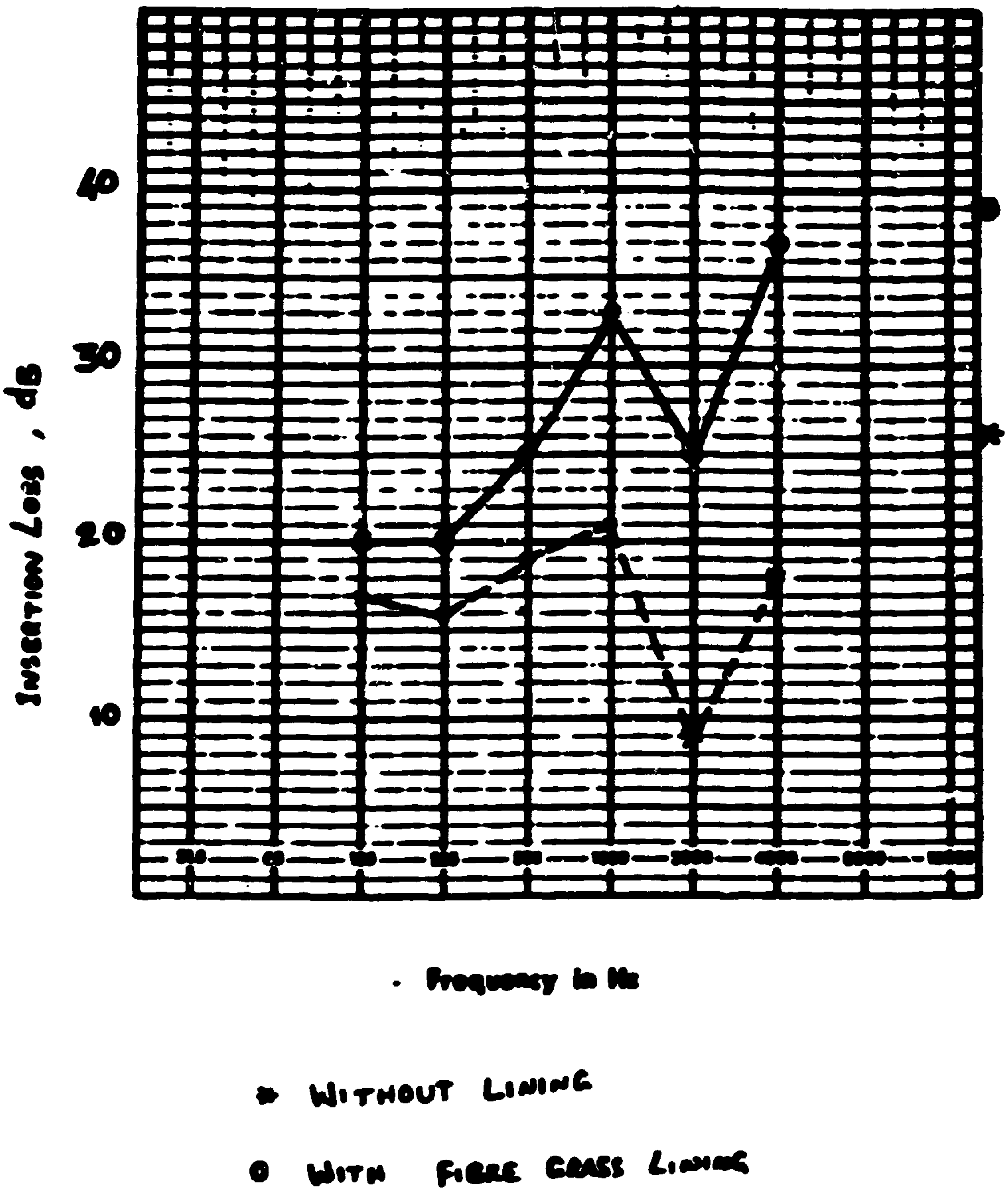

Fig.7 PREDICTED INSERTION LOSS

observed that the performance of the blower was affected. This is due to the fact that there is no proper air circulation inside the enclosure. Hence, proper ventilation is to be provided when the air circulation is needed or, the overheating of the inside environment is to be prevented.

4.4 OVERALL DISCUSSION

It can be seen from the results of the above experiments that in none of the cases, the expected insertion loss FIG. 7 was achieved. This is due to the lanuage from the enclosure which reduced the insertion loss greatly. For high insertion losses the enclosure must be made air tight.

5.0 CONCLUSION

Enclosing the machine/source is a powerful noise control along the sound transmission path. As discussed earlier an enclosure is to be designed carefully, by giving proper attention to the factors like seals, ventilation, vibration isolation etc.

There are two major obstacles which stand against the use of enclosures, viz. Space limitation and heating when space is not sufficient to enclose the machine, one may try to enclose the individual parts of the machine which are dominant sources of noise. The problem of heating of inside environment can be solved by providing forced ventilation.

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APPENDIX I

DESIGN GUIDELINES

I Dimensions/Volume

i) Source Volume ≤ (1/3) Enclosure Volume

ii) Low Frequency Loss Volume

iii) Material should be IMPERVIOUS

iv) Wall Thickness t,

II LINING

Transmission Loss Characteristics of Sound Absorbing Materials

III SEALS

IV MOUNTING

V ACCESSIBILITY

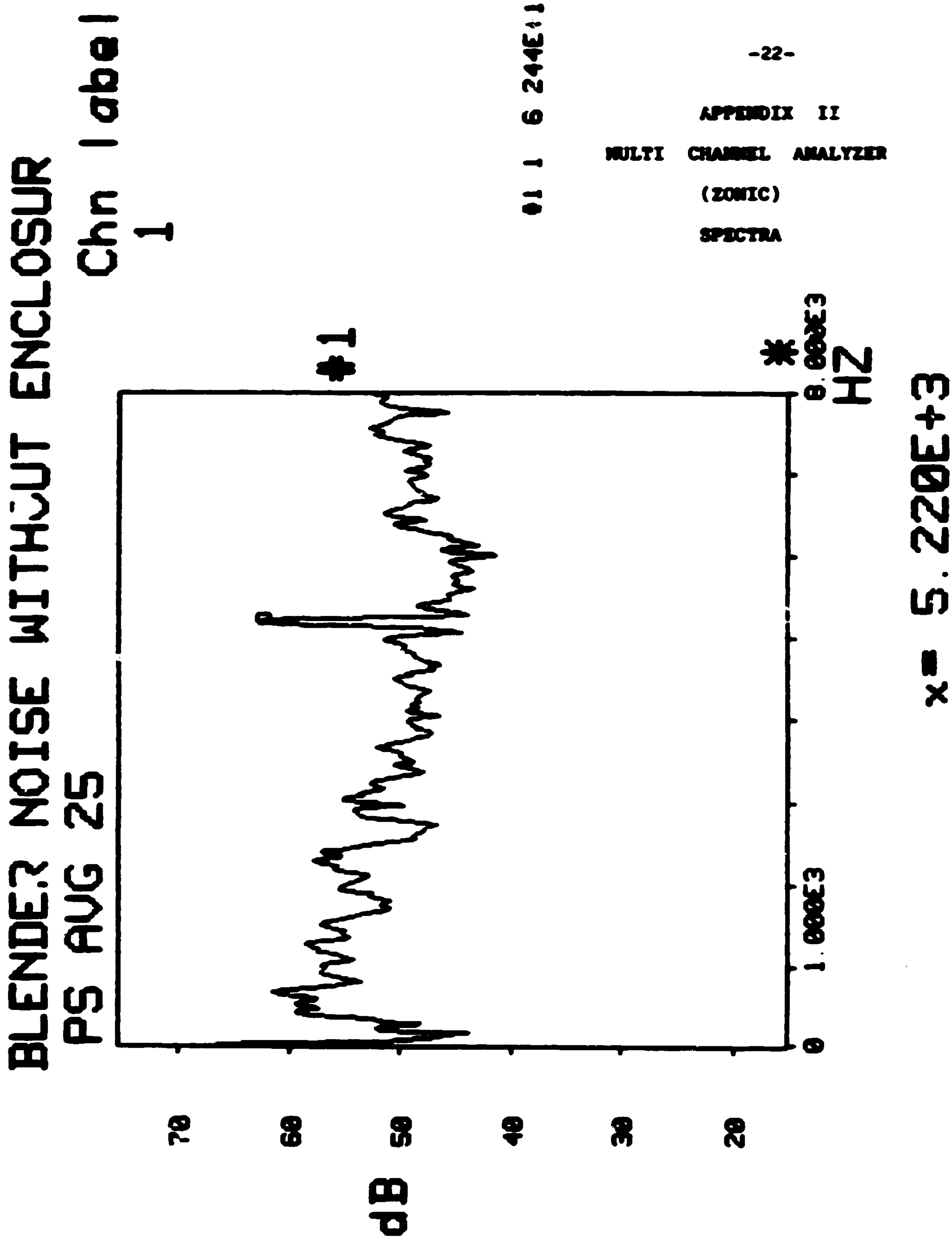
VI VENTILATION

APPENDIX II

MULTI CHANNEL ANALYZER

(ZONIC)

