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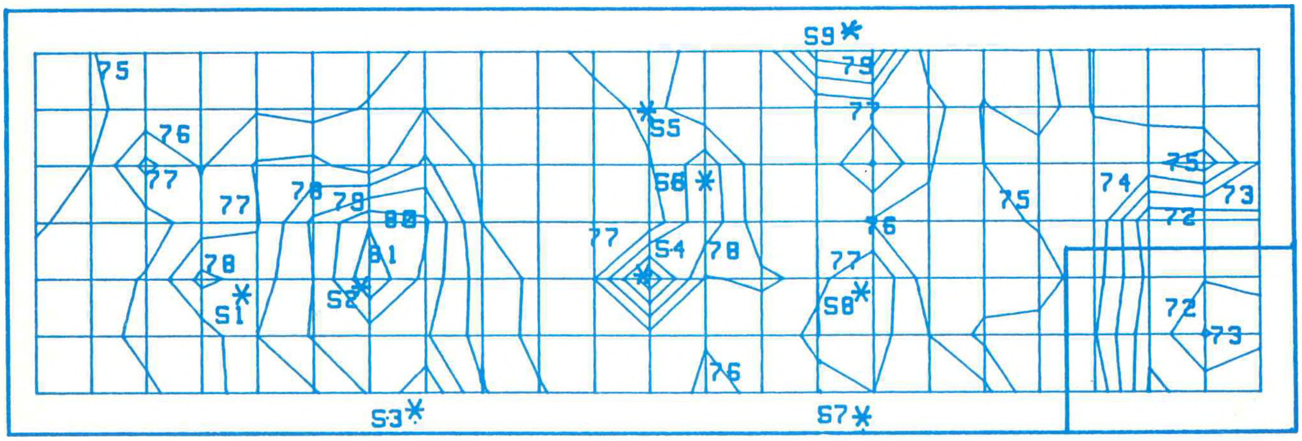

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EDITORIAL

Parmi les mammifères, l'espèce humaine présente au moins une caractéristique particulière à l'égard de ses capacités auditives. En effet, son domaine des fréquences audibles est le plus bas. Les humains ont par ailleurs une sensiblilité auditive relativement grande, le seuil d'audidibilité à 3-4 kHz chez les jeunes adultes n'étant pas très éloigné de la limite absolue imposée par le bruit aléatoire généré par le mouvement brownien des particules d'air. A quel environnement sonore et pour quels comportements auditifs notre espèce est-elle donc adaptée? L'abaissement du spectre des sons audibles s'est vraisemblablement effectué au détriment du pouvoir de localisation des sources sonores, mais au profit de l'utilisation maximale des signaux qui ont constitué la parole. Par ailleurs, la gamme dynamique étendue de l'audition humaine lui confère le pouvoir de déceler des événements sonores à des distances très variées. Paradoxalement, l'espèce humaine est en train de créer un environnement qui limite la communication verbale et la profondeur du champ sonore. Le bruit de circulation des milieux urbains, tout comme la musique dite d'ambiance des lieux de rencontre, rend difficile la communication verbale quand il ne la décourage pas. Il constitue un fond sonore terne, sans nuance, dénué d'information. Le milieu de travail industriel endommage l'audition et l'usage d'appareils de protection isole les gens au plan sonore tout en brouillant les capacités de localisation. Quand donc l'espèce humaine se redonnera-t-elle des payasages sonores à sa mesure? Une question cruciale non seulement pour les acousticiens-es mais aussi pour toute la population des pays industrialisés...

Among mammals, the human specie displays at least one unique feature regarding its auditory capabilities. It has the lowest frequency range of sensitivity. Humans have a relatively high sentivity, the hearing threshold at 3-4 kHz being not very far from the absolute limit imposed by the random noise generated by the brownien motion of air particules. To what sound environment and for what auditory behavior our specie is therefore adapted? The lowering of the audible spectrum has probably evolved at the expanse of precision in sound localization, but to the benefit of making the most use of signals that constitute speech. The wide dynamic range of the human hearing allows the detection of sound events over a wide range of distances. Paradoxically, the human specie is creating an environment that limits verbal communication and the depth of the audible field. Traffic noise in cities, as well as the environmental music in meeting places, make it difficult to communicate verbally, or simply discourage conversation. It creates a meaningless acoustic background, devoid of nuances and information. The industrial work environment damages hearing and the use of protectors isolates people acoustically and blurs sound localization. When will the human specie give itself soundscapes adapted to its capabilities? A crucial question not only to acousticians but also to the whole population of industrialized countries...

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ACOUSTICS AND MECHANICAL STANDARDS AT THE NATIONAL RESEARCH COUNCIL

by

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ABSTRACT

This article reviews current work in the Acoustics and Mechanical Standards Section of the Division of Physics at the National Research Council. The review of each project is placed in the perspective of the overall philosophy governing research decisions in the section, of the evolution of new projects and of administrative changes in recent years.

SOMMAIRE

Cet article passe en revue le travail présentement en cours dans la section d'acoustique et des étalons de mécanique de la division de physique au Conseil national de recherches. Le compte rendu de chaque projet est placé dans la perspective de la philosophie globale gouvernant les décisions de recherche de la section, de l'évolution de nouveaux projets, et des changements administratifs dans ces dernières années.

OVERVIEW

Editor Murray Hodgson has asked me to write an article on the work of the Acoustics Section in the Division of Physics at the National Research Council. A similar article on Auditory Physiology Research in Toronto appeared recently in Canadian Acoustics, Vol. 16, May 1988. The Acoustics Section was profiled once before, in Acoustics and Noise Control in Canada by Edgar Shaw in 1981. In that article Edgar Shaw traced the growth of the Acoustics Section back to its origins in 1929, and I refer the interested reader to his article for the first 52 years of our history. Reading that 1981 article I am struck by numerous impressions; at the one extreme is the continuity of some "generic" projects during the past seven years, and at the other extreme are the significant changes that have occured with the termination of some projects, the beginning of others, and in the evolution of the ways in which we conduct our business.

Since at least the 1950's, the philosophy governing the Section's work has been to select major areas of acoustical research where there are significant benefits to be derived either from new scientific knowledge or from economic or social improvements. A strong ingredient in our choice of projects is to do the things where we believe we have some special skills, knowledge or bright idea. The style of research in this laboratory is strongly rooted in physics, attacks both the theoretical and experimental aspects of any problem (so that each substantiates the other), searches for the underlying mechanisms, and attemps to maximize useful output with the minimum expenditure of resources.

It was already apparent in 1981 that the National Research Council was redefining its role so as to provide greater service to the industrial sector of the economy, having spent much of the previous quarter-century helping to build Canadian academia. This caused no great disturbance in the Acoustics Section because working with industry had always been one of our several goals that had been exploited on numerous occasions as opportunity allowed -- quietening of suction rolls for the pulp and paper industry, of nail-making machines for the steel industry, of rock drills for the mining industry, liquid-filled-cushions for ear defenders, and instrument development were just some of our developments that went into commercial production. Administrative changes in 1986 caused the Physics Division of NRC to be combined with the Division of Microstructural Sciences, and the new entity to be subdivided into three Laboratories. One of these three is the Laboratory for Basic Standards, within which the Acoustics Section acquired responsability for the primary national standard of mass and the derived standards of pressure and density, also the five staff members involved, and was renamed the Acoustics and Mechanical Standards Section.

ACOUSTICAL RESEARCH AND DEVELOPMENT

Our work on sound reproduction and the psychoacoustics of music listening has assisted the Canadian loudspeaker industry in growing from virtually nothing 15 years ago to the point where today it grosses at least $100 million per year, accounts for more than half the domestic market and is building a significant export market. This success arises from the careful blending of physical tests in anechoic and conventional rooms, controlled listening tests in specially designed rooms, knowledgeable interpretive methods and the skills needed to exploit the results. Our listening room, with its careful control over the frequency, distribution and damping of the room modes was the prototype for the International Electrotechnical Commission standard listening room. Hi-fi loudspeakers today are close to the perfection that is possible at any given price range -- this is a bold statement but indicates that any further improvements in listening will come from new approaches to the complete electroacoustic, room acoustic and listener system. For this reason the laboratory is embarking on a $2 million, three-year research and development project, in conjunction with a consortium of companies from the Canadian loudspeaker and electronic industries, to develop a "smart" loudspeaker system that will adjust to the listening environment and correct for imperfections in the reproduced signal. The Section's acoustical facilities were used last year for loudspeaker design and evaluation by 33 clients for a total of 94 days.

Another research and development project of long standing aims to understand the mechanisms of noise and vibration generation in small internal combustion engines, such as those in chain saws, and then to reduce this noise by better mufflers, engine design, vibration-isolating handles or other means as appropriate. Design constraints such as size and weight limitations make it essential to know the relative intensities of the several dominant noise sources (exhaust and intake noise, mechanical noise, surface radiation from the block). The relative magnitudes of the two known forcing functions, the combustion process and piston-cylinder wall impacts, have been investigated and some studies have also been made of the mechanisms responsible for the performance of some significantly improved muffler systems. A balanced design for a quieter device involves treating each of the sound sources by the necessary amount and with the minimum penalty to output power or performance. The design of vibration-isolating mounts, or handles, must allow for associated factors such as the need for stability or precise control.

A closely related project that grew from the work on chain saws involves the study of the epidemiology and cardiovascular mechanisms of damage to the hand and arm caused by exposure to vibration. Our recent work, both in laboratory and field studies, has revealed three patterns of sensorineural response to exposure of the hands to vibration. These patterns were detected by measuring mechanoreceptor-specific vibration perception thresholds using a technique developed here. These studies are conducted under contracts, or as shared cost projects, with the Forest Products Accident Prevention Association, INCO, and individuals at both Laval and McMaster Universities. The process of commercializing the NRC technique for measuring vibrotactile perception thresholds and of working towards the international standardization of the procedure is continuing.

An important goal of the Acoustics Section for many years has been to develop a detailed understanding of the human external and middle ear so that reliable, quantitative predictions of acoustical performance can be made. This will be of use in evaluating audiometric techniques above 8 kHz, for the development of hearing aids, and for the interpretation of various physiological and psychological acoustical effects. The project is proceeding through development of rigorous theory to describe sound propagation along the ear canal and coupling to the middle ear, and experimentally through measurements of real canal geometry and reflection properties of the middle ear. Fifteen ear canals have been measured, 1000 coordinate points each, and previous theories of sound propagation in rigid-walled tubes have been extended to allow for a non-straight tube of variable cross-section terminating in a distributed mechanical load, i.e. the eardrum. Measurement techniques based on phase, rather than the more conventional pressure measurements, have been found very useful in real ears, and experiments on mechanical models have been performed to verify the theory. The improved theory can be applied, making use of the measured data, to calculate the effect of intersubject variations on current audiometric procedures, to evaluate alternative procedures, and to explore the effect of ear canal geometry on hearing aid development.

Over a period of some 15 years our work on sound propagation outdoors has covered all the major interactions of sound waves with ground shape and its surface impedance, and with micrometeorological conditions such as wind and temperature gradients and turbulence.

Application of this new and more precise approach to the basis of prediction schemes has allowed an explanation of the sideline noise up a sloping hillside at Vancouver Airport, the improvement of airport and community noise prediction schemes by several authorities, and more accurate source location by arrays of receivers. We have recently completed theoretical and experimental studies of diffraction over curved surfaces, e.g. berms, of both moderate and very large impedance, and also the coupling of creeping waves across an impedance discontinuity. We are starting the investigation of near-surface seismic waves as we "pursue" airborne sound waves into the ground in order to understand better the surface behaviour of real grounds.

About two years ago we embarked on a project of active, adaptive control of sound fields with the intention of exploring new algorithms for signal processing, the use of multiple sensors for sensing and modifying the acoustic field, and the limitations of such systems. An experimental system allows cancellation of broadband noise in one dimension below about 500 Hz, and will be used to evaluate various control algorithms and derive hardware for more ambitious systems. Work on fundamental research in this area will be carried on in conjunction with the smart loudspeaker project outlined earlier that uses the same expertize.

Yet another new project, this evolving from the work on sound propagation, is concerned with the acoustical properties of porous and fibrous materials and how these are related to the physical parameters describing the microstructure of the material. Theoretical models currently used to describe porous materials involve such parameters as dc flow resistivity, porosity, tortuosity, shape and structure factors. Since these factors cannot always be measured in real materials they are often treated as adjustable constants in fitting measured data. This is a weak link in the justification of the use of specific theories for specific materials. Model porous materials for which the microstructure is known will be used to develop techniques for measuring these parameters. Measurement of the acoustical properties of these materials over a wide range of frequencies then allows the several theoretical approaches to be quantitatively assessed.

The National Research Council is mandated to maintain Canada's basic physical standards and the national standards of various derived quantities. Increasingly commercial contracts, and regulations, are requiring acoustical measurements that are traceable to national standards. To meet these needs the laboratory has a highly accurate microphone comparison system of unique design, and a primary reciprocity calibration system of exceptional stability, environmental control and precision. In an interesting reversal of its role, this latter system has been used as an electroacoustic method for studying the variation of the ratio of specific heats of air with temperature and with humidity, as well as other related physical quantities. The section also has apparatus for the calibration of sensors at frequencies from dc to about 5 Hz and sound pressure levels up to 160 dB. Yet another system is under construction, for the absolute calibration of accelerometers using a laser interferometer for measuring displacement.

The Acoustics Section works closely with national and international standards organizations such as CSA, ANSI, IEC, and ISO. This work relates primarily to the performance and specification of instruments, and especially to factors such as detector characteristics, time constants and weighting functions where it is now clear that allowed tolerances can often lead to variations in measurements that are much greater than would be inferred from the overall instrument specifications. Other standards work is related to measurement methods and prediction schemes.

