

TOWARDS AN EPIDEMIOLOGICAL PROCEDURE FOR THE CLASSIFICATION OF RESULTS FROM SCREENING AUDIOMETRY AMONG NOISE EXPOSED WORKERS

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ABSTRACT

Current methods for the classification of hearing impairment of noise-exposed workers using screening audiometry do not allow a clear definition of the severity of the noise problem in a plant. An epidemiological procedure is proposed relying on a statistical index of the age effect on hearing sensitivity. An example of application of the procedure is presented for a population of foundry workers. It is shown that a worker has approximately 4 chances in 10 of suffering from a significant hearing loss when employed in this plant for 15 years. The reliability of the procedure is discussed in terms of the size of the target population and the influence of extra-occupational sources of hearing loss.

SOMMAIRE

Dans l'état actuel des pratiques, les méthodes de classification des résultats d'examens de dépistage de la surdité professionnelle ne permettent pas de définir clairement l'ampleur du problème du bruit d'une usine donnée. Une méthode épidémiologique fondée entre autres sur les effets de l'âge sur l'acuité auditive est proposée. Un exemple d'application de la procédure est présentée sous la forme d'un bilan collectif d'une population de travailleurs d'un complexe sidérurgique. Le bilan montre qu'en moyenne un travailleur a approximativement 4 chances sur 10 d'être atteint d'une perte auditive significative due au bruit de l'usine après 15 années de travail. La fiabilité de la procédure est discutée en fonction de l'effectif de la population cible et de l'influence des facteurs extra-professionnels de détérioration de l'audition.

Introduction

It has been shown recently that the effectiveness of monitoring audiometry for secondary prevention of occupational hearing loss is seriously limited (1). This fact underlines the importance of a highly efficient use of the results of the very first hearing test performed on an industrial population. In this context, identification audiometry should actually aim at determining the severity of the noise problem or at verifying the effectiveness of a primary prevention program (noise control).

However, current methods for the classification of hearing impairment of noise-exposed workers, using screening audiometry, do not effectively serve such goals. Present classification relies on two sets of criteria: the first one relies on medico-legal definitions of hearing impairment (e.g., an average loss greater than

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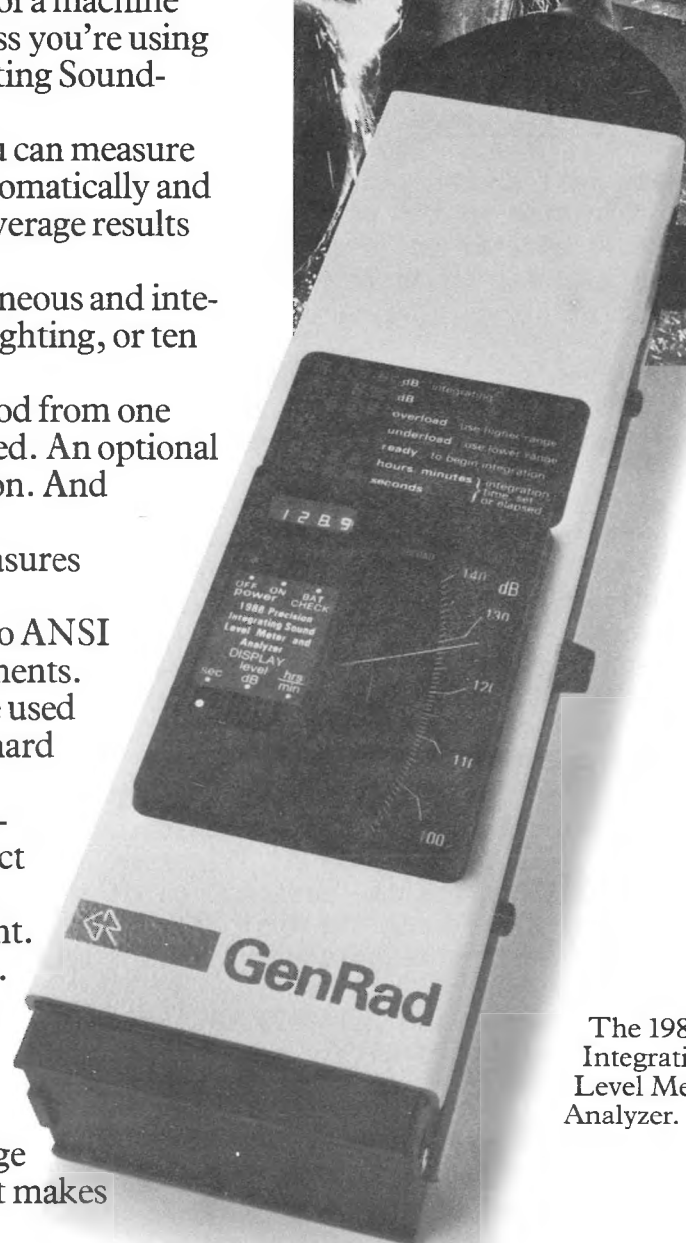
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25 dB at 500, 1000 and 2000 Hz); the second set of criteria is derived from a clinical evaluation of the audiogram configuration (2-5).