SPECTRA



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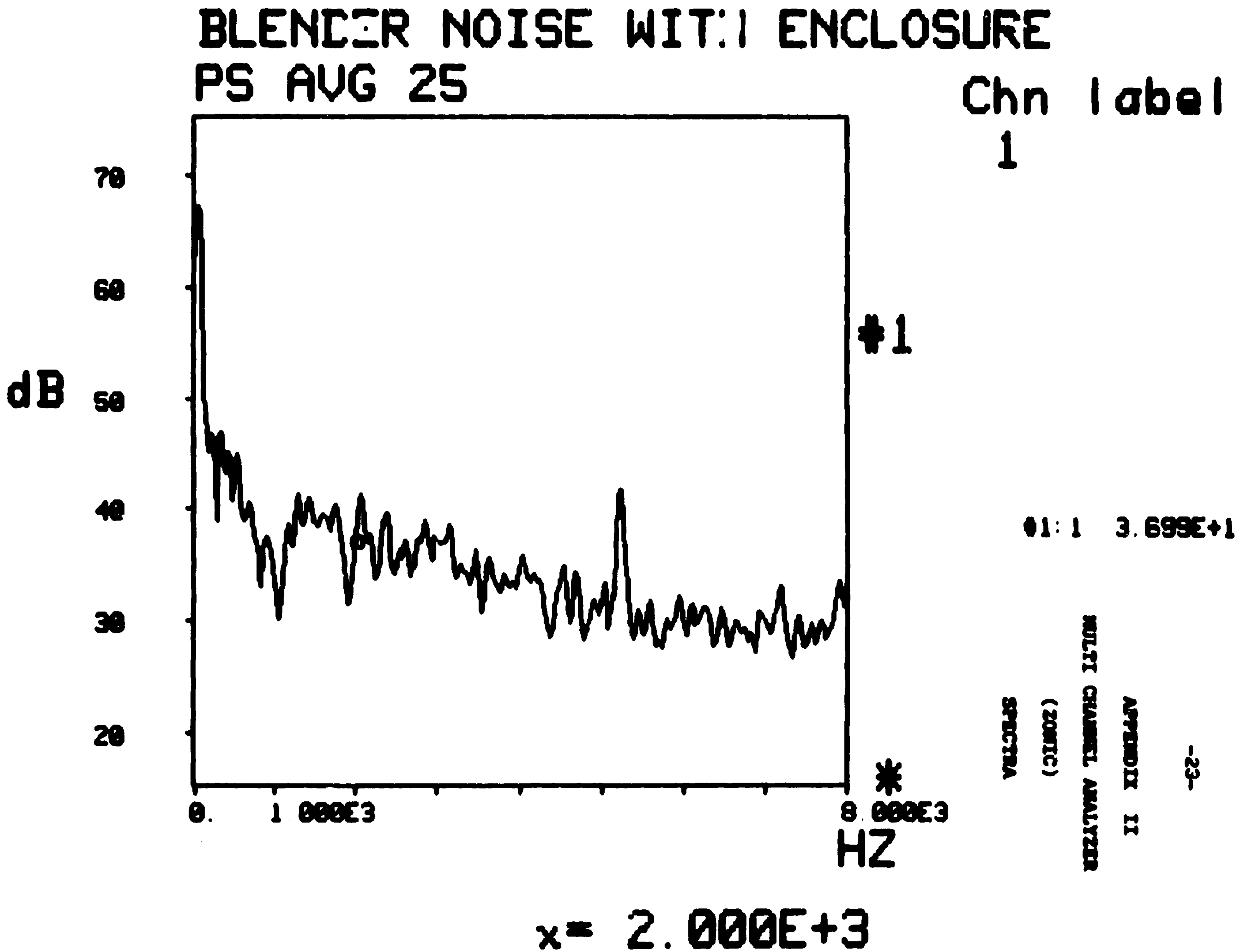

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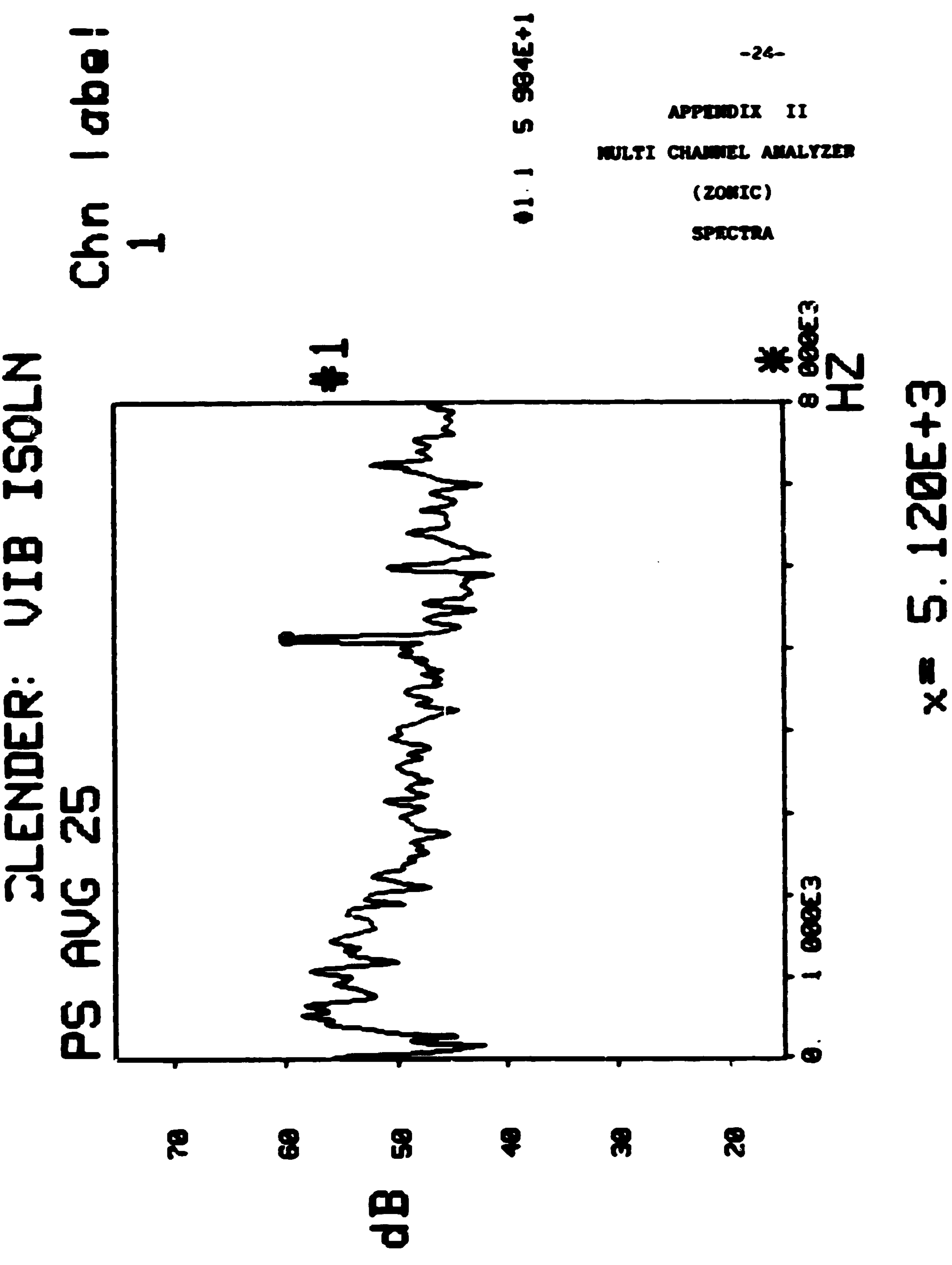

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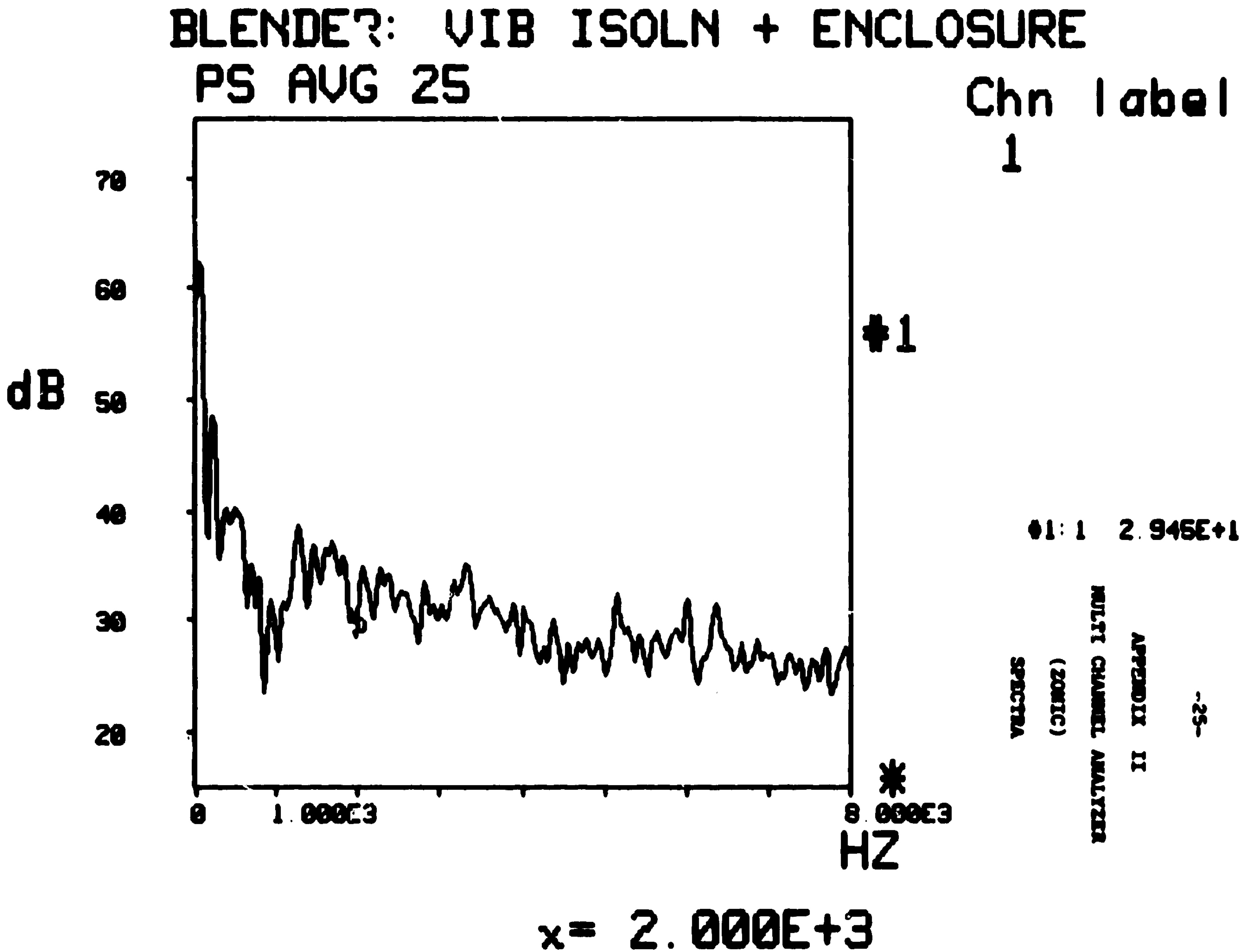