The Acoustics part of the Section currently consists of seven scientists (A.J. Brammer, G.A. Daigle, T.F.W. Embleton, M.R. Stinson, P. Schuck, F.E. Toole, G.S.K. Wong), three technicians (J.F. Quaroni, R. St. Denis, M.M. Vaillancourt) and five long-term guest workers or visiting scientists, three of whom are working on obtaining higher degrees.

MECHANICAL STANDARDS

As mentioned above the Section maintains the basic mass standard for Canada (the primary mass being a platinum-iridium kilogram), the reference mass standards, and also the primary national standards of pressure and density. These provide legal traceability for regulatory agencies, the Canadian Standards Association, Department of Consumer and Corporate Affairs (remember the local corner store or supermarket), and industries that require acoustical or mechanical standards for national or international trade. This activity includes the development of new analysis and measurement techniques to improve the reliability, ease of traceability and minimization of errors at the shop floor. Primary mass comparisons are made to a precision of about one part in 10^9. This requires very careful control over environmental factors; temperature affects the dimensional stability of the balance, and temperature and atmospheric pressure affect the difference in buoyancy corrections between masses of different densities.

The national primary standard of pressure is maintained by means of a mercury manometer. Through static expansion systems and pressure balances, any pressure in the range from 10 μPa to 5 MPa can be compared to the primary standard; indirectly presures can be measured to 150 MPa. (In acoustical terms this is a range of over 260 dB.) Residual gas analysers and ionization gauges are being studied in order to quantify the magnitude of, and understand the reasons for, the variations in these instruments.

The Mechanical Standards part of the Section currently consist of two scientists (A.K. Agarwal, G.D. Chapman) and three technicians (A.H. Bass, D.G. Kearney, L.E. Munro) whose efforts are supplemented from time to time with visiting scientists from the national laboratories of other countries. The most easily identifiable output from the mechanical standards' activities of the Section are calibration reports for numerous clients. Recently we have been assisting certain industrial manufacturers to develop their own standards laboratories, both by giving advice and by the training of their personnel in the ways of precision metrology.

REAL-TIME ANALYSER type 830

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1988, 16(4): 9-19

EXPERIMENTAL VALIDATION OF A RAY-TRACING MODEL FOR FACTORY NOISE PREDICTION

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ABSTRACT

Factory-noise prediction models are invaluable in allowing worker noise-exposure levels in a factory to be evaluated prior to construction and, if necessary, for modifications to be made or noise-control measures to be evaluated. Ray-tracing techniques have proven to have the necessary accuracy and flexibility. In order to evaluate the accuracy of a ray-tracing model, comparisons were made between predicted and measured sound pressure levels for a machine shop with nine noise sources in operation. The shop was modelled using the known geometry, source and receiver positions, air absorption coefficients and the measured source sound power levels. Surface absorption coefficients were chosen on the basis of reverberation time measurements in similar factories when empty. The machine shop fitting density and absorption cofficients were chosen on the basis of previous research and by comparing the predicted and measured sound propagation curves for the shop, varying the fitting density to obtain a best-fit agreement. The ray-tracing model proved to give an excellent prediction accuracy.

SOMMAIRE

Les modèles de prédiction des niveaux sonores à l'intérieur des usines sont d'une très grande utilité pour évaluer l'exposition au bruit des travailleurs lors de la construction ou de la modification de ces usines ou encore lorsque les mesures de contrôle de bruit s'avèrent nécessaires. La méthode des rayons (ou "ray- tracing") apparaît aujourd'hui comme l'une des méthodes les plus flexibles tout en offrant une bonne précision. Pour évaluer la précision de cette méthode, des comparaisons ont été réalisées entre des niveaux prédits et des niveaux mesurés pour une salle d'usinage contenant neuf sources de bruit. La modélisation a été réalisée en utilisant les données bien connues de dimensions, positions de sources et de récepteurs, d'absorption d'air et des puissances sonores mesurées des sources. Les coefficients d'absorption des parois ont été évalués en utilisant les temps de réverbération mesurés dans des usines vides et de construction similaire. Les facteurs d'encombrement (densité et absorption) ont été choisis en se basant sur les résultats de recherches précédentes et en comparant des courbes théoriques et expérimentales de propagation du son à l'intérieur de la salle étudiée. Les résultats obtenus démontrent l'excellente précision que peut offrir la méthode des rayons.

1. INTRODUCTION

Accurate methods for modelling and predicting noise levels in factories are invaluable in the planning of factory buildings, equipment layouts and of potential noise-control measures. They permit worker noise-exposure levels to be estimated before the factory is built and its equipment purchased. If predictions show noise levels will excede admissible limits the factory building, and/or equipment and worker locations, can be modified. Further, the efficacy of potential noise- reduction measures - acoustic enclosures and screens, absorbent surface treatments etc - can be evaluated for their cost effectiveness.

Many theoretical and empirical models exist for predicting factory noise levels [1]. These are based on various approaches: diffuse-field theory; empirical formulae based on quantification of experimental trends; the method of images, whereby reflections from surfaces are replaced by image sources; ray tracing, whereby rays radiated by the sources are followed as they propagate in the room until they reach the receiver. The various models predict noise levels as a function of the relevant factory-acoustic parameters - room geometry, surface acoustic properties, room contents, source and receiver coordinates, source powers etc - to a greater or lesser extent. For example, diffuse-field theory does not account for the presence of room contents, which have been shown significantly to modify factory sound fields [2], nor of the exact room shape and the distribution of surface absorption. Existing empirical formulae approximate the sound propagation curve inaccurately and provide limited frequency information. Method of image models account for room shape, surface absorption distribution and room contents, but assume parallelepipedic shape and isotropically distributed contents. Only ray tracing models can account for arbitrary shape, as well as arbitrary absorption and contents distributions.

In previous research aimed at determining the relative accuracies of the various models, predictions have been compared with controlled experiments in idealized situations - specifically, in a scale model and in a warehouse with rectangular obstacles [3]. The conclusion of this study was that a ray-tracing model [4], specifically designed for predicting factory noise levels, is highly accurate.

Unfortunately, validation of ray tracing or other models in idealised situations does not guarantee the accuracy of predictions made for real factories. This is partly because real factories do not have, for example, rectangular fittings. Further, whereas the relevant values of certain parameters - for example, the geometry, source power, source and receiver locations - can be estimated a-priori with good accuracy, it is not yet known how accurately to determine that of other parameters, such as the surface absorption coefficients and the fitting density.

The objective of the study reported here was further to validate the ray-tracing model in the case of a real factory. This was done by comparing ray-tracing predictions with the results of controlled measurements made in a machine shop.

2. THE RAY-TRACING MODEL

The ray-tracing model used in this work was that developed by the INRS in France and modified by the author. Full details of this model are published elsewhere [4] - only a brief description is given here. Of particular interest to factories is its ability to model the effect of the enclosure contents - the fittings. The fittings are the various obstacles in the space which scatter and absorb propagating sound. The distribution of obstacles, which scatter omni-directionally, is assumed to follow a Poisson distribution. The factory volume is subdivided into a number of sub-volumes; each sub-volume is assigned a fitting scattering cross-section density and an absorption coefficient. As implemented the model simulates an enclosure defined by plane, specularly-reflecting surfaces whose absorptions are quantified by their absorption coefficients. Sources are assumed to be omni- directional points. Receivers are defined by a plane of cubic cells of a certain side length and located at a certain height. Diffraction effects (such as those relevant to sound propagation over partial-height partitions) are not modelled.

Briefly, the ray-tracing procedure occurs as follows: for each source a large number of rays, with random direction, are radiated. Each ray propagates from the source and is followed until it strikes the nearest surface or obstacle. The ray is then redirected according to the appropriate reflection law - specular reflection in the case of a surface, random reflection in the case of an obstacle - and followed until its next reflection, and so on for a sufficiently large number of trajectories. The power of the ray, initially related to the source power, decreases as the ray propagates, according to spherical divergence and surface, fitting and air absorption. For each trajectory a test is made to see if the ray traverses any of the receiver cells. If so the power of the ray is assigned to that of the cell(s) and the ray continues. The sound pressure level at each receiver position is calculated from the total power of the corresponding cell.

The ray-tracing model was programmed in FORTRAN, with its compiled version run on an IBM 4381-2 computer. Each sound level prediction (five octave bands) involved run times of up to two hours.

Figure 1 - Photograph of the machine shop showing the room geometry and fitting layout. The partial-height partition is visible at the far end; the doors were closed during all tests.

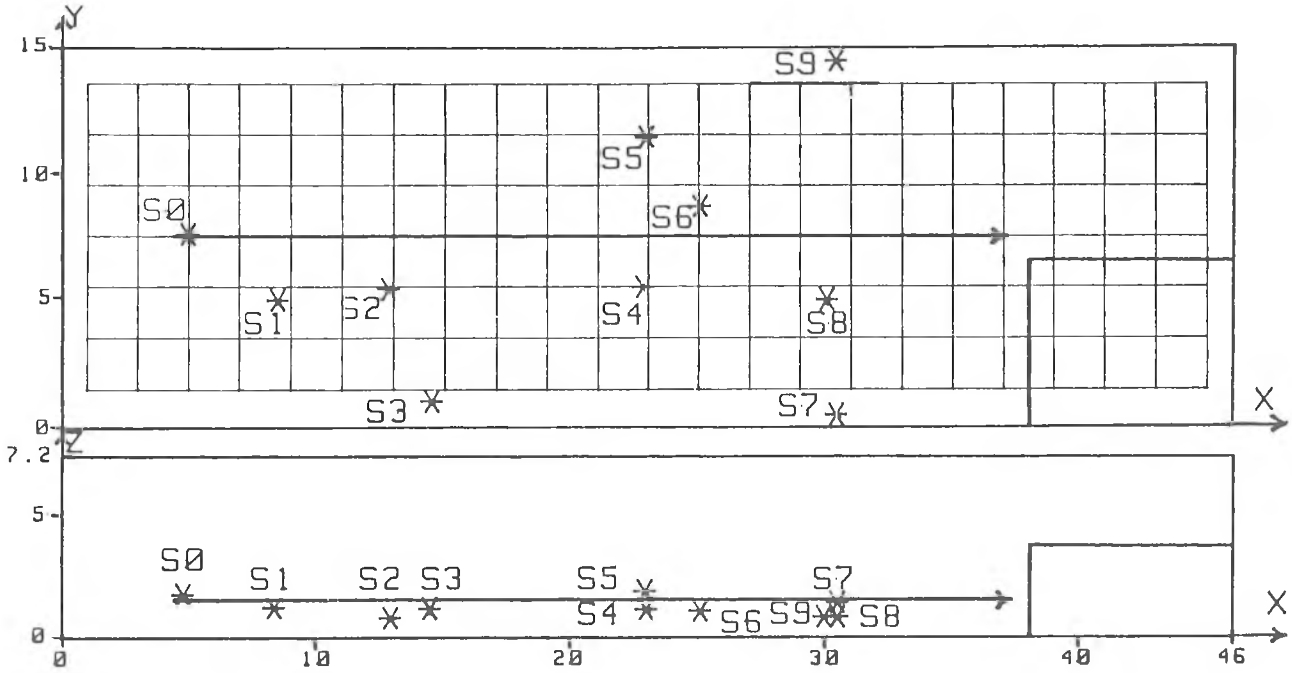

Figure 2 - Plan and section of the machine shop, showing the dimensions, source positions, receiver grid and the sound propagation measurement line (⟶).

3. THE MACHINE SHOP

Fig. 1 is a photograph of the machine shop as tested. The building, shown in plan and section in Fig. 2, is parallepipedic with dimensions of 46.3 m × 15.0 m × 7.2 m high. At one end was located a partial-height partition, separating the main machine shop from a small enclosure. The floor of the building was of concrete, its walls were of unpainted blockwork, its ceiling was of typical steel-deck construction (consisting of corrugated metal inside, insulation, a vapor barrier and gravel

Table 1 - Octave-band absorption coefficients of the machine-shop surfaces and of the air, used in all predictions

Octave band (Hz)	Surface absorption coefficient	Air absorption coefficient (Np/m)
250	0.12	0.0003
500	0.10	0.0005
1000	0.08	0.001
2000	0.06	0.003
4000	0.06	0.006

Table 2 - Description and octave-band sound power levels of the nine noise sources

N°	Name	Sound power level (dB re: 10^{-12} W) 250	500	1000	2000	4000
1.	Lathe	66.9	84.2	78.1	73.5	69.7
2.	Milling machine	79.5	86.1	87.8	84.3	78.2
3.	Radial saw	82.8	79.3	79.4	79.6	78.9
4.	Drill	75.9	78.2	81.4	78.8	68.6
5.	Band saw	77.5	74.2	72.8	71.0	68.2
6.	Grinder	78.4	80.8	77.4	72.1	70.5
7.	Dust collector	81.5	82.9	79.2	77.8	68.9
8.	Shear	82.2	80.7	78.7	74.6	64.6
9.	Sander	79.1	83.5	78.3	76.3	71.4

outside). The roof was supported by metal trusswork. The average octave-band absorption coefficients of the surfaces of industrial enclosures of this construction have previously been evaluated from measurements of the reverberation time in the nominally-empty buildings and have been found to vary little from one building to another [5]. On the basis of these results the absorption coefficients shown in Table 1 were used in all predictions. Note that all surfaces were assumed to have the same absorption; comparisons of sound propagation predictions and measurements for empty buildings have shown that excellent prediction accuracy is achieved under this assumption [6]. Air absorption values were those, also presented in Table 1, corresponding to a temperature of 25°C, a relative humidity of 80% - the conditions prevailing during the tests.