Then, when compiling the results of a screening program, one focuses on the number of referrals for clinical investigation. For various reasons, workers showing a notched audiogram in the range of 3000 to 6000 Hz usually are not referred. Moreover experience often shows that a majority of the referred cases involve other pathologies than occupational hearing losses. Consequently, the overall results of the identification audiometry program do not reflect at all the actual effect of the noise of a given industry on the hearing status of its population of workers.

This study is an attempt to develop an epidemiological procedure for the classification of the results of screening audiometry. It aims at estimating, with a high degree of credibility, the prevalence of hearing losses attributable to noise in populations of industrial workers.

Outline of the Procedure

1. Hearing test conditions

The objective of the procedure is to arrive at valid conclusions about the effects of industrial noise on the hearing status of a group of workers. The first step in this direction is to perform highly valid and reliable hearing threshold measurements.

It implies a painstaking control of the testing conditions and procedure:

- control of the background noise level in the testing environment, in accordance with the most recent standard at least for the testing frequencies between 500 and 6000 Hz (6)
- proper calibration and maintenance of the audiometer (7)
- adequate training and supervision of the examiner
- uniform instructions of all the workers tested
- proper adjustment of headband force and careful earphone placement
- for all workers tested, a minimum of 14 hours outside a noisy environment before undertaking the test (in order to prevent any contamination of the hearing threshold measurements by the presence of a noise induced temporary threshold shift).

2. Use of a questionnaire

Once the hearing status of the workers is adequately determined, the analysis must be supported by relevant information, such as (a) the history of noise exposure of the worker, (b) his history of illnesses and symptoms potentially associated with hearing deficits and (c) the description of the worker's condition at the time of the test (the interval between the test and the preceding noise exposure, signs of infection of the upper respiratory tract, alcohol or drug consumption, etc.).

This information can reliably be gathered using a questionnaire in controlled conditions. Recent data on the sensitivity and the specificity of health questionnaires clearly show that they can be a valuable tool in this context (8).

3. Hearing impairment criteria

In any population study of occupational hearing loss, the most difficult step is to determine what should be considered as a hearing deficit due to noise. Ideally a selected control population should be recruited and compared to the noise exposed group. But it is a complex and expensive task that is rarely practicable.

A simple solution is to apply age-effect corrections from presbycusis studies to the individual hearing threshold levels obtained. The approach adopted must however assure the smallest possible proportion of false-positives. In other words, a hearing loss can reliably be attributed to noise exposure only if it amounts to some significant value that would hardly be explainable strictly in terms of an age-effect, such a statement implies of course that other causes of hearing deficits are excluded.

In our procedure, a "significant hearing loss" (SHL) at a given frequency is defined as one greater than that attributable to age-effect in 90 per cent or more of the population. Generalized values of SHL can be found in Robinson and Sutton (9). Their computations are based on data from a number of presbycusis studies and the various assumptions underlying the estimation of age-effect are clearly discussed.

However, at the time we first applied the present procedure to screening audiometry data, these values were not available. We adopted provisional SHL criteria relying upon previously published generalized presbycusis values (10-11). These curves are based on results from 8 studies. Their use, at least in terms of median presbycusis corrections, is widespread among audiologists. Because of this, we have adopted SHL values that could be easily computed from the median presbycusis corrections already available.

Assuming a normal distribution of hearing threshold levels (HTL) for any age group under 69, dispersion data from Spoor and Passchier-Vermeer (11) show that the 90th centile values fall between 15 and 22 dB above the median hearing level at 3, 4 and 6 kHz for age groups between 20 and 69 years. For 0.5, 1 and 2 kHz, the difference between the 90th centile and the median extends from 8 dB at 20 years to 14 dB at 69 years of age. For reasons of simplicity, it was decided to adopt uniform dispersion criteria based on those for the more advanced ages. Hence it was estimated that adding 15 dB to the age-specific median presbycusis correction for 0.5 up to 3 kHz and adding 20 dB for 4 and 6 kHz would satisfy provisionally the above definition of a SHL.