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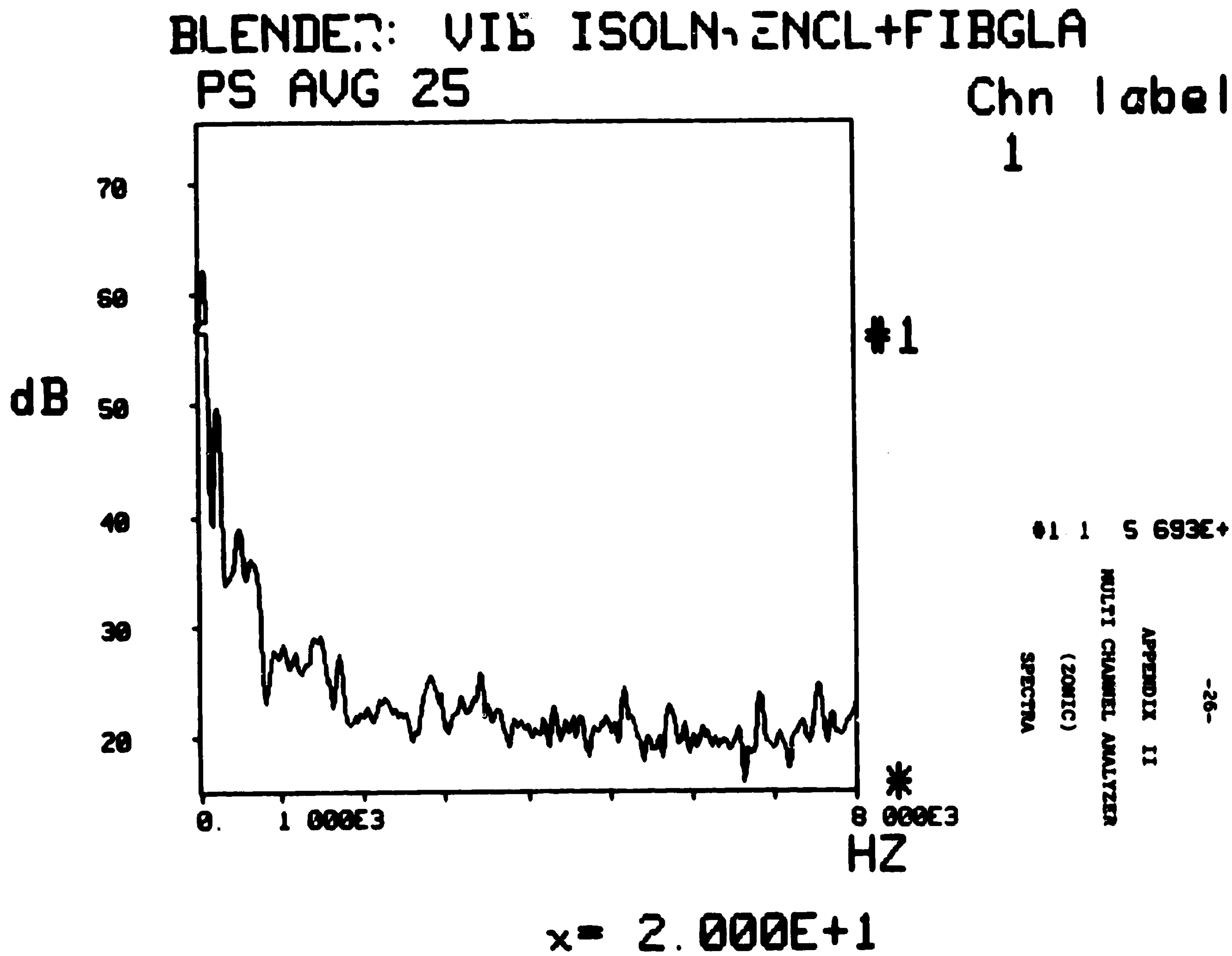

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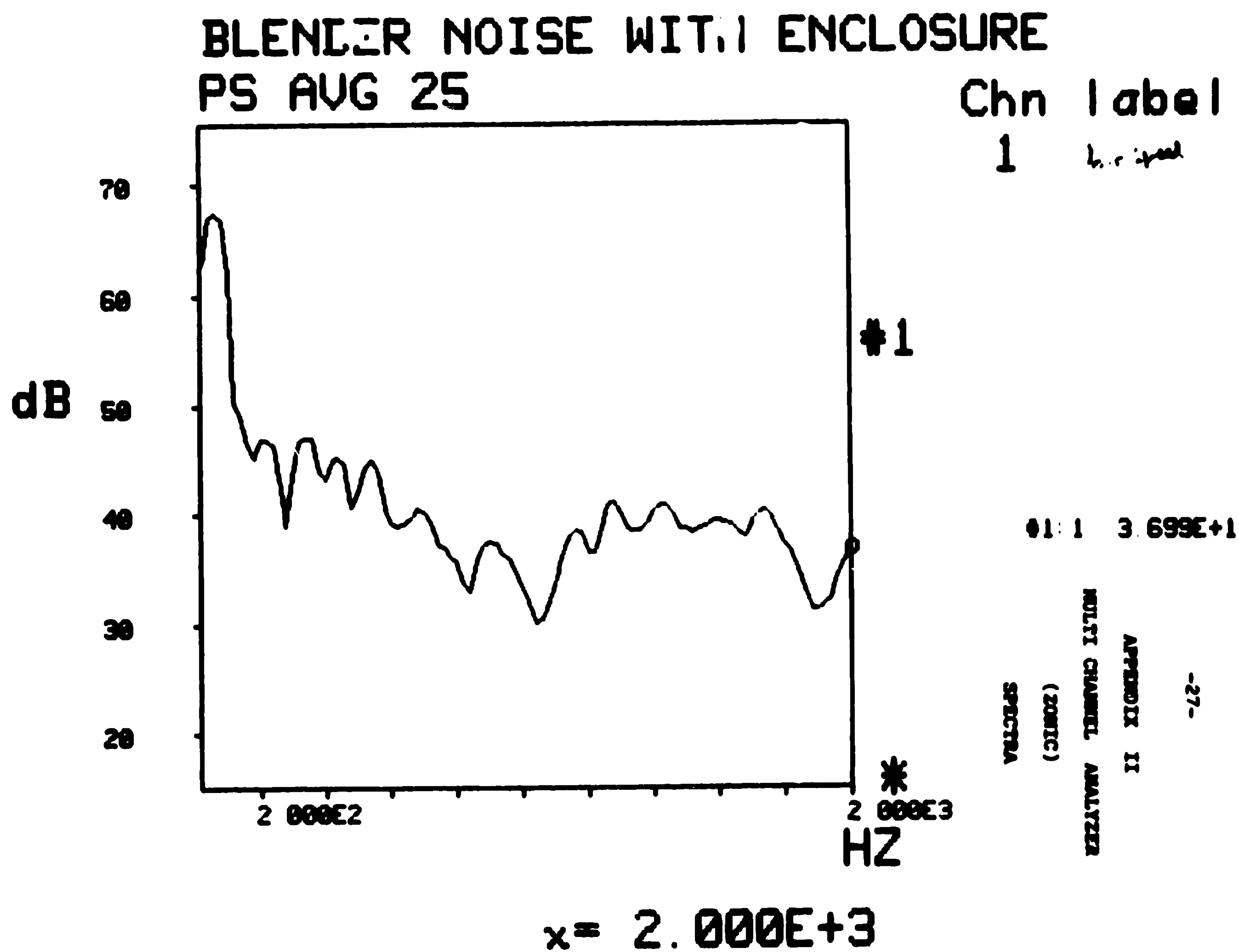

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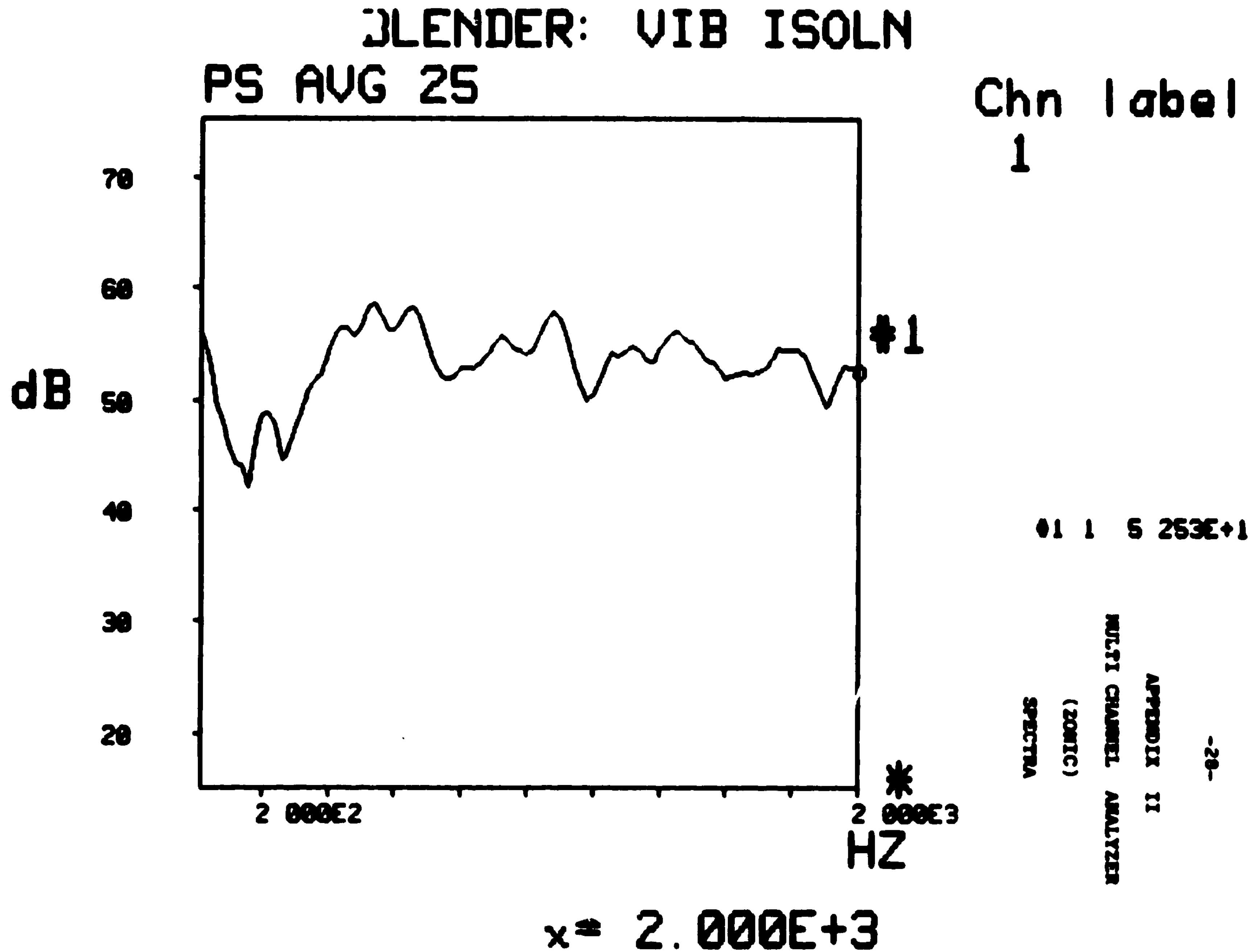