The machine shop contained many fittings distributed fairly uniformily over the floor area, though leaving two small, relatively empty open areas. They included machine tools and other equipment, work benches, cabinets and stock piles. The average fitting height was about 1.5 m.

During the sound pressure level measurements nine sources were in operation. Details of these sources are presented in Table 2; their plan positions in the machine shop are shown in Fig. 2. Note that the heights are those of the centres of gravity of the machine bodies. The 250-4000 Hz octave-band sound power levels of these sources were determined using sound-intensity techniques. A rectangular survey surface was defined around each source. The average normal sound intensity on each of the five sides of the surface was measured by continuously sweeping the intensity probe over the surface for about 2 min. Sound power levels were determined from the average intensities on the surface and from the surface area. These levels are presented in Table 2. During the intensity measurements only the machine under test was in operation. The machine tools were operated without stock; thus, the main noise sources were electric motors, gearboxes, bearings, ventilation fans and exhausts.

4. VALIDATION PROCEDURE

In order to validate the ray-tracing model in the machine shop, the following procedure was followed:

a. The machine shop was modelled with respect to its geometry, surface absorption coefficients, fitting distribution, source power, source and receiver locations and air absorption;

b. Measurements were made of the octave-band sound propagation in the factory. The sound propagation - the variation with distance from an omnidirectional point source of the sound pressure level minus the source sound power level - is the variable quantifying the influence of the enclosure on the variation of noise levels with distance from a source. In a multi-source situation the noise level at a receiver position is the energetic sum of the contributions of the various sources, each determined from the sound propagation curve for the appropriate source/receiver distance, and from the source power.

c. The sound propagation curves were predicted using the known parameter values; the unknown fitting densities and absorption coefficients were varied until a best fit with the experimental results was obtained;

d. The sound power of the sources were measured;

e. Sound pressure levels were measured at positions on a grid throughout the machine shop, with all sources operating;

f. Sound pressure levels at the grid positions were predicted using the known and best-fit parameter values;

g. Measured and predicted sound pressure levels were compared.

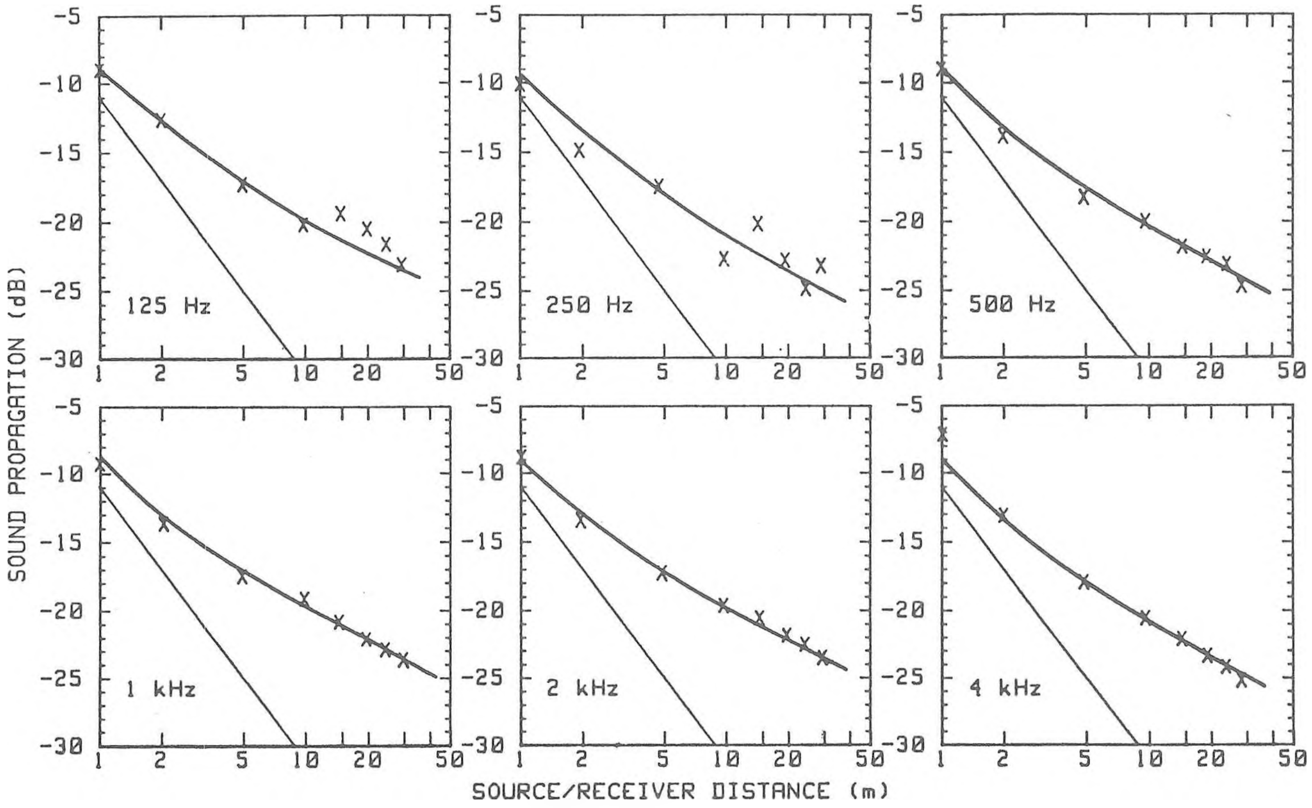

Figure 3 - Octave-band sound propagation curves for the machine shop as measured (X) and predicted (▬). Also show for reference is the free-field sound propagation (——).

5. EXPERIMENTAL DETAILS

5.1 Sound propagation

Measurements were made of the sound propagation in the machine shop, in octave bands from 250-4000 Hz. An dodecahedral loudspeaker array, consisting of 12 KEF B110-B loudspeaker units, was located at 5 m from one end wall at mid width, as shown in Fig. 2; the source height was 1.7 m. The loudspeaker array radiated omnidirectionally within 1 dB in the octave bands 250-1000 Hz and within 2 and 3 dB in the 2 and 4 kHz bands, respectively. The octave-band sound power levels of the array had been previously measured using sound-intensity techniques. With this array radiating broadband noise, octave-band sound pressure levels were measured at distances of 1, 2, 5, 10, 15, 20, 25 and 30 m from the source along the room centre line as shown in Fig. 2. The sound propagation was calculated from the octave-band sound pressure and source power levels. Fig. 3 shows the measured curves. Note that, as is always the case in real factories, no constant-level reverberant field existed far from the source - in general levels decreased with distance. At low frequencies the curves are less smooth at large distances than they are at high frequencies. While the precise explanation of these low frequency variations is not known, they can be assumed to be due to a combination of modal effects and the influence of obstacles near the measurement positions.

5.2 Sound pressure levels

Measurements were also made, with the nine noise sources in operation and in octave bands from 250-4000 Hz, of the sound pressure levels at 161 receiver positions on a 7 × 23 grid as shown in Fig. 2. The receiver positions were at 2 m centres along the two horizontal room axes, and at a height of 1.5 m. Positions within 1 m of a noise source or large obstacle were noted. Measurements were also made of the background noise levels, which were found to be more than 15 dB below the noise levels due to the machines at all positions and in all octave bands. From the measured octave-band levels, the dB(A) level was calculated. For information, Fig. 4 shows the measured dB(A) levels in the form of an iso-contour map for an inter-contour interval of 1 dB(A). Also shown in this figure are the noise source positions. Note that level peaks occur near source positions as expected. Note also that a level peak occurs at a position with coordinates of approximately $x = 5$ m, $y = 10$ m. This occured due to a high level in the 500 Hz octave band only. No sound source was near this position and no explanation, except measurement error, is known for the existence of this peak.

6. MODELLING OF THE EXPERIMENTAL CONFIGURATIONS

6.1 Sound propagation

In order to determine the effective fitting densities and absorption coefficients the sound propagation measurement configuration was modelled by ray tracing. Regarding the fitting distribution, the shop volume was divided into upper and lower sub-volumes, delimited by the horizontal plane at a height of 1.5 m, the average fitting height. On the basis of previous comparisons between sound propagation measurements in empty factories of similar construction and predictions [5], a fitting density of 0.03 m^{-1} and a fitting absorption coefficient of 0.05 were assigned to the upper region, which was essentially empty but contained a mobile crane, lighting fixtures and the roof trusswork.

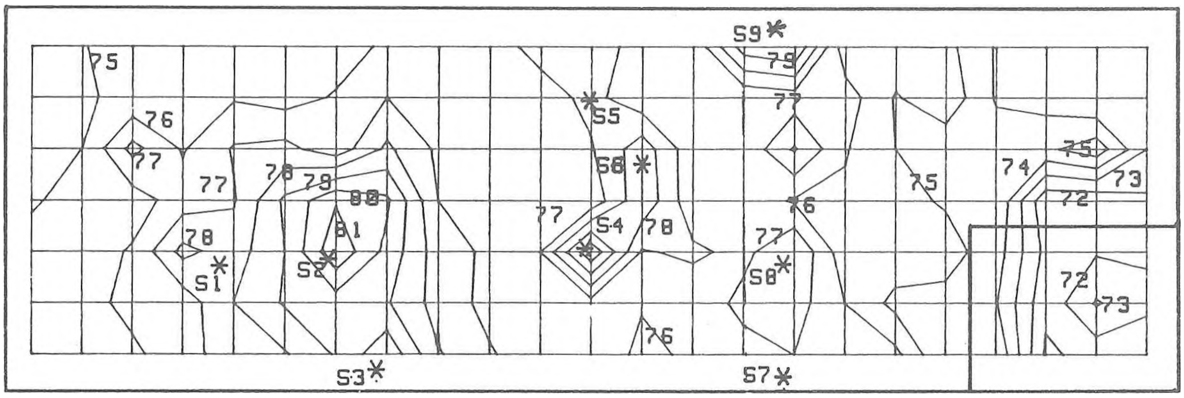

Figure 4 - Iso-contour map of dB(A) sound pressure levels measured in the machine shop

In order to determine the fitting density and absorption coefficient of the lower region, containing the main fittings, the following procedure was followed:

a. With the fitting absorption coefficient set to 0.05 [3] the fitting density was varied. While it was found possible to find a fitting density which gave good agreement with experimental results at larger distances from the source, levels at smaller source distances were always overestimated by 1-2 dB.
b. With the fitting absorption coefficient increased to 0.1 in order to decrease predicted levels at shorter source distances, the fitting density was varied until a best fit was obtained in all octave bands. Fig. 3 shows the curves predicted with the best-fit density of 0.23 m^{-1}. The agreement is excellent at all frequencies and distances. Differences of more than 1 dB occur only at large distances and low frequencies, for which significant local variation of the measured sound propagation levels occured, as previously discussed.

In summary, with the machine shop modelled as discussed above, ray-tracing models the measured octave-band sound propagation with excellent accuracy.

6.2 Sound pressure levels

With the room modelled as discussed above, and using the measured source power levels and best-fit fitting density and absorption coefficient, octave-band sound

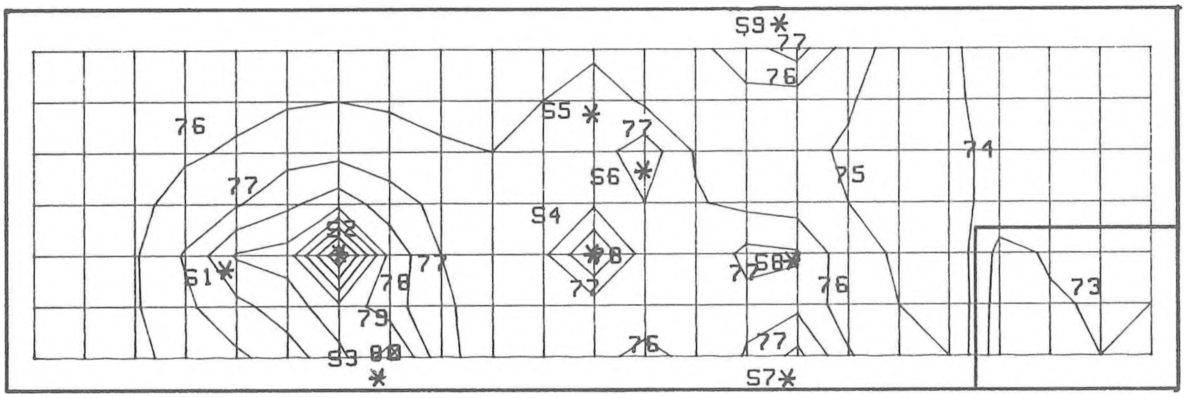

Figure 5 - Iso-contour map of dB(A) sound pressure levels in the machine shop as predicted using best-fit parameters

Table 3 - Ranges, averages and standard deviations in dB of the differences between the predicted and measured sound pressure levels at 161 grid positions in the machine shop

	Octave band (Hz)					
Quantity	250	500	1000	2000	4000	A
Minimum	-5.1	-6.8	-3.5	-1.8	-2.4	-2.9
Maximum	6.1	2.8	2.9	2.5	2.3	2.1
Average	-0.2	-1.2	0.0	0.2	0.2	-0.3
Standard deviation	1.6	1.9	0.9	0.7	0.9	0.9

pressure levels were predicted for all 161 grid position. The predicted levels correspond to the average level in a 2 m cube centred at the grid point. The octave-band levels were used to calculate dB(A) levels. As an example the predicted dB(A) iso-contour map is shown in Fig. 5.

In order to evaluate the accuracy of prediction, measured octave-band and dB(A) levels were subtracted from the corresponding predicted levels for all grid positions. The ranges, averages and standard deviations of the differences were then evaluated - these are presented in Table 3. As an example Fig. 6 shows the iso-contour map of the difference between the predicted and measured dB(A) levels, with the source positions superimposed.