This simplification implies that the criteria tend to be overly specific when applied to younger age groups and possibly overly sensitive with older groups, at least for a male population. This is confirmed by a comparison with the corresponding criteria derived from the generalized age-effect curves from Robinson and Sutton as shown in Table I. Thus, at the age of 25, our provisional criteria would correspond to the 99th centile. But, at the age of 55, they would approach the 85th centile at 3 kHz and above.

Table I. Comparison for two age groups of males of the criteria for the age-effects in dB (re: audiometric zero) associated with the 90th centile.

Frequencies (kHz)	Age groups (years)	Present study		Robinson & Sutton ⁹		Thiery et al. ¹²	
		<u>25-29</u>	<u>55-59</u>	<u>27.5</u>	<u>57.5</u>	<u>18-30</u>	<u>51-60</u>
0.5		15	21	9	17	12	18
1		15	21	9	18	13	22
2		15	26	10	27	17	26
3		15	32	12	39	13	35
4		20	43	13	51	15	37
6		20	47	15	57	25	50

Nevertheless, our criteria are valuable estimations of the limits that statistically define hearing impairments. This is supported by the comparison with the data from the most recently published age-effect study on an otologically screened population by Thiery et al (12). A close correspondance between the latter set of data and the present criteria can be observed (see Table I). It is therefore likely that our criteria represent valid indices of SHLs as defined above when applied to hearing losses due to industrial noise exposure.

4. Classification of individual data

The first step in classifying the audiograms is to identify (and refer for clinical investigation) those showing signs of pathological conditions other than occupational hearing loss. Those demonstrating SHLs due to noise exposure outside the industrial environment (for instance, during military service) should also be identified. The remaining cases will show either normal hearing or SHLs attributable to occupational noise exposure.

The severity of the noise-induced hearing damage can be estimated according to the number of audiometric frequencies affected by a SHL. A tentative categorization was adopted:

- level I: A SHL at 1 or 2 frequencies; this corresponds to the first signs of hearing damage at 4 or 6 kHz.
- level II: SHLs at 3 frequencies; this represents the typical notched audiogram, in the range of 3 to 6 kHz.
- level III: SHLs at 4 frequencies or more; in this case the hearing loss extends to 2 kHz or below, without being eligible for compensation, according to the Quebec criteria given in the example in the Introduction.
- level IV: hearing losses that satisfy the currently accepted medico-legal definition of impairment in Quebec. The workers falling into this category are referred for clinical investigation.

5. Collective analysis

The object of the collective analysis is the severity of the noise problem in the industry under study. Compiling the data according to the above categories will first allow the division of the population of workers into two subsets:

- a group of workers suffering from hearing loss of extra-occupational origin (pathological condition or non-occupational noise exposures)
- a group of workers whose hearing status can be considered as representative of those exposed to occupational noise (those with normal hearing and those with SHLs due to industrial noise).

Since this latter group may include individuals exposed to noise in factories other than the one under study, it is desirable to identify those exposed only to the target environment. But, considering the high degree of mobility of the workers from one plant to another, the outcome of such a selection would generally result in very small final samples of workers. For this reason, the selection criterion adopted in the present procedure is based on the relative duration of exposure in the plant under study compared to other working environments. If exposure to other noisy industrial environments has been shorter than the time spent in the present environment, the hearing loss observed can be attributed in larger measure to the environment representing the longest exposure.

Thus, the severity of the noise problem in the plant studies can be estimated by computing the prevalence of occupational SHLs among the workers having spent the larger part of their working life in this plant. Accordingly, comparisons between

different industries or between departments within a large industry can be performed if the average number of years of exposure inside and outside the industry is considered.

An Example of Application of the Procedure

The procedure outlined above was applied to a population of 965 workers employed in a foundry. Over 35 percent of these workers were exposed daily to noise levels exceeding 90 dBA for 8 hours.