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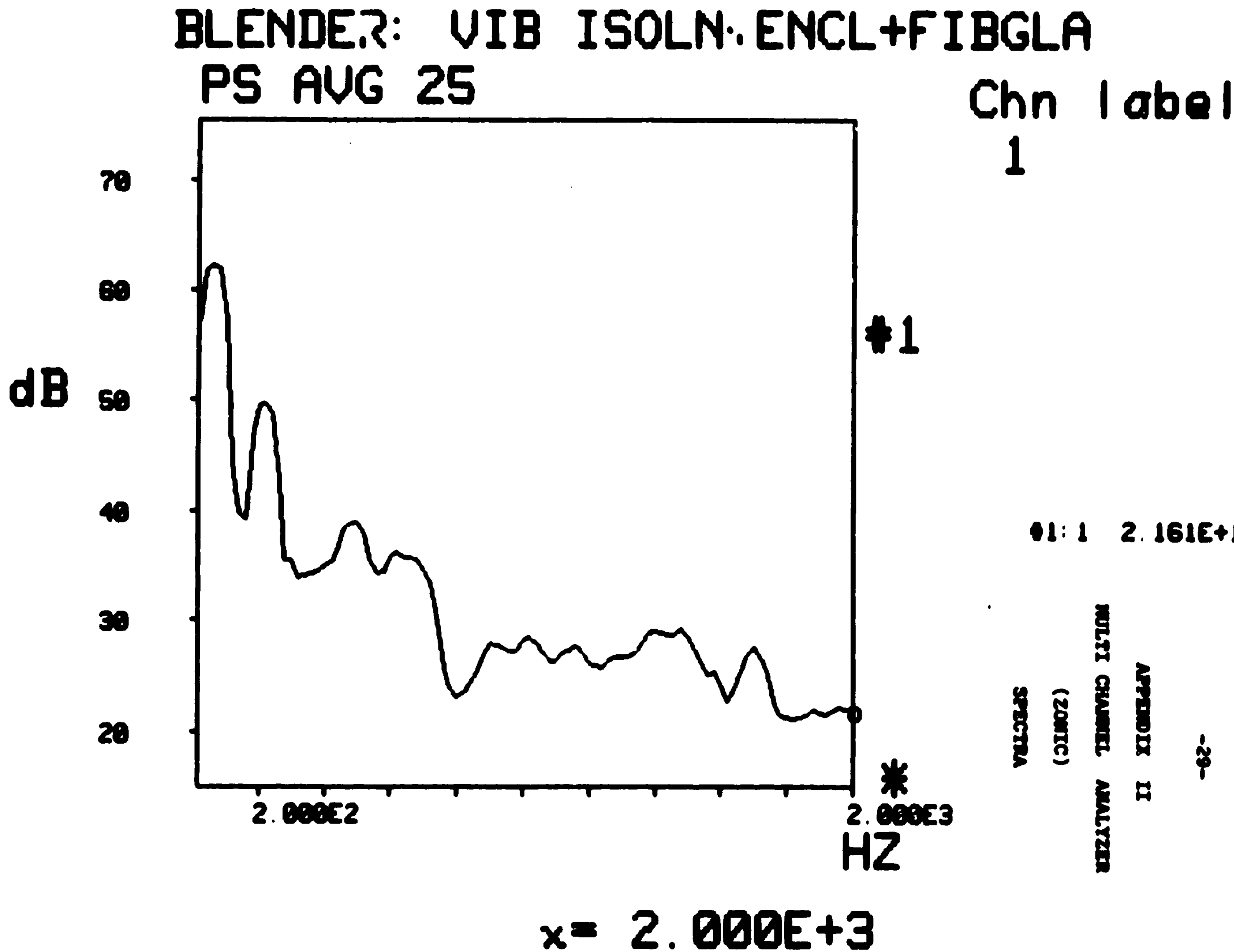

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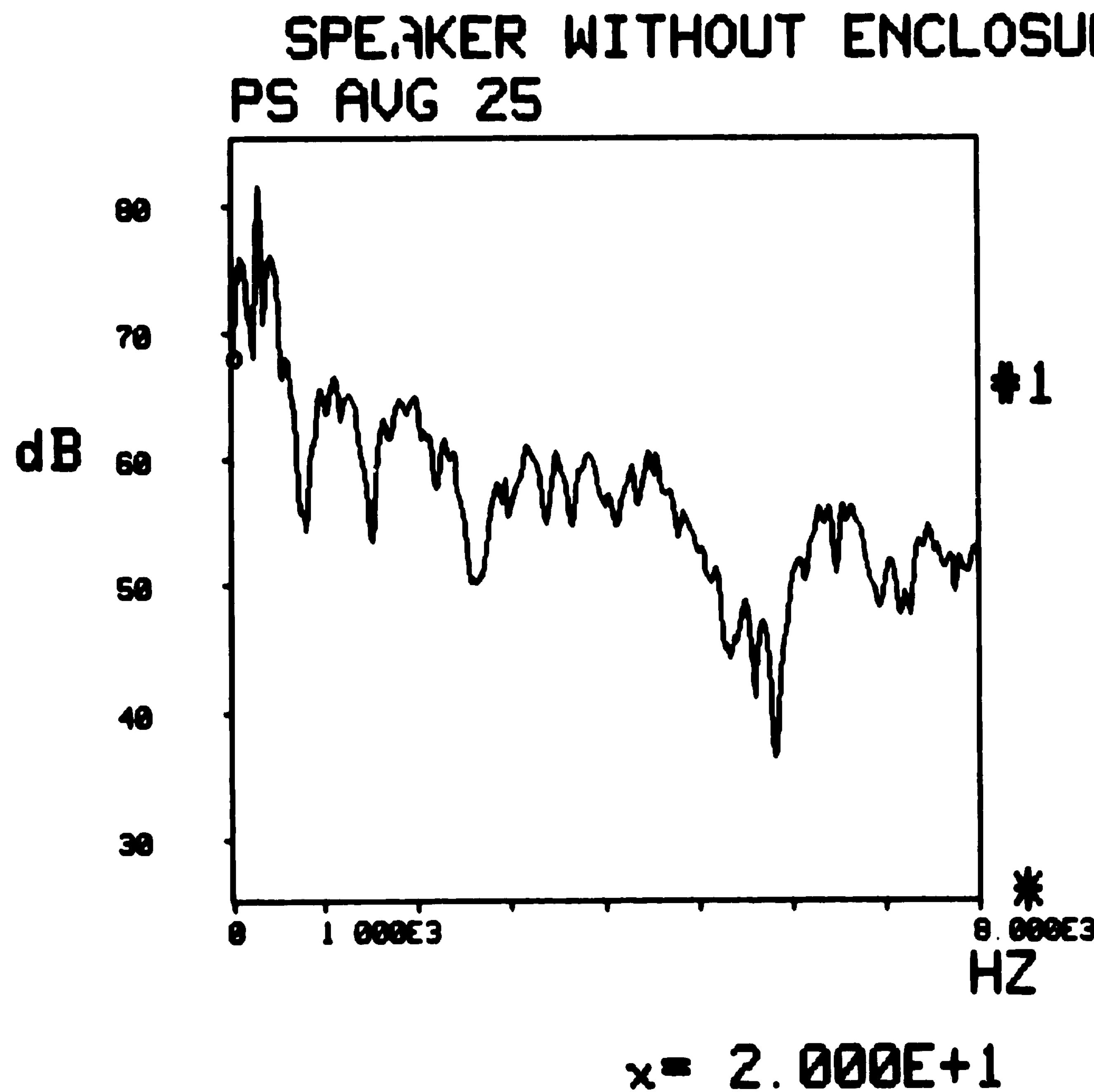

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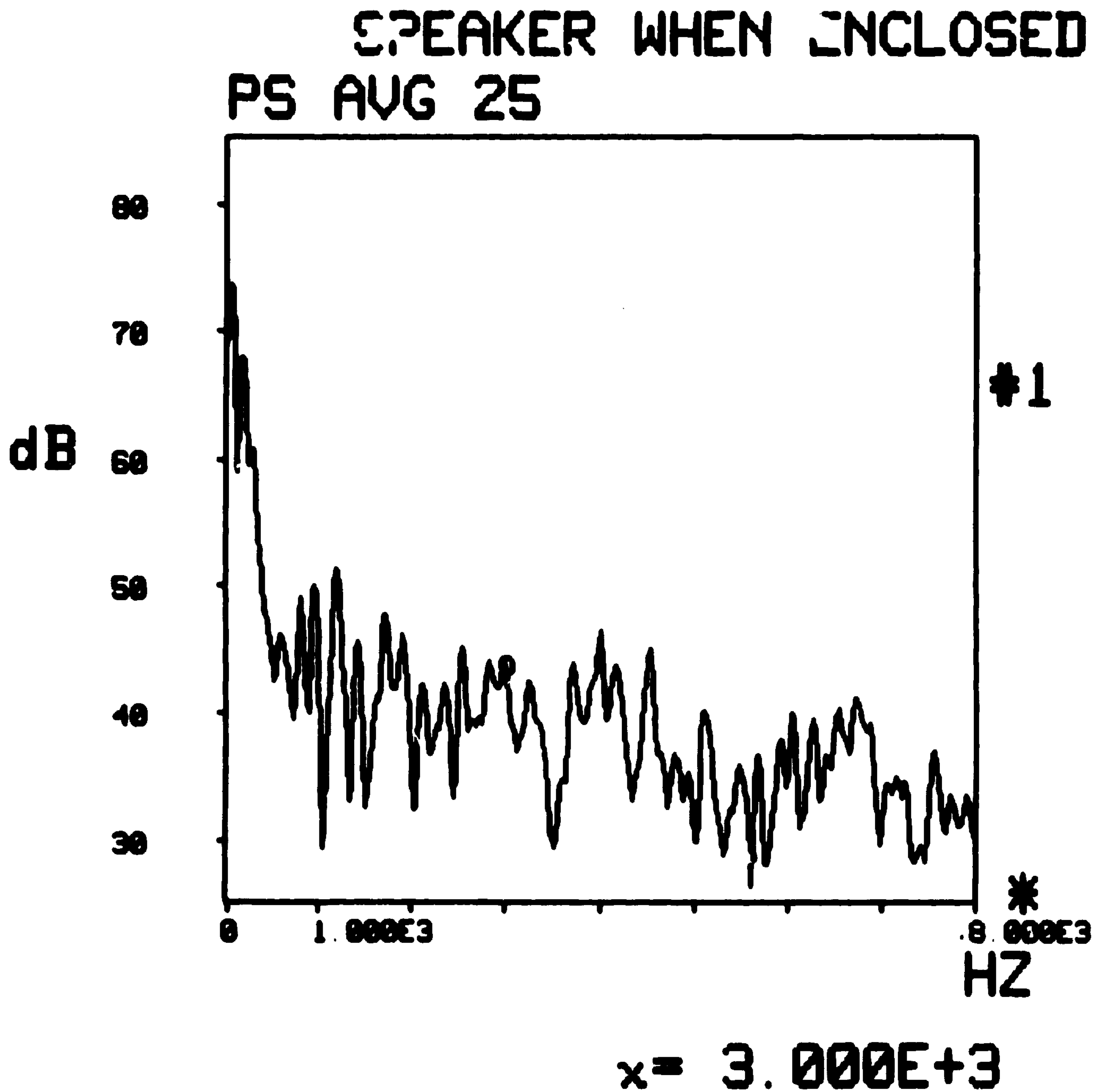