With respect to these results, several observations can be made:

a. Differences between predicted and measured levels range from -7 to +6 dB at individual points, though the average differences are, in general, very small. The standard deviations are of the order of 1.5 dB at 250 and 500 Hz and 0.9 dB at higher frequencies. On average the prediction accuracy is very high.

b. Prediction accuracy is lowest at low frequency. This is probably partly due to the fact that the local variation of the sound propagation curves at low frequencies were not modelled, as discussed above. At 500 Hz the unexplained high measured level near x = 5 m, y = 10 m makes the accuracy appear artificially low.

c. As a rule, prediction overestimates levels at as many positions as it underestimates levels. In certain cases the prediction accuracy is low at positions near noise sources (eg. source 1). This is not surprising since the sources may not have been omni-directional as modelled, and since levels near sources depend highly on the exact positions of the active sources and the receiver, these not having been accurately modelled. Note however that the prediction accuracy was high for receiver positions near certain other sources (eg. source 2). Further the accuracy was, in general, no worse at positions near large obstacles than far from them.

d. In general, the prediction accuracy was lower than average at positions near the partial-height partition, both inside and outside the enclosure. Levels inside the enclosure near its short wall were underestimated at all frequencies. This can be explained by the fact that the ray-tracing model did not model diffraction over the top of the partition, this tending to increase levels in the shadow zone of the partition. Also, levels tended to be overestimated at high frequencies outside the enclosure near its long wall; the

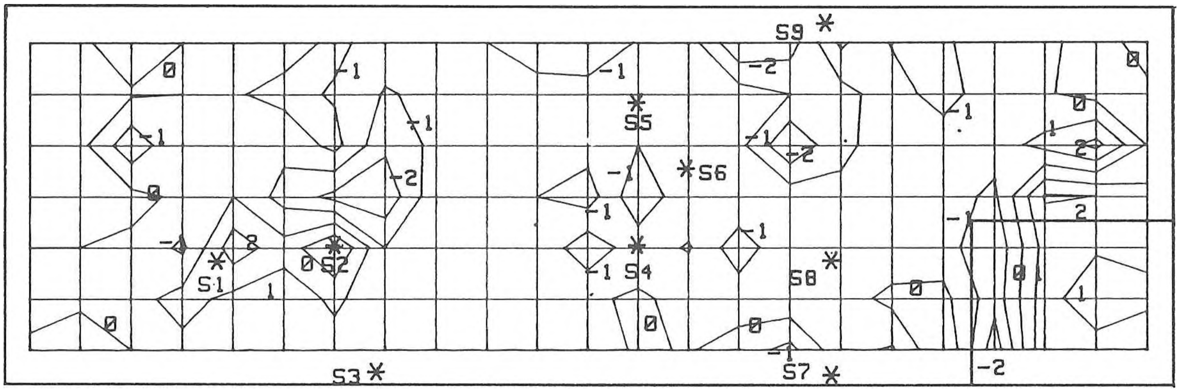

Figure 6 - Iso-contour map of the differences between the predicted and measured dB(A) sound pressure levels

reason for this is not known. Finally levels tended to be underestimated at low frequency in the relatively open region of the shop bounded by x = 33 m, x = 38 m, y = 3 m and y = 15 m. It would be reasonable to hypothesise that this underestimation can be explained by the fact that the floor of the shop was assumed to be uniformly fitted, with no open spaces, and the fact that noise levels decrease more rapidly with distance in a fitted region than in an open one. However no such undestimation occured with respect to the other open region at the centre of the machine shop.

7. CONCLUSION

Ray-tracing has been shown to predict noise levels throughout a workshop - whether close to or far from noise sources or obstacles, and in an enclosure created by a partial-height partition - with very good accuracy. The accuracy is lower than average at low frequencies than at high frequencies, probably due to modal effects. The accuracy is also low in the enclosure in the shadow zone of the partition; work is in progress to account for diffraction effects in the ray-tracing model.

While these tests were carried out for a real factory, this still represents a somewhat ideal situation. First, it was possible to estimate surface absorption coefficients from previous research. Further it was possible to measure the source powers under good conditions. More importantly, it was possible to measure the sound propagation in the existing factory when not in operation in order to estimate the fitting density. It is not yet known how to determine the factory fitting density a priori.

With the machine shop modelled with such accuracy it would, of course, be possible to investigate the efficacy of noise control measures such as surface absorbent treatments and acoustic screens.

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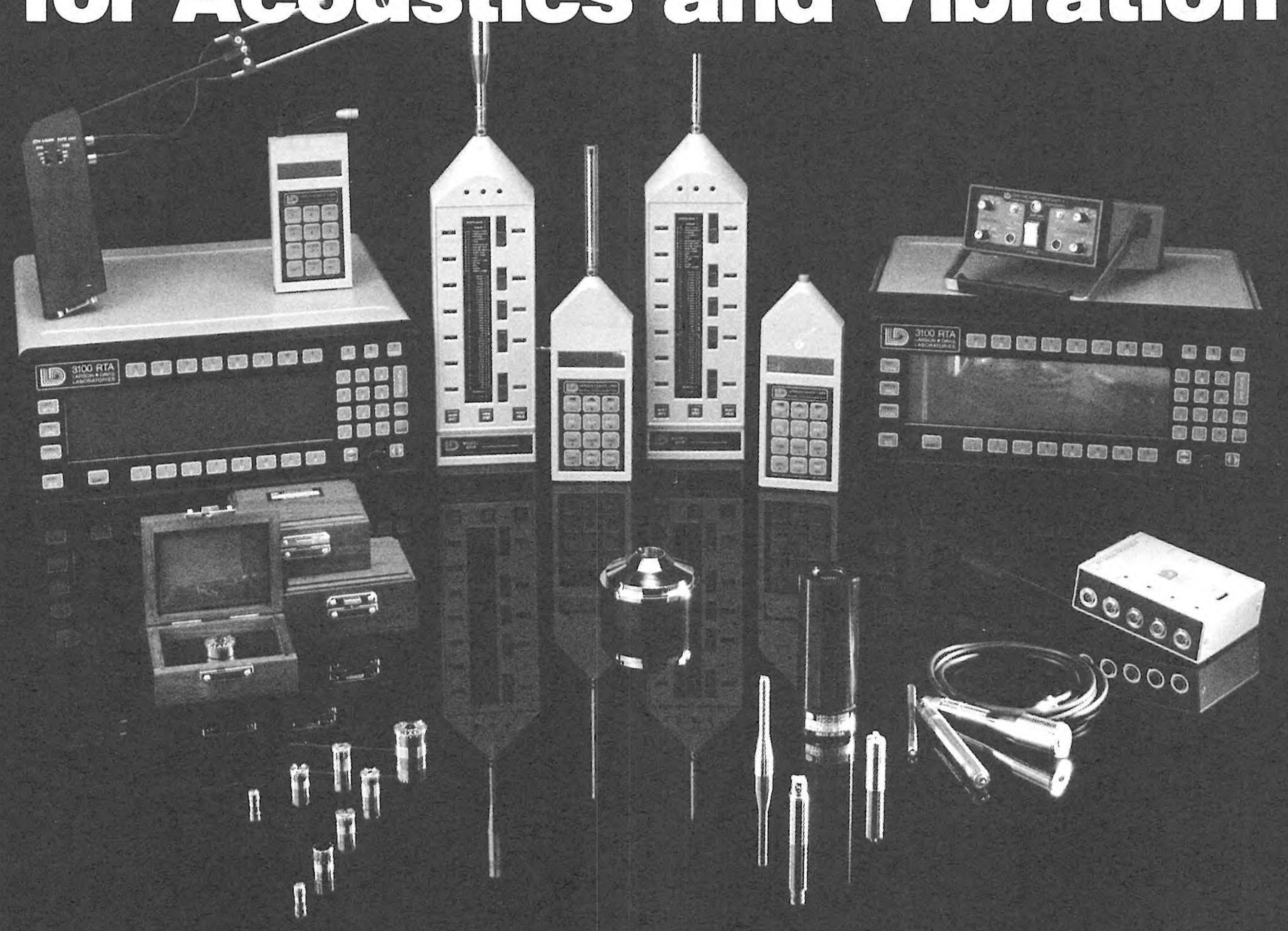

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VALIDATION EXPÉRIMENTALE DE L'ANALYSE DES SOURCES DE BRUIT CYCLIQUE AU MOYEN DE LA TECHNIQUE DE FENÊTRAGE TEMPOREL

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RÉSUMÉ

Cet article aborde la problématique de l'analyse temps/fréquence de signaux acoustiques non stationnaires et répétitifs. La technique de fenêtrage temporel ("Gating Technique") sera examinée au moyen d'un système de calibration spécialement développé à cette fin. Nous mettrons en évidence la présence d'un délai interne du système ainsi que son rôle crucial lors de l'analyse des résultats. L'importance de la variabilité de la vitesse de révolution des machines tournantes sera examinée. Nous illustrerons ensuite comment cette technique peut être utilisée afin de prédire l'efficacité d'un traitement acoustique à la source.

SUMMARY

This article considers the problem of the time/frequency analysis of non-stationary, repetitive acoustic signals. The technique of temporal gating is examined by means of a calibration system specially developped for this purpose. The presence of an internal system delay, and its crucial role during the analysis of results, are demonstrated. The importance of the variability of the speed of rotation of rotating machines is also examined. Finally, it is shown how the technique can be used to predict the efficacy of an acoustic treatment of the source.

1. INTRODUCTION

L'analyse des signaux acoustiques et leur représentation temps/fréquence ont fait l'objet ces dernières années de nombreuses recherches. Une approche particulièrement prometteuse pour l'analyse des signaux non stationnaires consiste à utiliser la transformée de Wigner-Ville |1-2|. Plusieurs auteurs ont utilisé cette transformée |3-6| afin d'étudier la relation temps/fréquence du signal. On obtient, grâce à cette transformée, l'évolution en fonction du temps du spectre instantané du signal. La mise en oeuvre de la transformée de Wigner Ville requiert toutefois de longs calculs itératifs et elle est pour le moment peu adaptée pour l'analyse in situ des problèmes de bruit. De plus, cette méthode est encore très nouvelle et nécessitera encore quelques études avant de devenir parfaitement maîtrisée.

Dans le domaine de l'ingénierie acoustique une approche poursuivant le même objectif a été développée en s'appuyant cette fois-ci non pas sur un calcul utilisant la transformée de Fourier (FFT) mais plutôt sur le contrôle temporel de filtres digitaux récursifs. Cette technique, appelée fenêtrage temporel ("Gating Technique"), a été développée pour l'analyse des signaux acoustiques et vibratoires émis par des machines tournantes et donc pour des sources cycliques. Rasmussen et al. [7-10] ont démontré que le fenêtrage temporel permet d'examiner, comme la transformée de Wigner Ville, la variation du spectre d'intensité ou de pression acoustique en fonction du temps de signaux non stationnaires. On peut ainsi, pour une machine cyclique, identifier les relations de cause à effet entre les mécanismes mobiles et le rayonnement acoustique produit. Jusqu'à maintenant plusieurs ont utilisé cette approche dans des cas concrets sans se pencher toutefois sur les limites de la technique et de l'instrumentation qui lui est associée. Comme il n'existait pas de façon simple de calibrer un tel système on était donc contraint à s'en remettre aux manufacturiers. L'objectif premier de cette étude consistait donc à valider la technique de fenêtrage temporel tout en mettant à l'épreuve la chaîne instrumentale utilisée.

Dans cet article nous présenterons dans un premier temps une brève description de la technique. Nous décrirons ensuite la démarche utilisée afin de vérifier les limites d'utilisation des systèmes employés. Nous décrirons également le système de calibration spécifiquement développé à cette fin. Nous verrons par la suite, lors de l'analyse des données, comment un délai interne peut perturber les résultats en provoquant un déphasage temporel par rapport au signal de synchronisation. Finalement, nous verrons dans un cas concret comment cette technique peut permettre de prédire le niveau de réduction du bruit associé à la modification du mécanisme générateur.