1. Hearing test conditions

All hearing tests were performed using fixed frequency Bekesy audiometry under the direct supervision of graduate students in audiology. The audiometers were calibrated according to the reference equivalent threshold sound pressure levels specified by ANSI (S3.6-1969) (7) standard. The background noise level in the testing room was below the permissible level specified by ANSI (S3.1-1977) (6) standard at 250 Hz and above.

Hearing threshold levels of the workers were measured at 500, 1000, 2000, 3000, 4000 and 6000 Hz in both ears.

2. Classification of individual data

The classification of individual data is reported in Table II. It can be seen that one worker out of three suffered from a SHL attributable to industrial noise exposure, but only one out of 20 was possibly eligible for compensation (according to the low fence criterion in effect in Quebec, that is an average loss of 25 dB at 500, 1000 and 2000 Hz in one or both ears.

Table II. Collective treatment for a large plant (N=965)

Classification of individual data			
(PERCENT OF TOTAL POPULATION)			
Normals	SHL occupational	SHL extra- occupational	Other pathologies
53.3	33.7	8.9	4.0
Levels			
I	II	III	IV
(eligible for compensation)			
18.9	6.8	3.1	4.9

A closer look at the distribution of the SHLs among the different levels allows one to make the following observations:

- a majority of the affected workers suffered from a noise induced hearing loss at one or two frequencies (level I), that is at 4 kHz and at 6 or 3 kHz;
- the proportion of affected workers decreases dramatically when 3 frequencies (level II) or 4 frequencies and more (level III) are considered;
- nevertheless, 29 of the 33 percent affected were not eligible for compensation and for this reason, would probably not have been identified as suffering from a hearing damage due to noise in the context of conventional classifications.

Such a result points out the advantage of the present procedure. As stated above, the proportion of cases referred for further clinical investigation and possibly for compensation is frequently considered as the index of the severity of the noise problem in the factory. The present finding of 33 percent affected workers is at variance with the usual 5 to 15 percent of referred cases. Moreover, this overall result is meaningful in itself if one considers the above definition of a SHL. The outcome of a hearing test program performed within a factory is sufficient in and of itself to define the severity of the noise problem in the plant.

3. Prevalence of SHL among the target population

A more reliable evaluation of the actual effect of the noise in the plant can be obtained when the prevalence of SHL is computed on the target population. Here, the workers suffering from a hearing loss from an extra-occupational origin as well as those exposed during a longer period of time to the noise of other plants are not considered.

Table III. Prevalence of SHL among the target population of the effect the noise of the plant under study (N=719).

Total prevalence of SHL: 38.8% (Standard error: 1.8%)						
Average length of service: 14 years						
Prevalence of SHL according to classes of length of service						
Length of service (years)	<u>0-4.9</u>	<u>5-9.9</u>	<u>10-14.9</u>	<u>15-19.9</u>	<u>20-24.9</u>	<u>25</u>
Prevalence of SHL (percent)	20.8	31.8	34.9	48.7	57.6	54.5
N	221	110	63	76	113	123

It can be seen from Table III that, on an average, a worker has approximately 4 chances in 10 of suffering from a SHL when employed in this plant. This proportion is a function of the length of service in the industry. As reported by several authors the rate of growth of hearing loss in the range of 3 to 6 kHz is high during the first five years of exposure and decreases markedly thereafter (13-15). This phenomenon appears also to be true in terms of the proportion of workers affected by a SHL, as shown in Table III. But the increase in the prevalence of SHL, at least in the present case, approaches a ceiling after 15 to 20 years of exposure. At this time, approximately one worker out of two suffers from a SHL because of the noise in this plant.

A further analysis can possibly be performed in comparing the prevalence of SHLs across shops within the factory. But in the present case the relatively high degree of mobility among shops and the wide differences in average length of service from one shop to another would make such an analysis hardly meaningful.

Discussion and Conclusions

If hearing conservation programs aim solely at preventing hearing losses, eligible for compensation, conventional classifications of audiograms are certainly adequate. But if one also intends to protect the physical integrity of the workers, one should rely more on an epidemiological than a clinical approach. Identification audiometry can serve as an effective prevention tool if it is truly oriented towards the noise problem and the whole population of the workers of a given industry.

The data from the one plant presented in this study is merely an example of the application of the general procedure outlined. The relationship of the data to the degree of risk of hearing loss due to occupational noise is not clear. For this the analysis needs to be performed with comparable data from several plants. This will be possible in the near future as the present procedure is applied over a number of different industrial populations.