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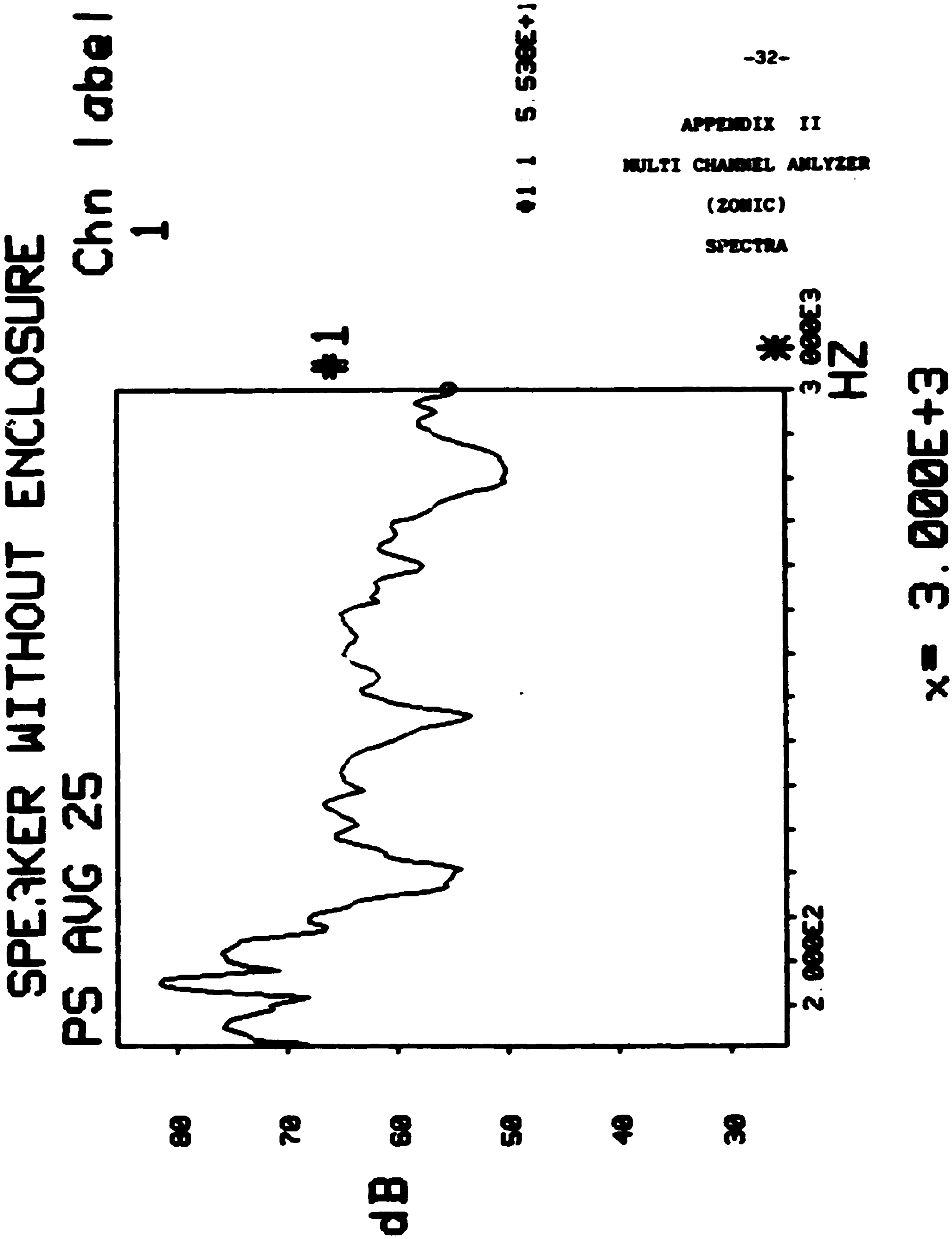

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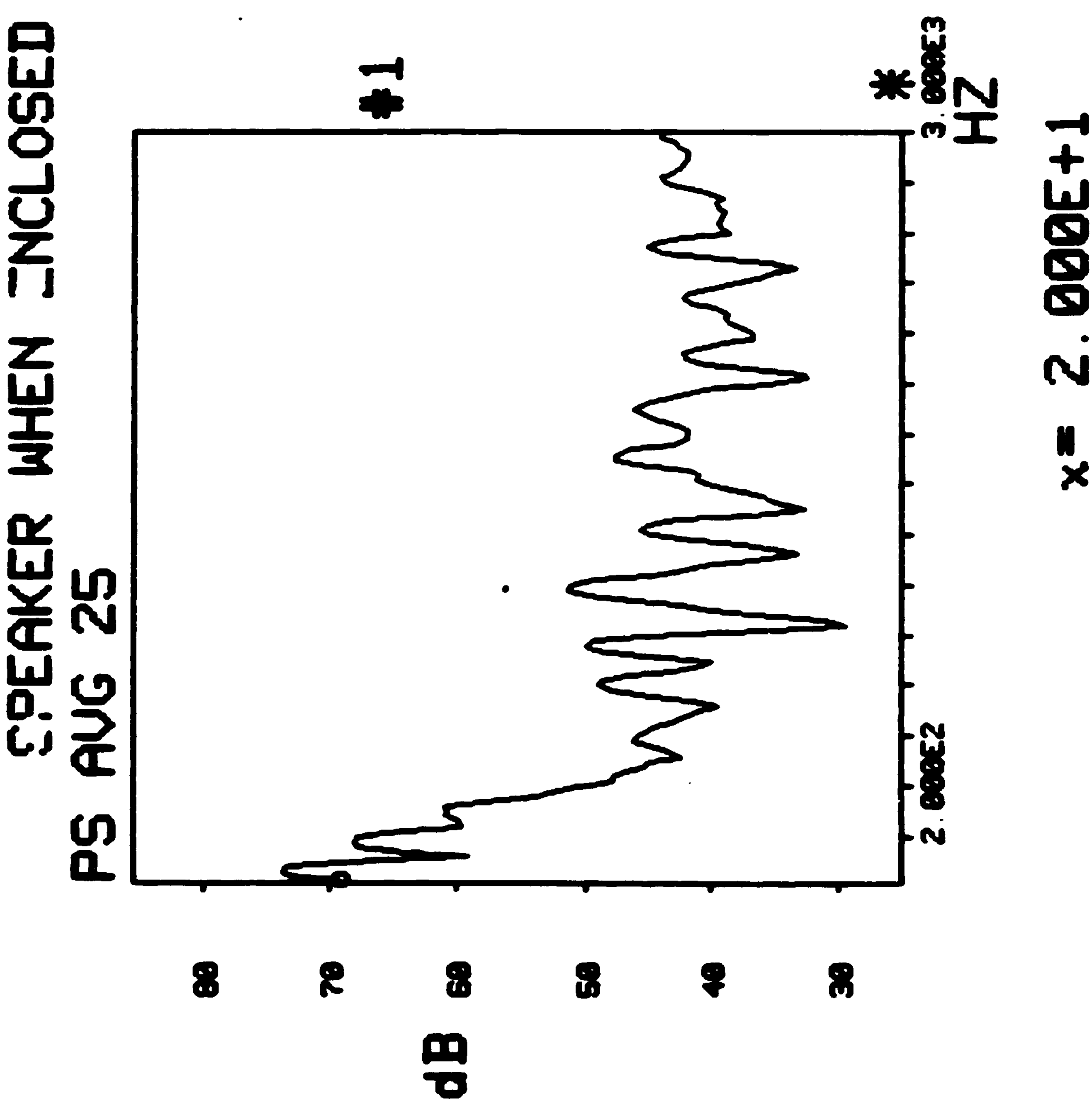

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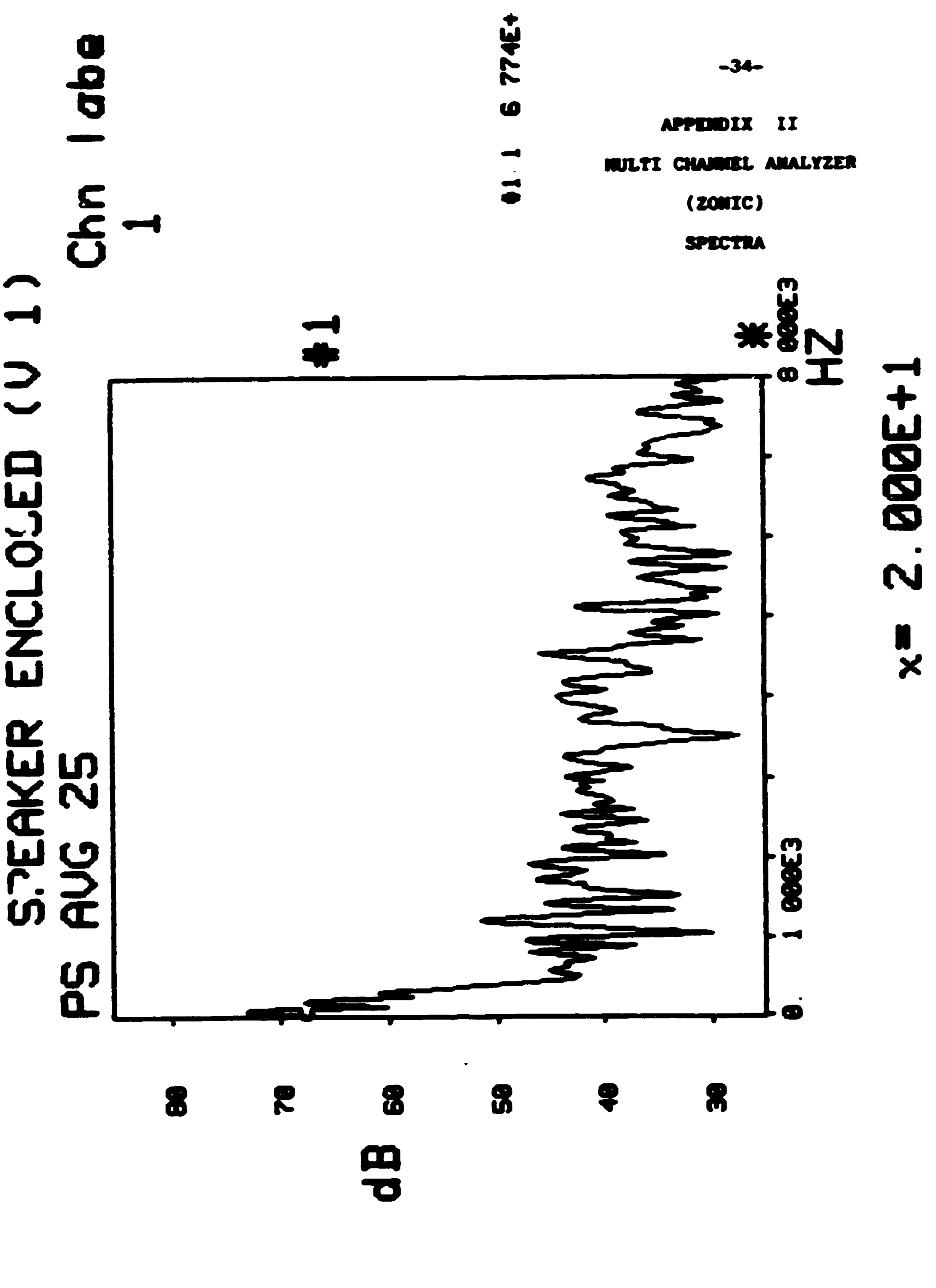