2. REVUE DE LA TECHNIQUE

Grâce à l'emploi de filtres digitaux récursifs, il est possible d'analyser les signaux en temps réel. Le système de fenêtrage temporel (Gating System) que nous avons utilisé (voir figure 1) a été développé par le manufacturier Bruël and Kjaër. Il est composé d'un

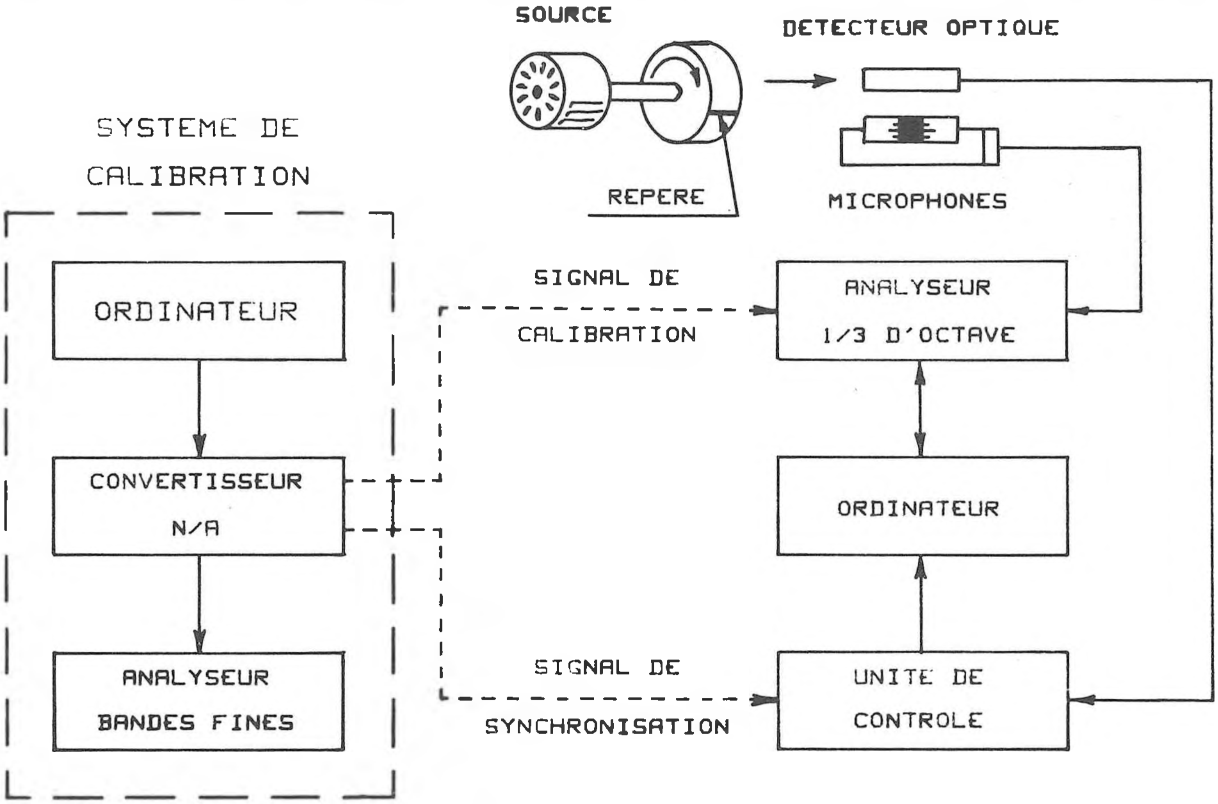

Figure 1 - Système de fenêtrage temporel et de calibration

système d'analyse intensimétrique, d'un ordinateur et d'une unité de contrôle. La synchronisation s'effectue grâce à un capteur optique. Définissons les différents paramètres:

t : temps (s)
N : nombre de cycle (rotation)
T : période d'un cycle (s)
t_w : durée d'une fenêtre (s)
n_w : nombre total de fenêtres dans un cycle

Le diagramme temporel de la figure 2 illustre le principe de la technique. La durée totale d'un cycle est représentée par le cercle. Ce cycle est subdivisé en un certain nombre de fenêtres, appelées aussi tranches, chacune d'une durée de t_w égale à T/n_w.

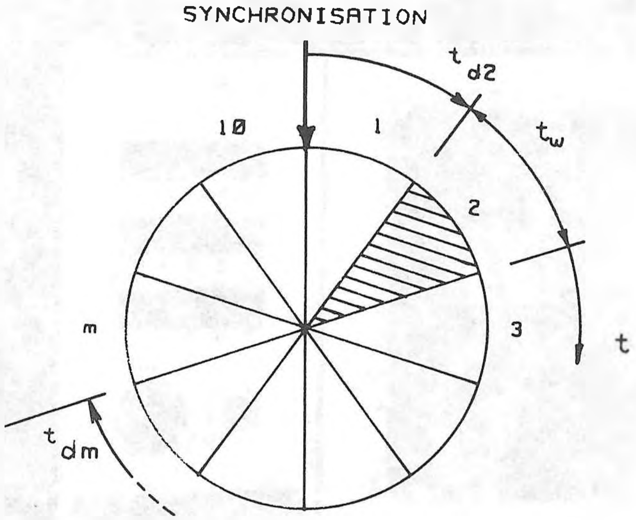

Figure 2 - Diagramme temporel illustrant la technique du fenêtrage temporel

Un délai t_{dm} permet de contrôler, relativement à un signal de synchronisation donné, le début de l'intégration. Le principe de la mesure de la pression ou de l'intensité acoustique contenue dans la fenêtre m s'exprime par la relation suivante:

$$p_m^2 = \frac{1}{N} \sum_{n=1}^{N} \int_{t_{dm}}^{t_{dm}+t_w} \frac{1}{t_w} \cdot p^2 \, (1+(n-1).T) \, dt \qquad (1)$$

$$t_{dm} = (m-1) \, t_w \qquad (2)$$

Il est donc possible en contrôlant t_{dm} de ne considérer qu'une partie bien spécifique du cycle de la machine. Afin d'améliorer la précision de la mesure on effectue la moyenne des valeurs obtenues pour plusieurs cycles. En répétant le même processus pour chacune des fenêtres on peut déterminer un spectre sonore pour chacune d'elle et conséquemment on est à même d'évaluer la variation temporelle du spectre. Une représentation graphique type de cette variation est illustrée à la figure 3. L'axe vertical représente les niveaux exprimés en dB. Les axes de fréquence et de temps définissent un plan horizontal. On obtient donc un graphique en trois dimensions. Connaissant la vitesse de rotation, l'axe de profondeur peut être converti soit en temps, soit en tranche ou en degré de rotation (0-360°) comme c'est le cas ici. Notons à la figure 3 la présence de deux évènements bien distincts.

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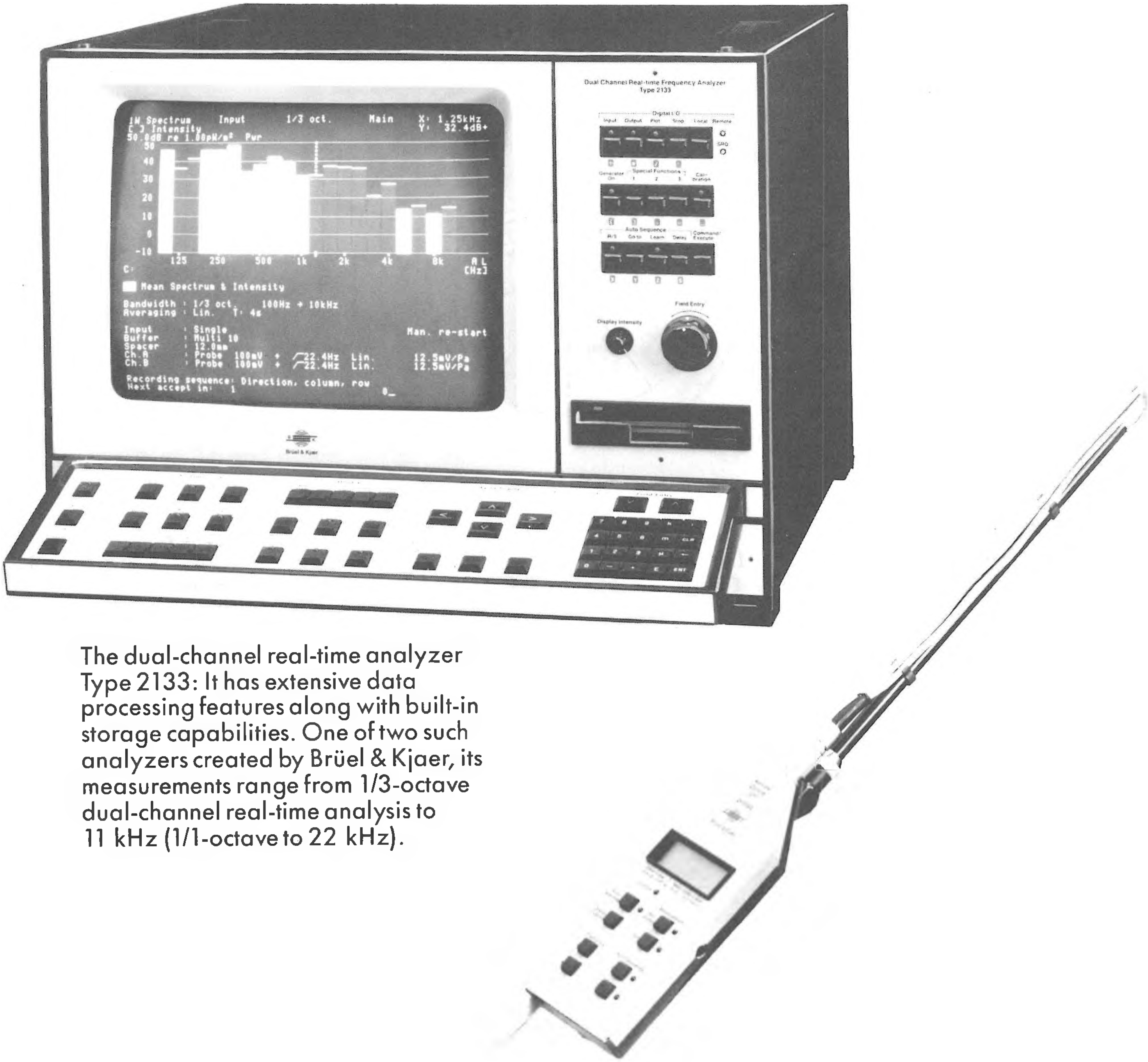

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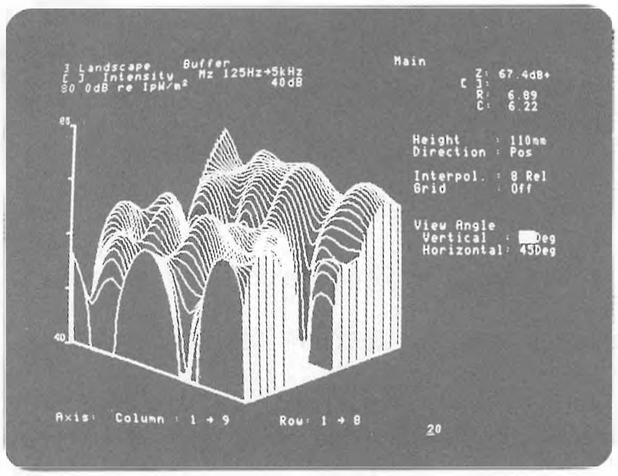

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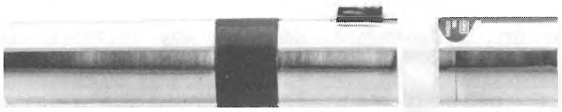

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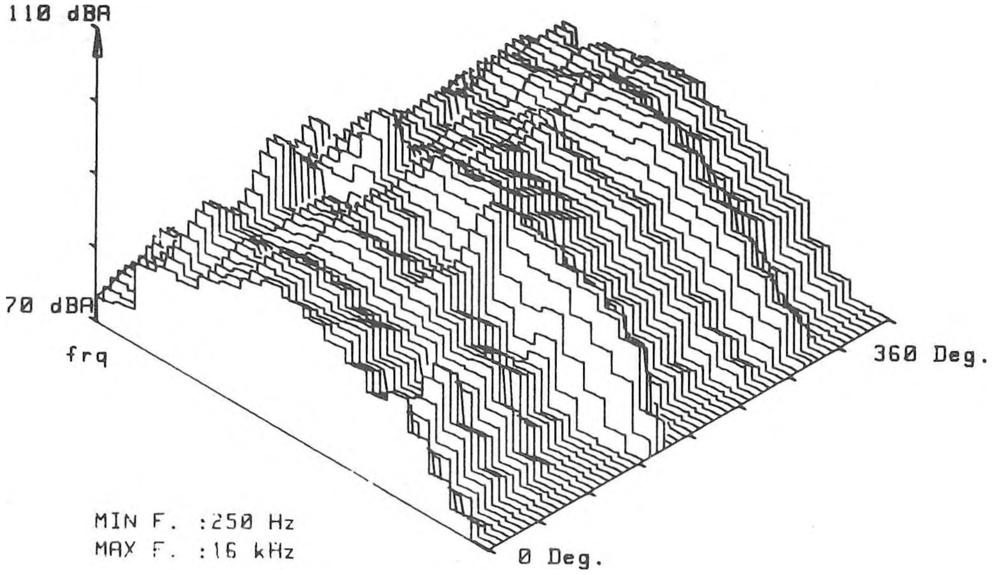

Figure 3 - Représentation graphique de la variation temporelle d'un spectre

3. DESCRIPTION DU SYSTÈME DE CALIBRATION

Dans le but d'étudier les limites d'utilisation de la technique de fenêtrage temporel, un système de calibration a été développé. Ce système permet de générer un signal dont l'amplitude est variable au cours d'un cycle et dont le contenu spectral est contrôlé et donc connu. Le système de calibration utilisé est illustré à la figure 1. Un ordinateur synthétise un signal prédéterminé dont on connaît le contenu spectral. Ce signal est converti du numérique à un signal analogique par un convertisseur N/A. Celui-ci peut, de plus, répéter le même signal à un rythme prédéterminé. Parallèlement, un signal de synchronisation très précis est aussi produit par le convertisseur N/A afin d'annoncer le début du cycle. La position du signal de calibration relativement au signal de synchronisation peut être contrôlée par t_e qui représente ainsi le délai temporel entre ces deux signaux. Un analyseur FFT est utilisé afin d'évaluer précisément t_e et de contrôler le contenu spectral du signal de calibration.

Le signal temporel choisi pour la calibration est illustré à la figure 4a. Ce signal a un front de montée très abrupt et peut être représenté par une impulsion de Dirac. Sa durée est de l'ordre de 0.02 ms. Son spectre est illustré à la figure 4b.