The above results show that such an epidemiological approach is applicable to a large factory. It can also be valuable for small industries, as will be shown from the results of a study currently in progress. But in those cases, because of the small number of workers studied, the confidence intervals for the proportion of affected workers are considerably wider. Nevertheless, computing the prevalence of SHL attributable to the noise can serve as a valid index for the comparison of the severity of the noise problem from one factory to another or from one type of industrial production to another. This is especially true if the above procedure is applied in a uniform fashion in several plants.

There is no doubt that the present procedure could be improved, upon sharpening its ability to identify the influence of extra-occupational sources of SHL. This is particularly true (a) for after-effects of various diseases that affect hearing significantly and also (b) for non-occupational noise exposures that could be severe enough for being responsible for a SHL. Nevertheless, the present study represents a first step towards an effective use of identification audiometry for secondary prevention of occupational hearing loss.

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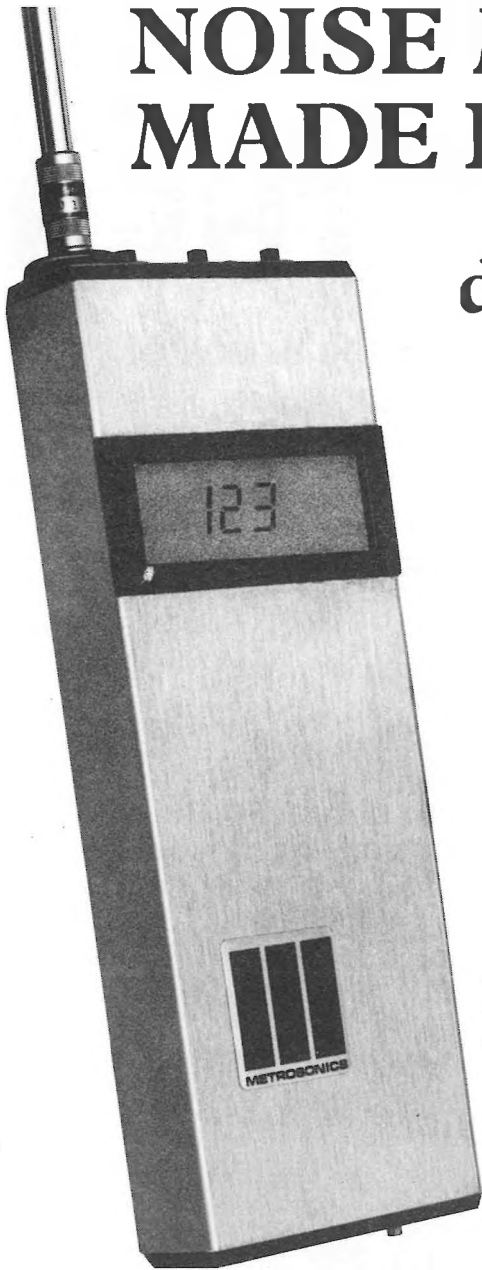
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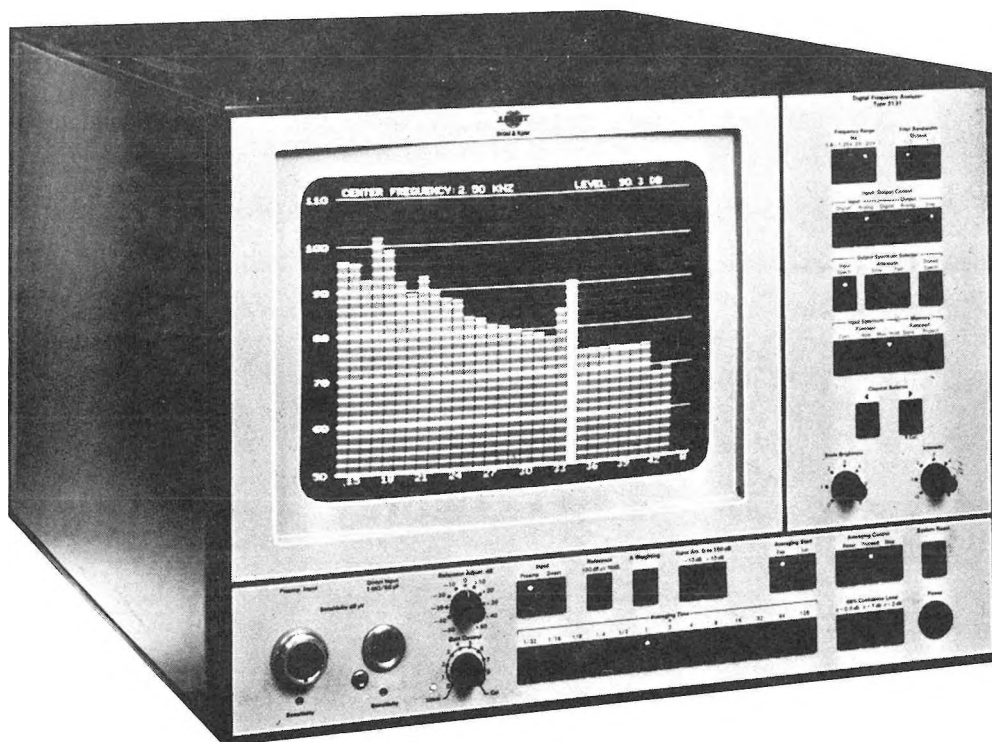
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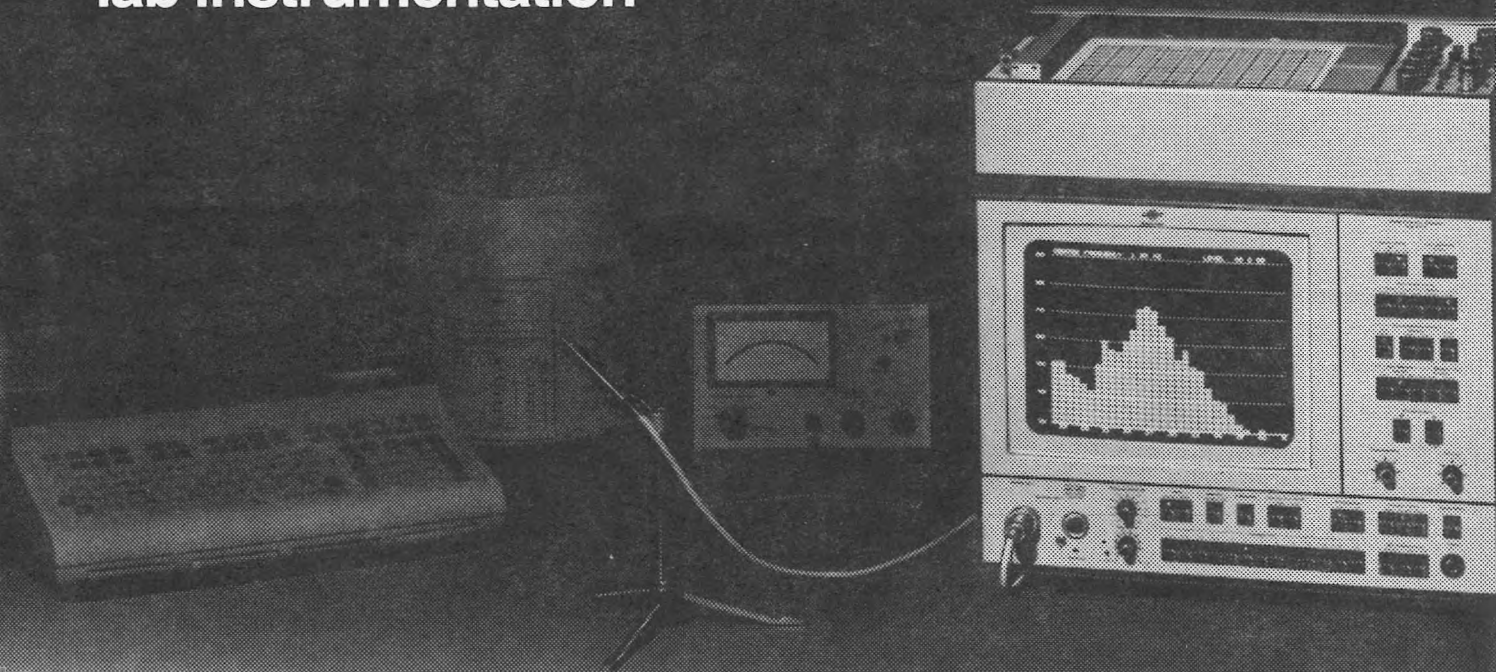
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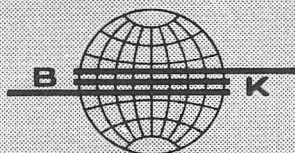
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