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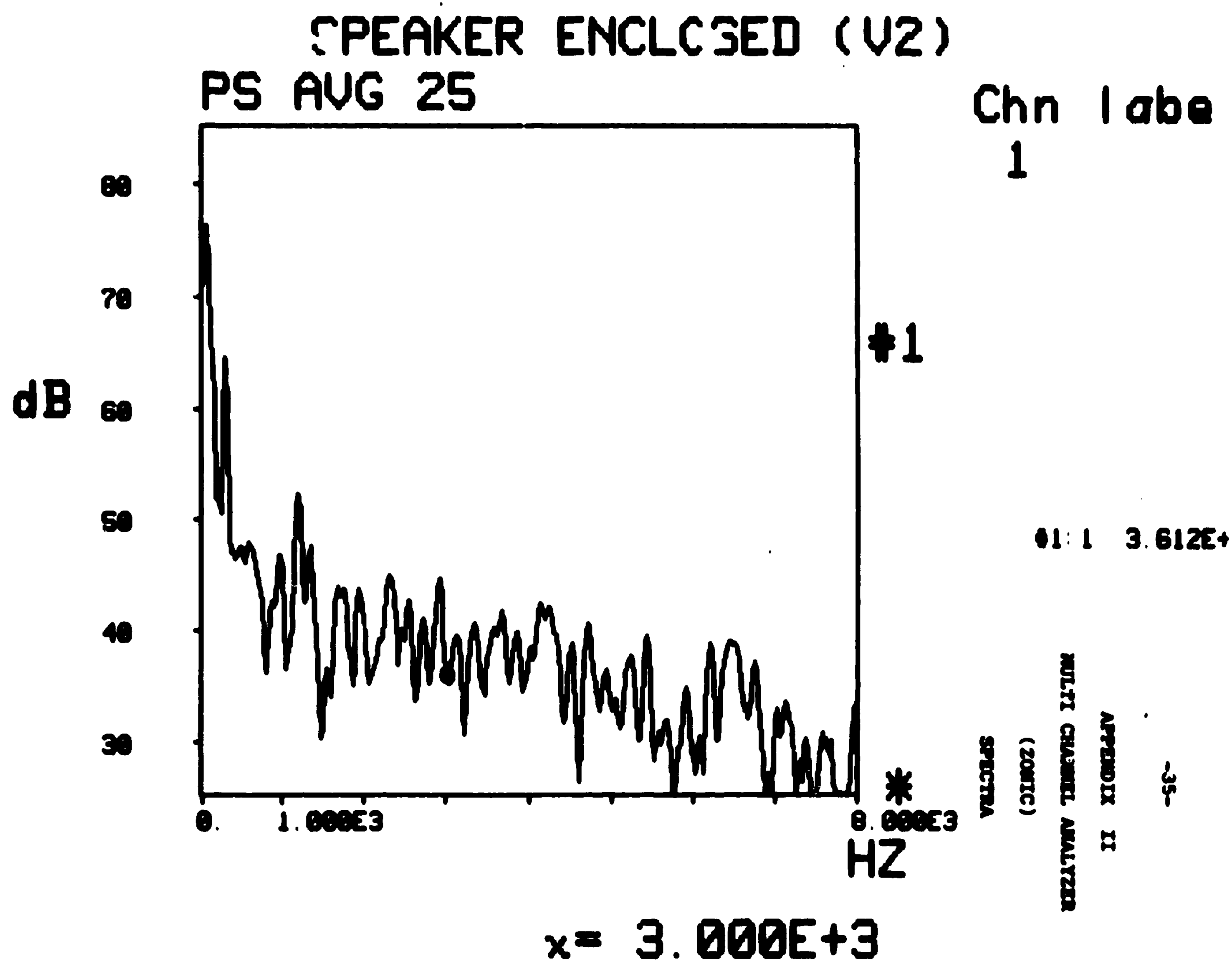

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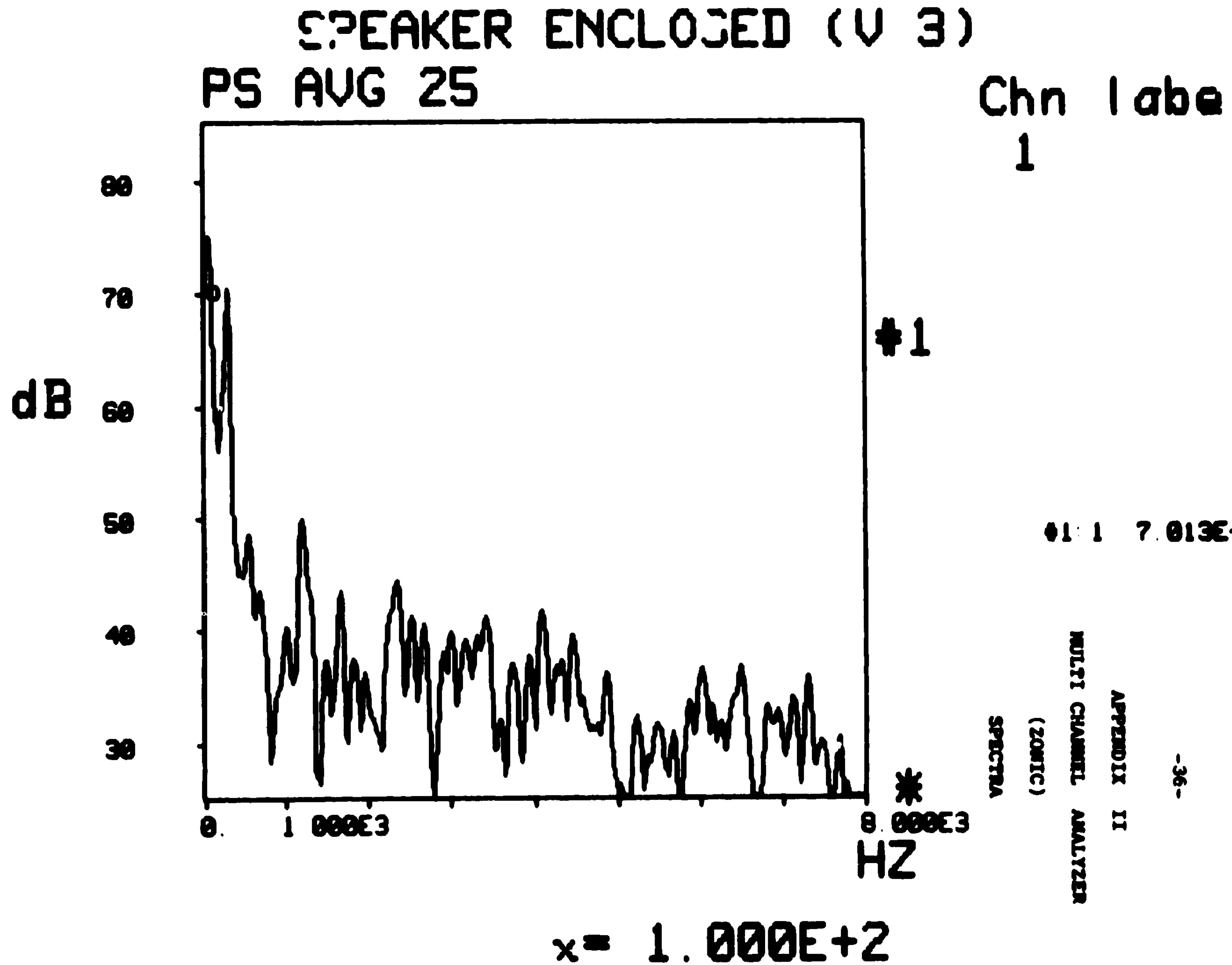