- Signification du temps d'intégration

Lors de l'analyse classique d'un évènement unique de nature impulsionnelle, le temps d'intégration est habituellement associé à la période durant laquelle l'énergie sonore sera cumulée. On divise ensuite cette valeur par le temps d'intégration pour en faire la moyenne. Par exemple pour la mesure de la pression sonore, la moyenne quadratique se calcule comme suit:

$$p_{rms}^2(t) = \frac{1}{T_i} \int_o^{T_i} p^2(t)\, dt \qquad (3)$$

T_i étant ici le temps d'intégration

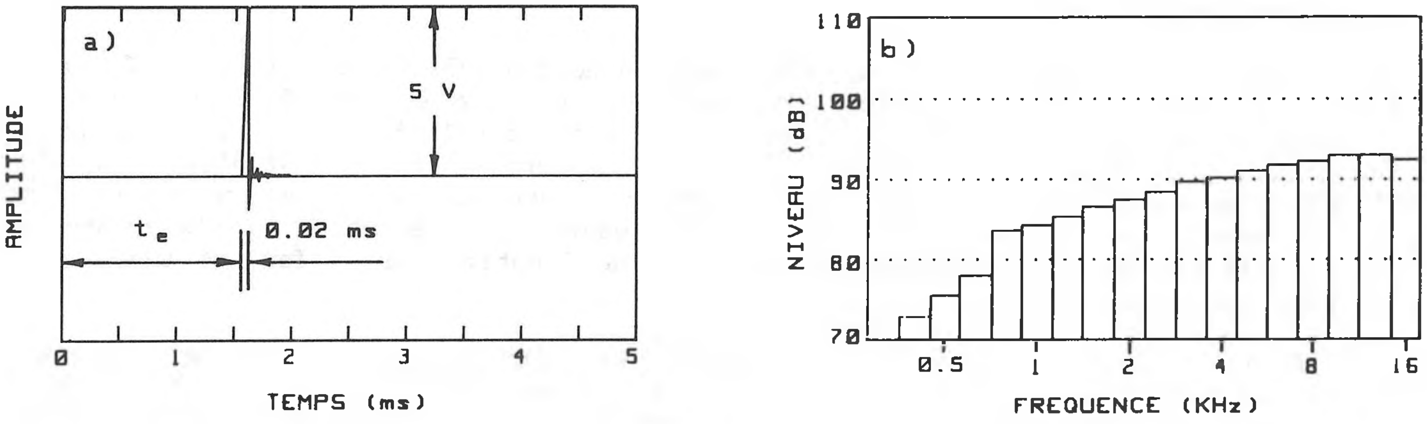

Figure 4 - Signal de calibration. a) Représentation temporelle b) Contenu spectral

Pour une même impulsion de l'onde à t = 0 sec et dont la durée est inférieure à T_i, plus le temps d'intégration est court, plus le niveau mesuré sera élevé. À la limite, si T_i tend vers zéro, on mesurera la valeur crête.

Lors de l'analyse de signaux répétitifs (que l'on assume ici rigoureusement identiques d'un cycle à l'autre) la situation n'est plus la même. L'amplitude du spectre mesuré ne varie plus en fonction du temps d'intégration (pour un nombre fini de cycles). Même si le temps d'intégration est doublé, le nombre de cycle considéré est aussi doublé de même que l'énergie comptabilisée par l'intégrateur. La figure 5 illustre ce comportement. En utilisant le système de calibration pour fournir à l'analyseur un signal répétitif (sans utiliser de technique de fenêtrage) trois temps d'intégration différents ont été utilisés. Comme on peut le constater les trois cas fournissent la même quantité d'énergie moyenne.

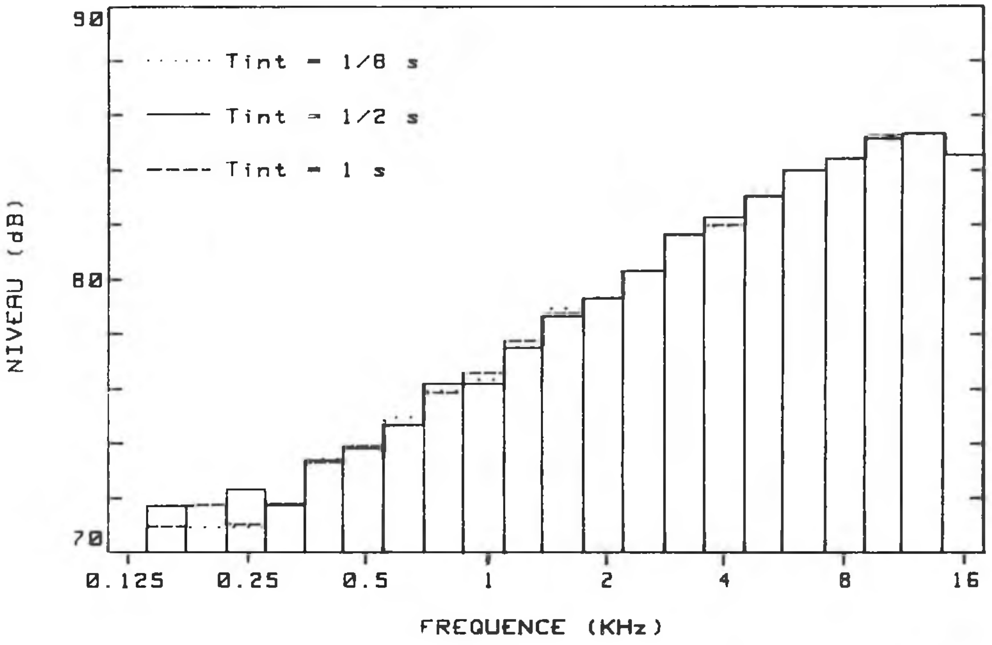

Figure 5 - Comparaison des spectres d'un même signal impulsif pour trois temps d'intégration différents

- Signification du temps d'intégration pour la technique du fenêtrage temporel

Pour la technique du fenêtrage temporel, on ne considère plus cette fois-ci la moyenne de l'énergie sur tout un cycle. On subdivise ce cycle en une série de tranches. En comparant les équations 1 et 3 on s'aperçoit que le temps d'intégration est représenté maintenant par la longueur d'une tranche t_w. Plus le nombre de tranche est élevé plus le temps d'intégration sera court et ainsi, les variations temporelles du spectre seront d'autant plus visibles. Le fait de répéter N fois la mesure (voir équation 1) n'augmente pas le temps d'intégration mais améliore la précision de l'estimation en faisant une moyenne de plusieurs essais.

L'analyse spectrale classique d'un signal répétitif nous fournit le spectre moyen quelque soit le nombre de cycle considéré. L'analyse temps/fréquence nous permet de visualiser la variation du spectre au cours du cycle. Cependant, en calculant la somme des niveaux de toutes les tranches comprises dans un cycle et en divisant cette somme par le nombre de tranche, on devrait retrouver le spectre moyen obtenu par l'analyse classique. Afin de démontrer cette allégation, le système de calibration a été mis à contribution et le spectre moyen a été mesuré à la fois avec l'anayseur seul et avec le système de fenêtrage temporel. Les résultats illustrés à la figure 6 démontrent qu'effectivement les deux façons d'analyser le signal conduisent aux mêmes résultats et donc nous assurent du bon fonctionnement du système de fenêtrage temporel.

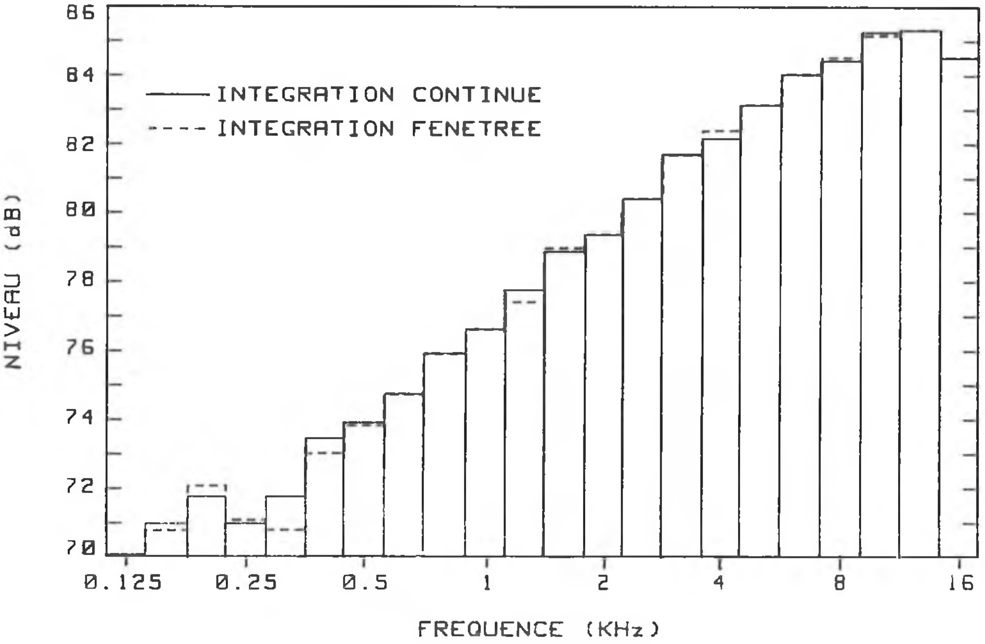

Figure 6 - Comparaison des spectres obtenus par intégration continue versus moyennage sur l'ensemble des fenêtres

4. CARACTÉRISATION D'UN DÉLAI INTERNE

Le fenêtrage temporel nous permet de quantifier, pour une portion d'un cycle de la machine, l'énergie rayonnée au cours de ce laps de temps. On peut ainsi identifier les contributions respectives des divers éléments de la machine au cours d'un cycle. Une parfaite synchronisation s'impose donc. Notons également que le fenêtrage temporel ne peut être utilisé s'il y a glissement entre les différents éléments mécaniques de la machine étudiée.

La synchronisation s'effectue généralement au moyen d'un capteur optique pointé sur une partie tournante du mécanisme. Afin de vérifier la précision de la synchronisation, le système de calibration fut mis à contribution. Le convertisseur N/A génère un pulse de synchronisation au début de chaque cycle. Comme il est possible de déplacer le signal synthétisé à l'intérieur du cycle (en variant t_e, voir figure 4) et comme ce signal ressemble à un Dirac, il est donc possible de vérifier la précision de synchronisation du système en faisant apparaître l'évènement dans la fenêtre (tranche) de notre choix. La figure 7a) montre que lorsque t_e vaut 6.8 ms il y a encore de l'énergie dans la dernière tranche (10° tranche). Ce n'est que lorsque t_e vaut 7.1 ms (figure 7b) que toute l'énergie se retrouve dans la première tranche. La figure 8 montre schématiquement que par rapport au signal de synchronisation il existe un délai interne dont on doit absolument tenir compte afin de pouvoir obtenir un diagnostique précis. En effet, pour une machine tournant à 1000 RPM, ce

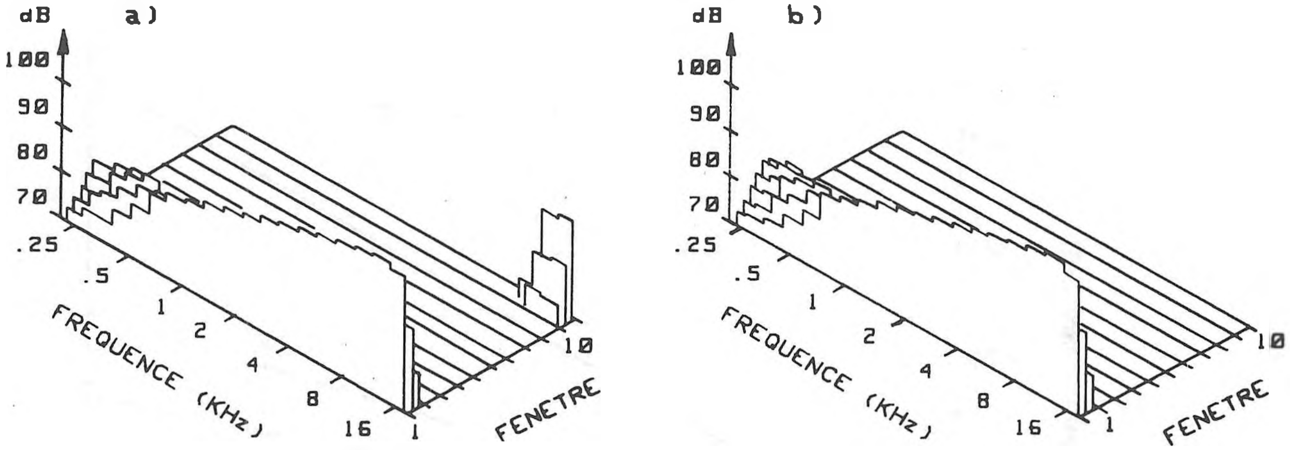

Figure 7 - Évaluation du délai interne par la variation de la position du signal de calibration. a) t_e = 6,8 ms b) t_e = 7,1 ms

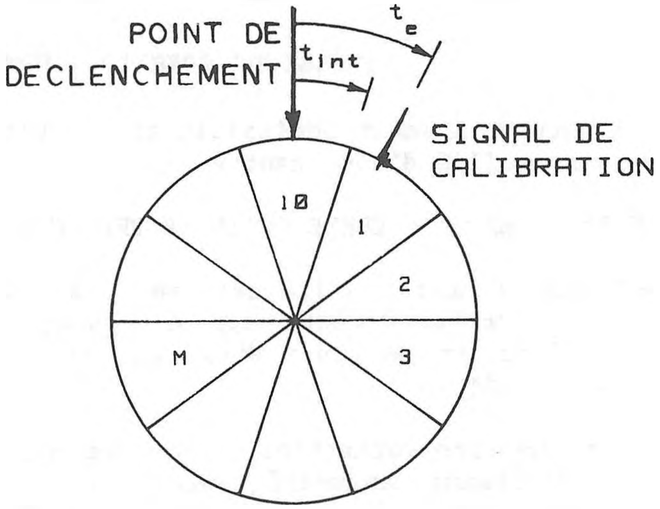

Figure 8 - Illustration du délai interne par rapport au point de déclenchement

délai équivaut à une rotation par rapport à la marque de synchronisation de 43 degrés. Il est donc impérieux de connaître ce déphasage pour localiser adéquatement l'évènement par rapport à la position des mécanismes cycliques.

5. FLUCTUATION DE LA VITESSE DE ROTATION

La vitesse de rotation des machines tournantes n'est pas toujours constante et des variations peuvent être notées sur des périodes de temps plus ou moins longues. Ces variations de vitesse peuvent fausser la mesure en déplaçant des évènements d'une fenêtre à l'autre. Dépendant des gammes de vitesses et du nombre de tranches considérées, une instabilité plus ou moins grande de la vitesse de rotation peut être tolérée. Afin de quantifier l'ordre de grandeur de ces instabilités, la figure 9 fournit pour différents nombres de tranches une relation entre la vitesse de rotation de la machine et l'écart de variation maximal permis. Cet écart serait responsable du glissement du phénomène d'une fenêtre seulement. On peut noter que plus le nombre de fenêtres est élevé, plus la variation de vitesse permise est faible.

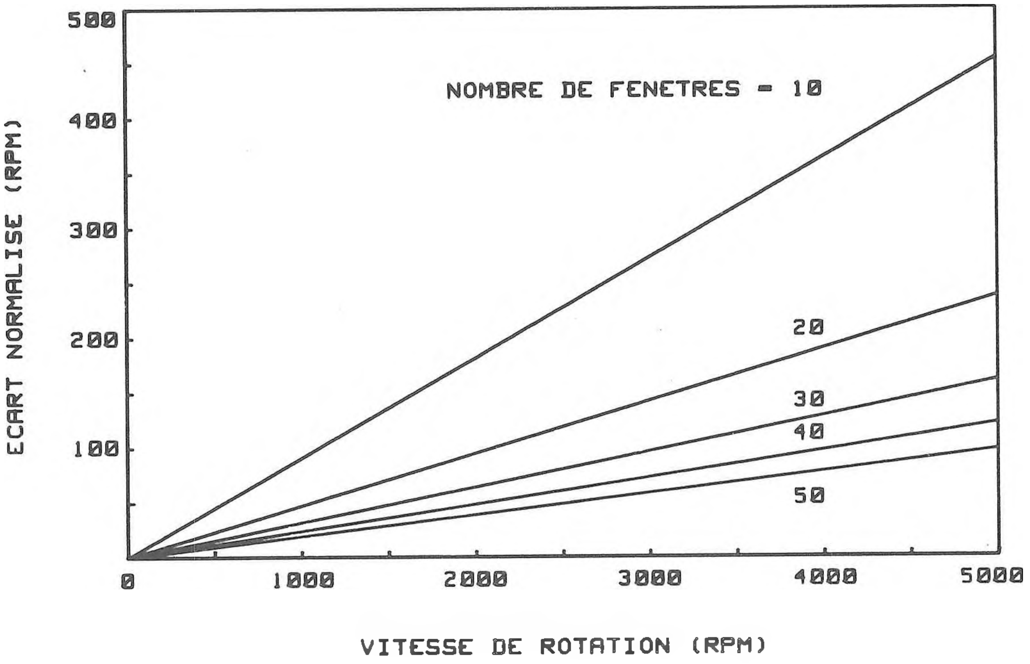

Figure 9 - Abaque illustrant l'écart admissible sur la vitesse de rotation pour un glissement normalisé d'une tranche

6. LA TECHNIQUE DE FENÊTRAGE TEMPOREL COMME OUTIL DE PRÉDICTION

La technique du fenêtrage temporel a été utilisée jusqu'à ce jour principalement comme outil d'identification des sources. Cette approche peut être également utilisée afin d'évaluer le potentiel de réduction de bruit d'un traitement à la source. Voyons comment cette technique a été mise à profit.

Dans une imprimerie une machine permettant de brocher des magazines produisait un bruit de nature répétitive. Le diagramme temps-fréquence (voir figure 3) enregistré grâce à la technique du fenêtrage temporel près de cette machine, nous laisse voir qu'au cours d'un cycle deux évènements remarquables se produisent. Connaissant le fonctionnement des mécanismes et prenant en considération le délai interne quantifié précédemment, des mesures préliminaires ont permis d'identifier deux sources de bruit appelés S1 et S2. La source 1 génère dans la 17e tranche et la source 2 dans la 9e du cycle. Deux mesures supplémentaires ont été enregistrées respectivement près des deux sources. Les résultats sont illustrés à la figure 10. Nous pouvons constater ici la variation temporelle du niveau total exprimé en dBA, mais aussi l'augmentation de l'importance relative de chaque source suivant que la mesure est prise près ou loin de celle-ci. Ainsi on a pu arriver à localiser physiquement cette fois-ci la position de chacune des sources. On peut identifier grâce à cette figure que la source 2 est dominante. Il était possible de modifier temporairement la source 2 afin de diminuer son influence. La figure 11 illustre l'efficacité réelle de la modification apportée. On peut constater que le niveau de la tranche 9 a été diminué de 5 dB. Cependant, en

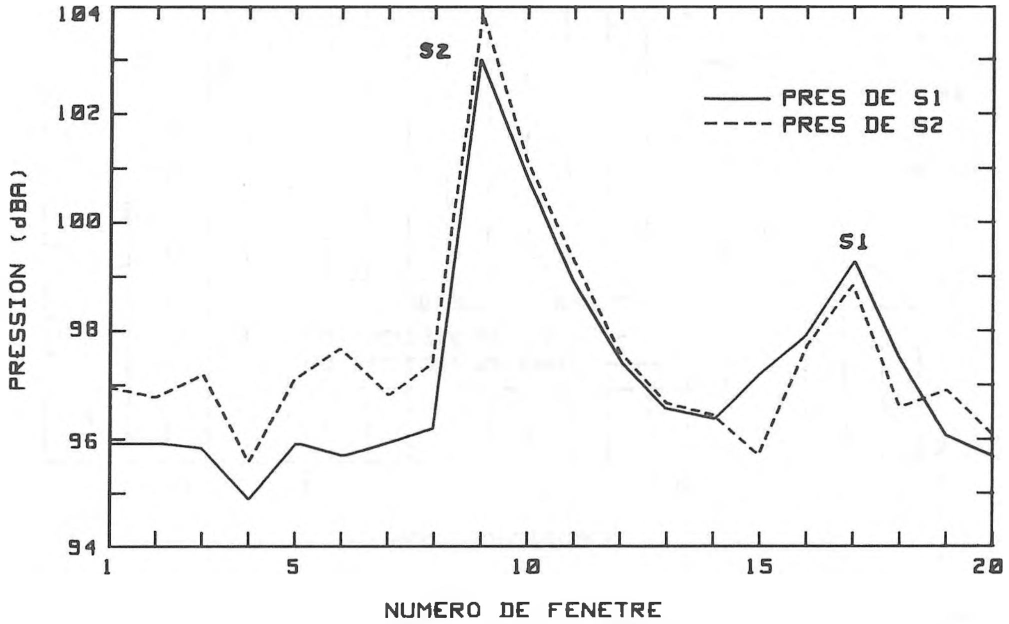

Figure 10 - Variation temporelle du niveau sonore mesuré respectivement près des sources S1 et S2

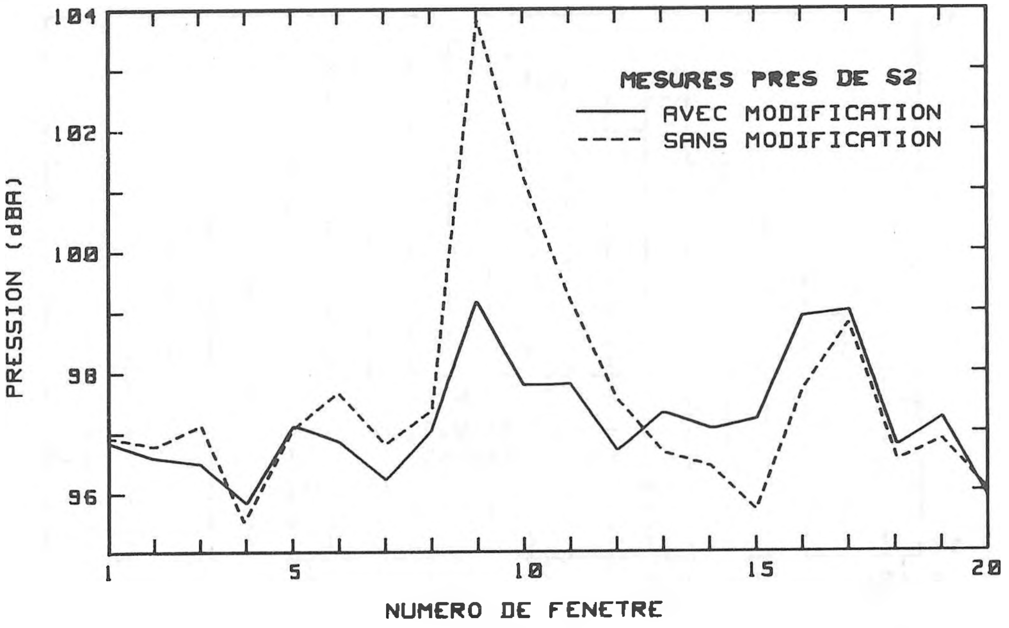

Figure 11 - Variation temporelle du niveau avant et après traitement de la source 2

examinant les spectres de la figure 12, on constate que le traitement de cette source diminue peu le niveau moyen. Afin de vérifier s'il aurait été possible de prédire ce comportement au moyen de la technique de fenêtrage temporel, les données de la figure 10 furent utilisées. Les niveaux des tranches 9, 10 et 11 furent rabaissés au niveau des tranches 8 et 12. On avait pu ainsi, par calcul, éliminer artificiellement la source 2. La figure 13

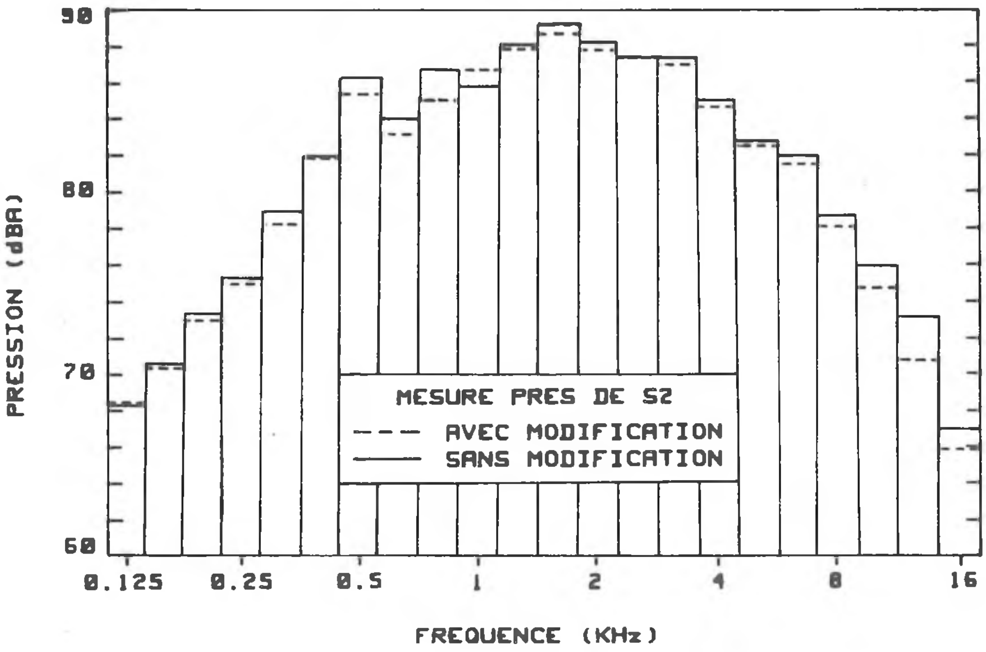

Figure 12 - Mesure en terme de pression moyenne (valeur efficace) de l'efficacité du traitement de la source 2

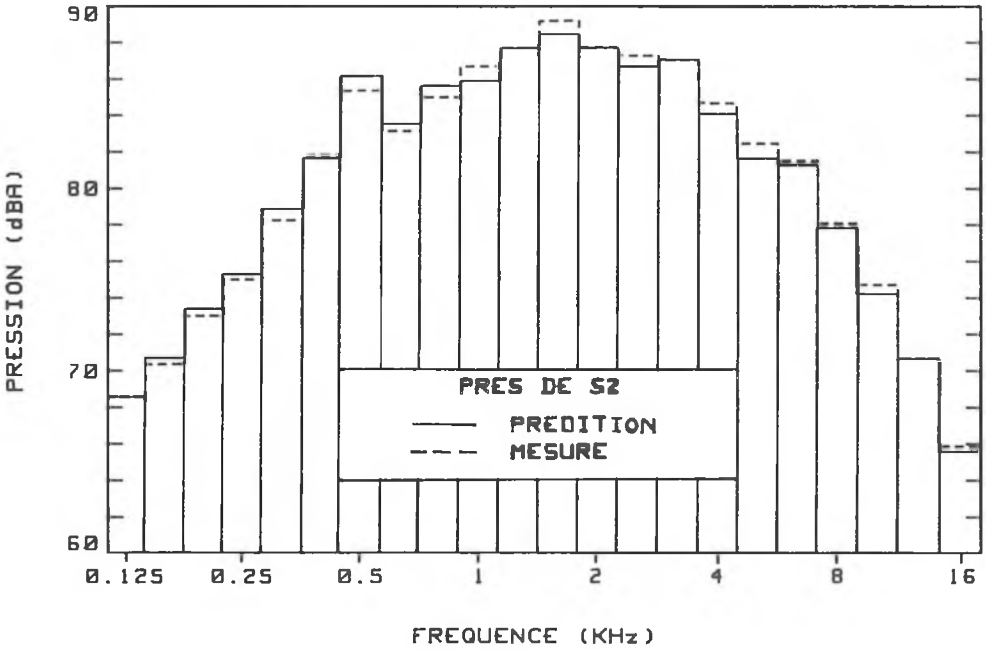

Figure 13 - Comparaison des niveaux prédits et mesurés associés à un traitement à la source 2

compare les niveaux prédits et mesurés. Les niveaux du spectre sonore moyen prédits sont très près des niveaux mesurés. Notons que ceci ne peut être imputable seulement au fait que l'élimination de la source 2 n'avait pas d'effet remarquable car, il a été démontré à la section 3 que le calcul d'un niveau moyen ne peut être que rigoureusement évalué par la moyenne des niveaux de chaque tranche. Dans ce cas-ci, l'utilisation du fenêtrage temporel nous aurait permis de constater, sans avoir à modifier la source, du faible potentiel de réduction du niveau moyen associé à l'élimination de la source 2.