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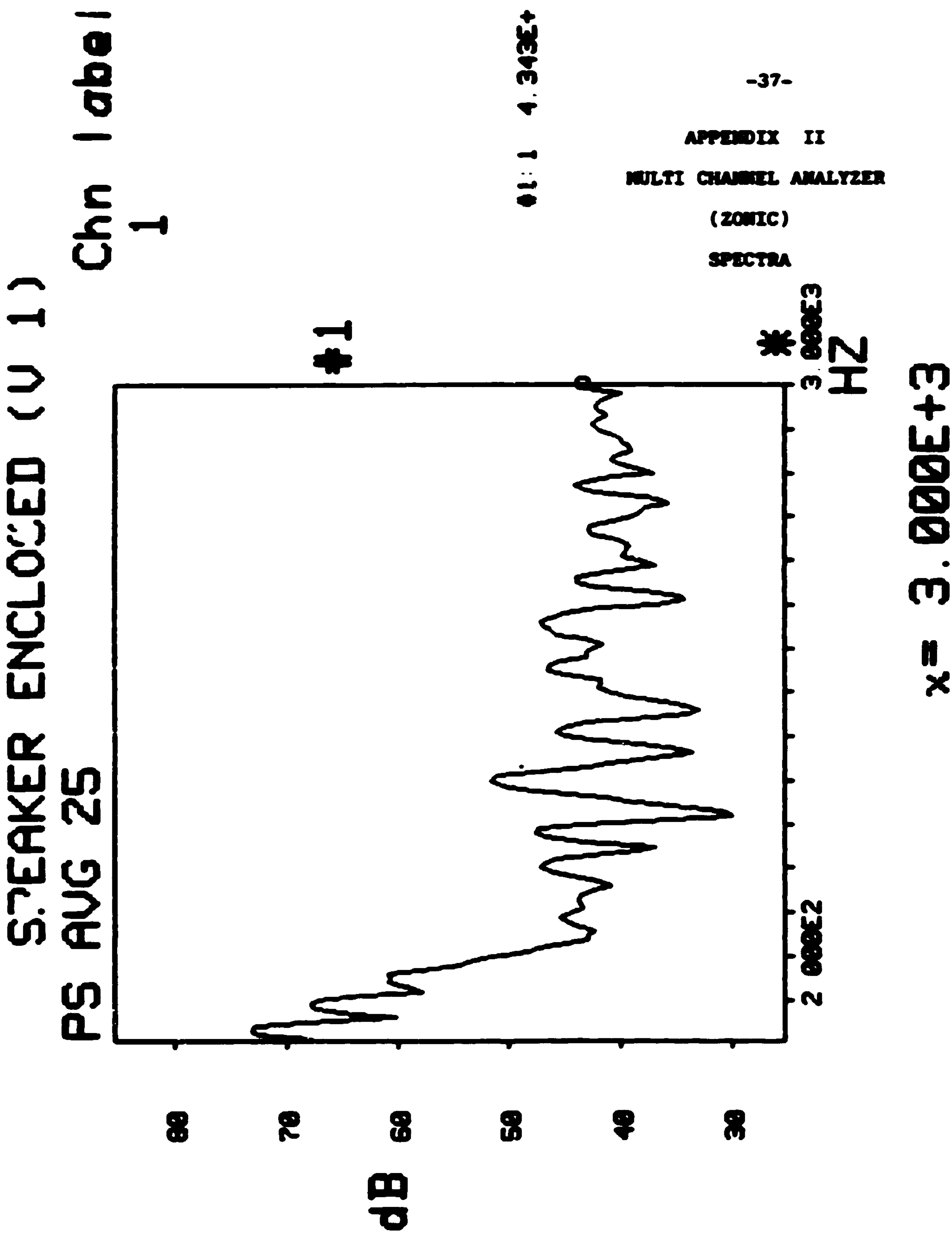

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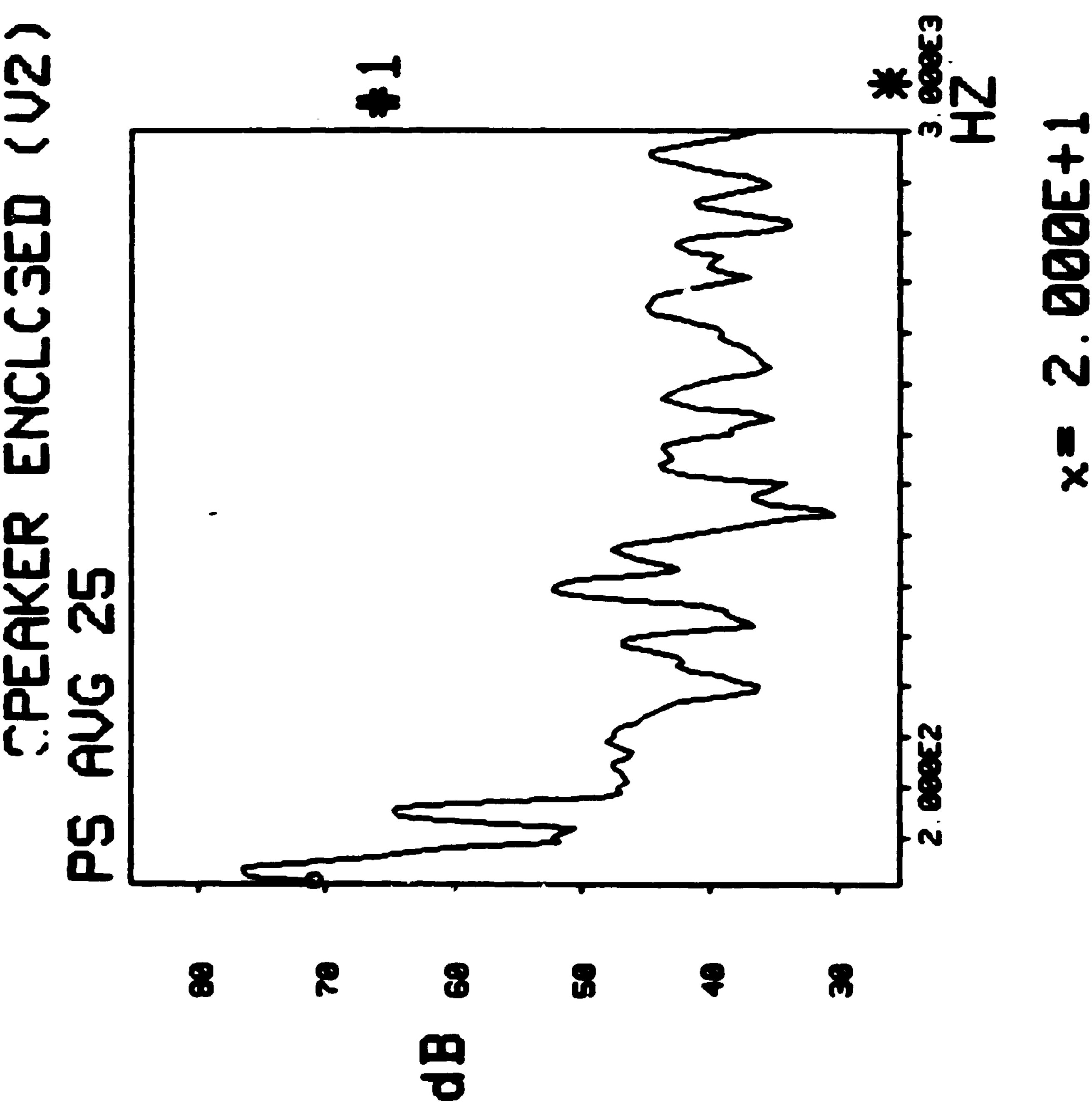

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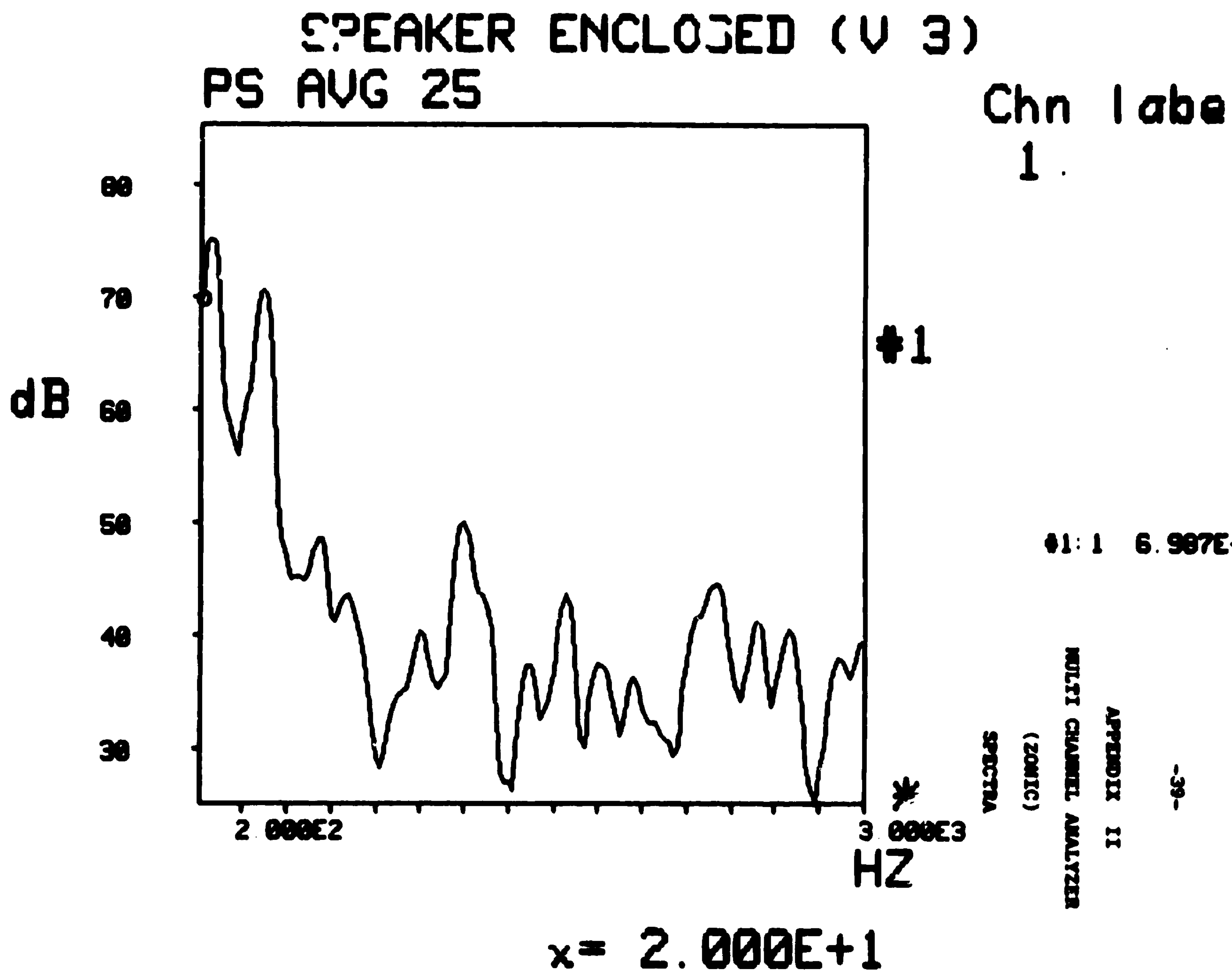

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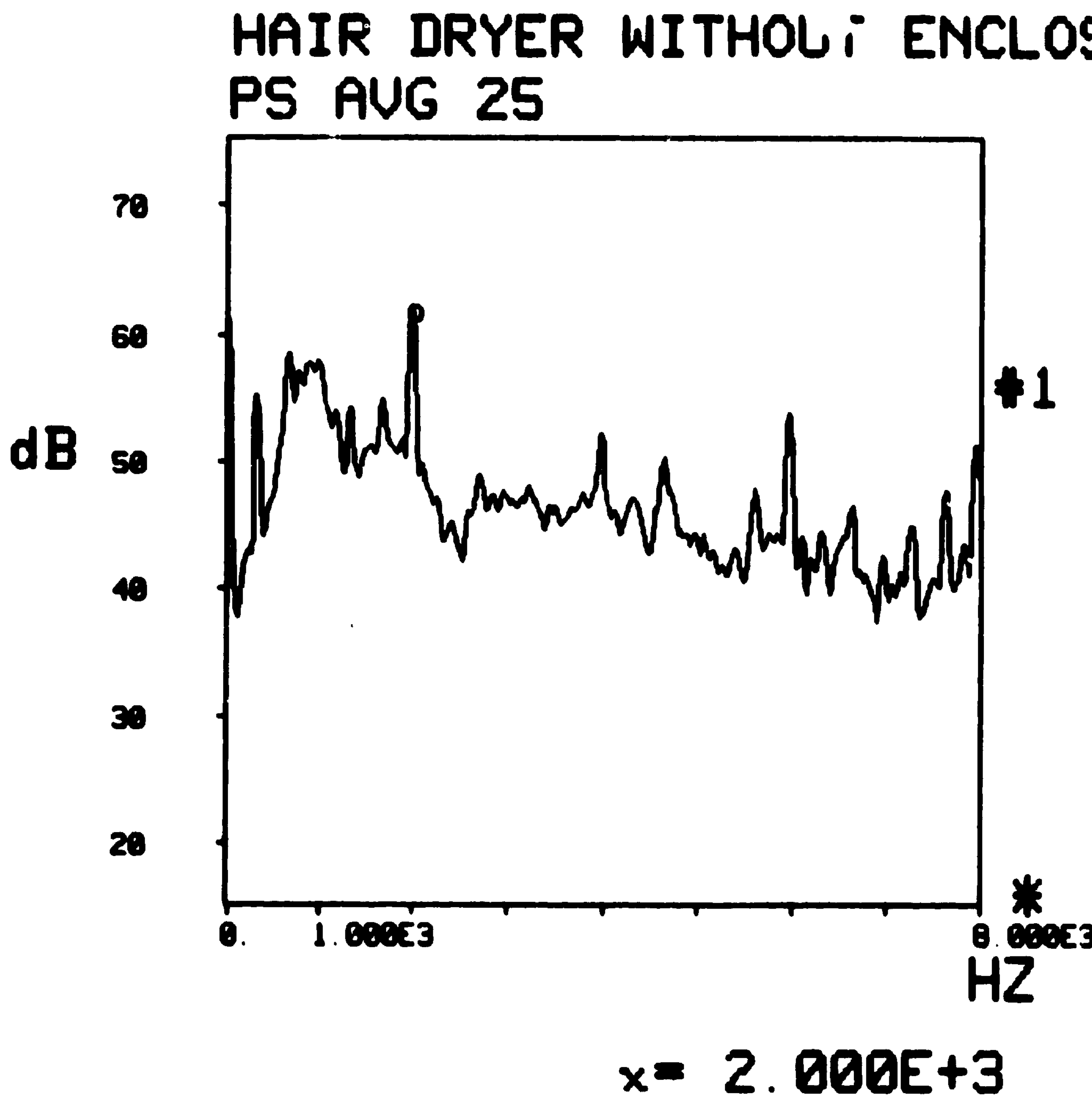

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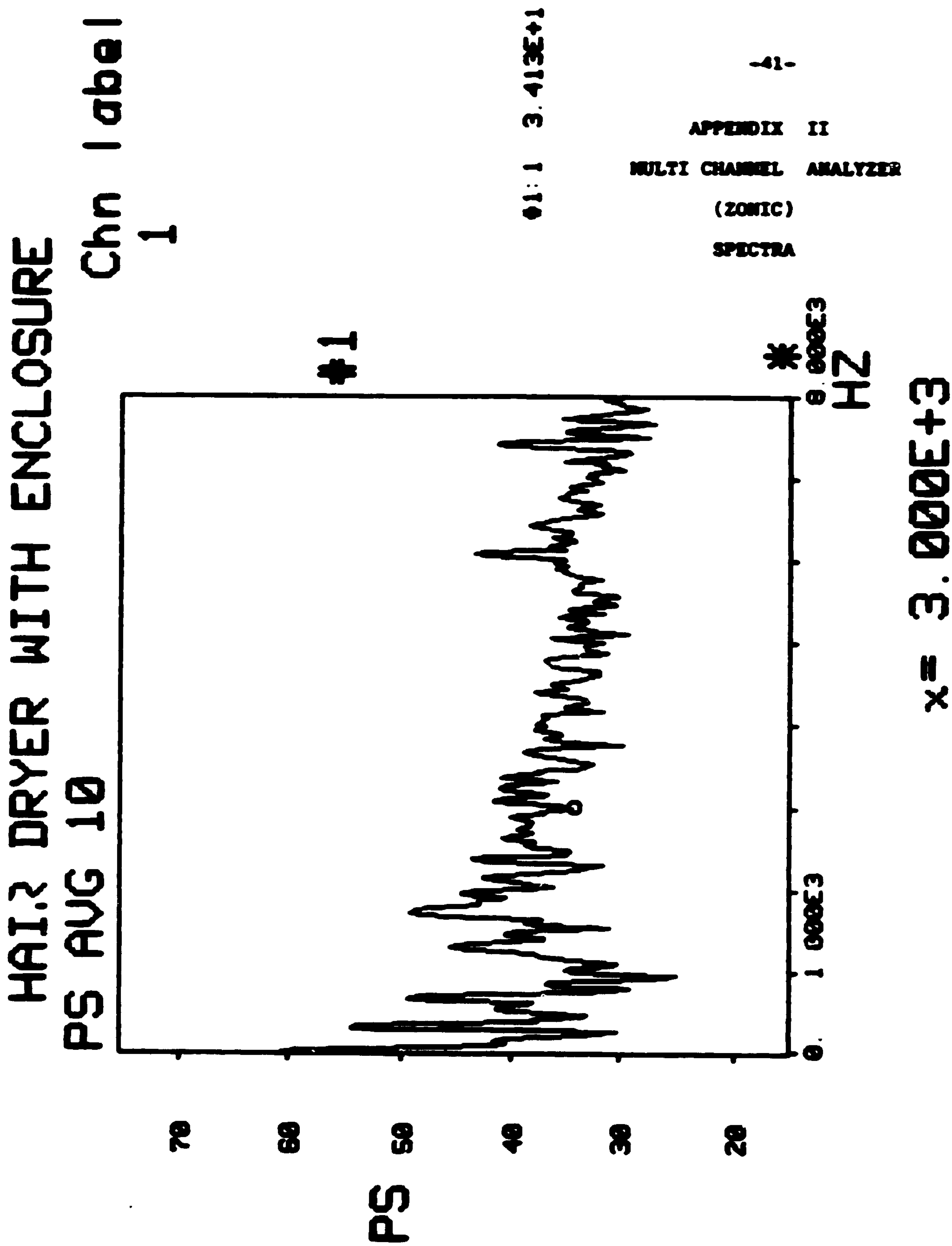

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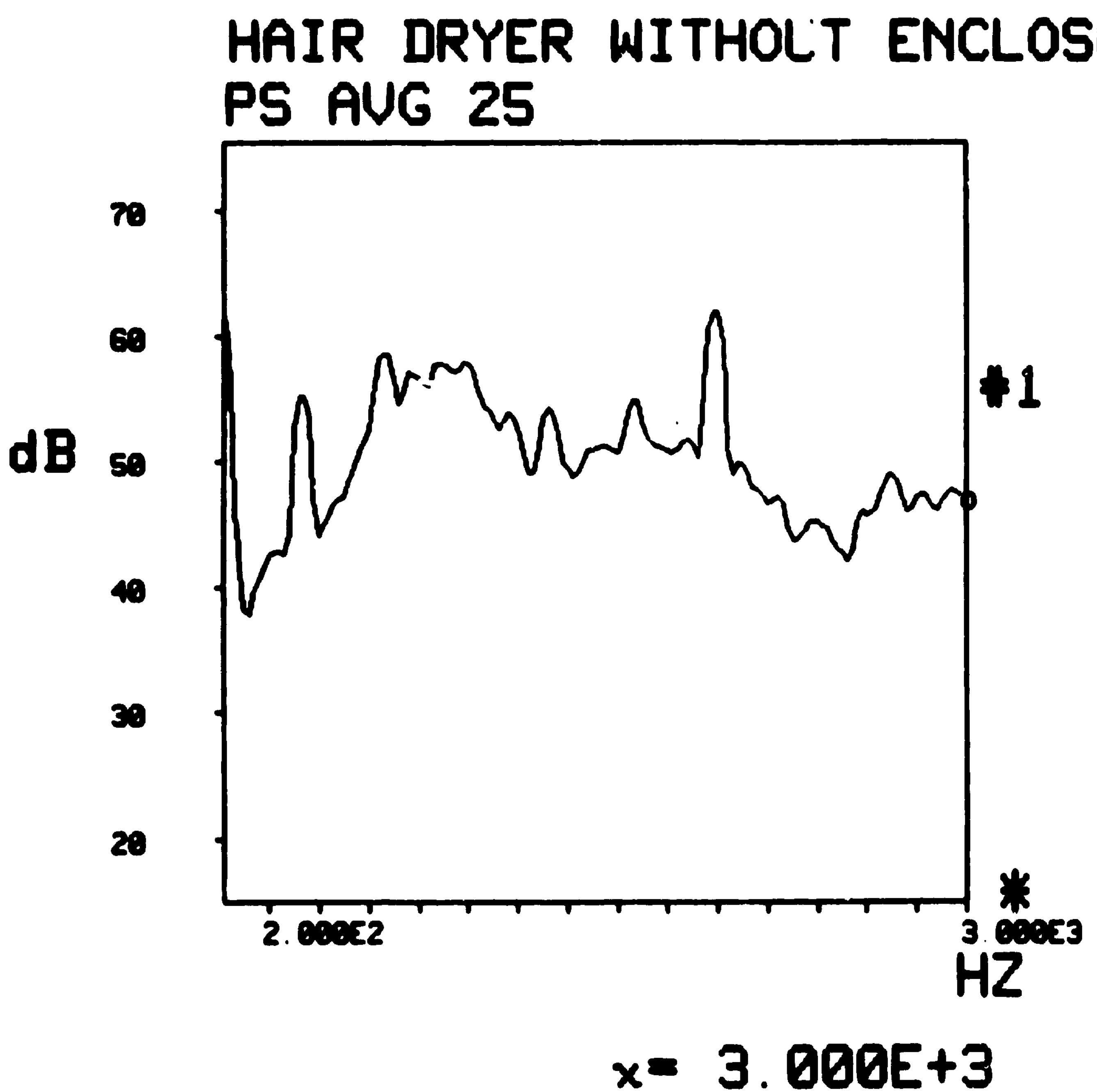

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