Un impact mécanique génère des vibrations qui peuvent se transmettre au bâti de la machine et aux tôles qui y sont fixées. Ces tôles en vibrant, peuvent rayonner de façon importante. Un fait intéressant à noter ici est que la technique du fenêtrage temporel, qui permet d'éliminer artificiellement l'impact, fournit une limite inférieure du potentiel de réduction du niveau de bruit associé à l'élimination d'un impact mécanique.

CONCLUSION

La technique de fenêtrage temporel permet d'obtenir pour des sources cycliques l'évolution du spectre en fonction du temps. Nous avons démontré grâce à un système de calibration, que la quantification des spectres s'effectuait adéquatement. Nous avons identifié qu'il était essentiel de tenir compte d'un délai interne au système. Ce délai par rapport au signal de synchronisation a été évalué dans ce cas-ci à 7.1 ms. Nous avons également évalué l'importance de la variation de la vitesse de rotation. Cette variation ne peut excéder certaines limites car les phénomènes se chevauchent et la technique perd alors de sa précision. Finalement, en considérant le délai interne préalablement identifié, nous avons démontré comment la technique du fenêtrage temporel pouvait être mise à profit afin de prédire le potentiel de réduction du bruit associé à l'élimination d'un impact mécanique.

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REVIEW OF NOISE-CON 88 PROCEEDINGS

by Tim Kelsall
Hatch Associates Ltd.
21 St. Clair Avenue East
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Internoise has departed from North America for another year and its North American Clone, NOISE-CON has taken its place for those of us whose budgets or tastes do not allow travel off the continent. This year it was held at the Ray Herrick Laboratories in Purdue. My own budgets did not even stretch as far as Indiana, so I have had to content myself with the proceedings and try to gain some idea of the flavour of the conference from them.

A quick glance through the pages indicates that acoustics is alive and well in North America, even with the jet-setters elsewhere. I say North America not just because this review is in Canadian Acoustics but also because a quick glance reveals a good selection of Canadian authors with familiar names like Osman, Daigle, Nicolas and Sachs. Indeed even this is too narrow as there are authors from China, Brazil, Scandinavia, and most European countries. This is a sure indication that this supposedly "alternative" conference is acquiring a strong international following.

Of course, like all these conferences, the quality varies widely. Some papers (unnamed by me) are case-histories of every-day noise control jobs which give little new insights to practitioners who deal with exactly the same thing on a regular basis. Other papers, as usual, are so abstruse that one immediately questions whether the effort involved in deciphering the equations (even if I could and even if they were all there) would be sufficiently repaid.

What the proceedings do succeed in doing admirably is giving a good overview of the work being done in noise control, especially in the universities. These include such diverse areas as aeroacoustics applied to fans, especially small fans for business machines, propagation of sound, muffler analysis, acoustic intensity, open plan offices and factory acoustics. This series of proceedings probably gives a better overview of who is doing what in a compact format than any other with which I am familiar.

The compact format has its drawbacks however. Authors are limited severely as to the number of pages they may use. As a result, much of the information is practically unusable. In part, this is also due to the current tendency to regard conferences as places to advertise what people are doing without giving away how it is done. This is especially evident in the papers describing software being offered, and is evident as much from the Universities as it is from private consultants. Perhaps modern times necessitate this approach, but it does detract from the original purpose of such conferences and proceedings.

The papers are too numerous and varied to allow any reasonable discussion of their contents within the space of a short review. The proceedings, for those who were not there can best be regarded as the Yellow Pages to what is being done around North America and elsewhere. For those interested in particular subjects it will be necessary to contact the authors directly and hope they have a longer version of their paper available. Still there is some meat available within the proceedings and they should repay at least a quick browse.

NEWS / INFORMATIONS

Seminars and courses / Séminaires et cours

4th Annual Seminars on Audition: "Signal Processing Techniques in Hearing Aids". February 25, 1989, Chimo Hotel, 7095 Woodbine Avenue, Markham, Ontario. Contact: Marshall Chasin, Program Co-ordinator. [tel. (416) 731 1785]

Conferences / Congrès

2nd International Symposium of Cochlear Mechanism and Otoacoustic Emissions, 9-11 March 1989, Rome, Italy. Contact: Amplifon Centre for Research and Studies, via Ripamonti 129, 1-20141 Milano, Italy. [Fax 2-563033]

8th FASE Symposium on Environmental Acoustics, 24 April 1989, Zaragoza, Spain. Contact: Viajes El Corte Ingles, Dpto. Congresos, Avda. César Augusto, 14, 2. planta, 50004 Zaragoza, Spain. [Tal. (76) 21 56 69; Fax. (76) 43 77 27]

IEEE 1989 International Conference on Acoustics, Speech, and Signal Processing, May 23-26 1989, Glasgow, Scotland, U.K. Contact: Peter M. Grant, Dept. of Electrical Enfineering, University of Edinburg, The King's Buildings, Edinburg EH9 3JL, Scotland, U.K. [Tel. (031) 667 1081; Fax. (031) 662 4358]

Noise Control Conference, , June 7-10 1989, Budapest, Hungary. Contact: Optical, Acoustical and Filmtechnical Society, Fo u. 68, H-1027, Budapest II.

Tranducers '89 - The 5th International Conference on Solid-State Sensors and Actuators, June 25-30, 1989, Montreux, Switzerland. Contact: Prof. R.S. Muller, Berkeley Sensor and Actuator Center, University of California, Berkeley, CA 94720, U.S.A.

Noise and Vibration '89, August 16-18, 1989, Singapore. Contact: The Secretariat, International Conference on Noise and Vibration '89, c/o School of Mechanical & Production Engineering, Nanyang Technological Institute, Nanyang Avenue, Singapore 2263. [tel. 2651744 ext 578; Fax. 2641859]

INTER-NOISE '89, International Conference on Noise Control Engineering, December 4-6, 1989, Newport Beach, CA, U.S.A. Contact: INTER-NOISE 89 Conference Secretariat, P.O. Box 2469, Arlington Branch, NY 12603, USA.

XXth International Congress of Audiology, 11-15 November 1990, Puerto de la Cruz, Tenerife, Spain. Contact: Ms Dolores Aledo,, Pérez de Rozas,, 8, 38004 Santa Cruz de Tenerife, Cnary Islands, Spain. [Tel. (34) (22) 27 54 88; telex: 91106 GCCT-E]

CAA - ACOUSTICAL WEEK 1988

Toronto

... One more Acoustical Week in Toronto, the first since 1982. Yes, we met again. As always, it was a happy occasion to meet old friends, to make new friends, to see what they are doing and why not, to learn some new stuff.

For the members of the Organizing Committee, this week was great. It allowed us to flex our muscles, to try our best, to enjoy the success and also to lear from our errors, so that next time we will do it even better!

As announced, the week started with the Hearing Conservation Seminar on Monday. This was followed by the Building Noise Control and the Blasting Vibration and Noise on Tuesday. The last seminar, Traffic Noise took place on Wednesday morning. All the seminars were organized by Vic Schroter (MOL) with a lot of help and enthusiasm from volunteer speakers. The total attendance was 145 people.

For Wednesday, John Kowalewski (Ontario Hydro) organized a visit to the Ontario Hydro Dobson Research Laboratory. John was also the organizer of the Annual Banquet. On that occasion, our surprise entertainer (he didn't reveal her name even to his wife until the last moment!!!) was the Canadian best cellist (and one of the top in the world) Offra Harnoy.

John Hemingway (Vibron) who was responsible for the exhibits, organized a visit to the Sound Level Laboratories at the York University Campus. It was a very interesting experience, enjoyed by all the attendees.

Thursday and Friday are traditionally symposium days. This time we managed to run four similtaneous sessions for the three half-days. Many very interesting papers were organized by the session chairmen. Thanks to Raymond Hétu (Editor of the Journal), abstracts of the papers were published well in advance. Whole papers were published in the proceedings and were given to participants upon registration. This was made possible through the work of the Acoustical Week Secretary Francine Parry (Bilsom International).

We had also the Student's Paper contest. Aubrey Edwards (Ontario Hydro) was the chairman of the selection committee. The first prize went to Lynne Molinari (Ontario Hydro) for her paper A study of the relationship between noise levels, annoyance and work performance within offices.

All in all, the Acoustical Week in Toronto was a great success! We wish our friends in Halifax (where next years meeting will be held) all the best and we hope to meet all of you there.

Finally, we should commend our Chairman Winston Sydenborg (Blachford Ltd.) for his excellent work in making this week possible.

The week in numbers

1. Attendance

Seminars

Noise Control - 92
Blasting - 29
Hearing - 14
Traffic - 10

Visits

Dobson - 16
Sound - 12

2. Exhibitor - 76

3. Banquet - 76

4. Symposium - 95

5. New Members - 43

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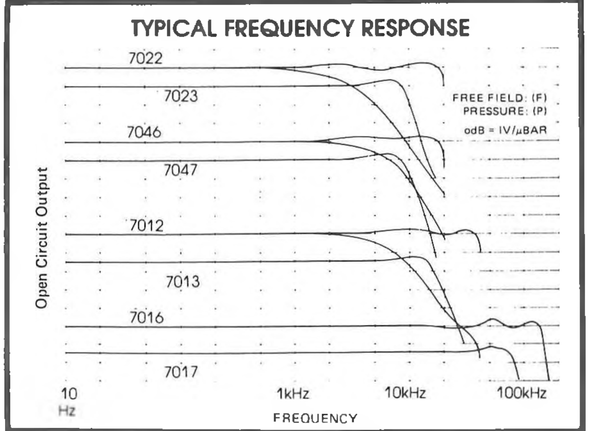
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PRIX ANNUELS DES DIRECTEURS DE L'ACA

Annuellement, les Directeurs et les membres de l'Exécutif de l'Association Canadienne de l'Acoustique (ACA) accordent deux prix d'un montant respectif de 500$ pour les meilleurs articles publiés dans **Canadian Acoustics/Acoustique canadienne**. Ces prix sont décernés pour encourager la communauté scientifique à soumettre des articles de qualité à la revue.

Les articles publiés en 1987 ont été évalués selon les critères suivants: (1) intérêt scientifique général, (2) contribution au progrès technique ou aux connaissances théoriques et pratiques, (3) qualité de l'analyse théorique, (4) pertinence et originalité de l'approche expérimentale (ou analyse théorique) (5) qualité des résultats et de la discussion, (6) qualité du texte et de la présentation.

Dans la catégorie "étudiant" le prix a été décerné à Monsieur D.C. Stredulinski pour son article intitulé "Acoustics of piping and ducts". Les co-auteurs étaient A. Craggs et M.G. Faulkner du département de génie mécanique de l'Université de l'Alberta (Edmonton).

Dans la catégorie "professionnel" le prix a été accordé à Monsieur Raymond Hétu, Ph.D. pour son article intitulé "Non-acoustic environmental factor influences on occupational hearing impairment". Les co-auteurs étaient R. Phaneuf et C. Marien du Groupe d'acoustique de l'Université de Montréal.

Nous tenons à offrir nos félicitations aux deux gagnants et à les remercier d'avoir soumis leur manuscrit à la revue de l'ACA.

ANNUAL DIRECTORS AWARDS - CAA

Annually, Directors and members of the Executive Board of the **Canadian Acoustical Association** (CAA) award two prizes (500$ each) for the best papers published in "Canadian Acoustics". These prizes are issued to stimulate submission of good papers to the journal.

The 1987 papers have been evaluated according to the following criteria: (1) scientific general interest, (2) contribution to technical progress or theoritical knowledge, (3) quality of theoritical analysis, (4) relevance and originality of experimental approach, (5) quality of results and discussion, (6) quality of text and presentation.

In the student category, the prize has been awarded to Mister D.C. Stredulinski for his article on "Acoustics of piping and ducts". Coauthors were A. Craggs and M.G. Faulkner from the Department of Mechanical Engineering of the University of Alberta (Edmonton).

In the professional category, the prize has been issued to Mister Raymond Hétu, Ph.D. for his article entitled "Non-acoustic environmental factor influences on occupational hearing impairment". Coauthors were R. Phaneuf and C. Marien from the Groupe d'acoustique de l'Université de Montréal.

We are proud of the winners and wish them our best congratulations. We also thank them for having submitted their manuscript to **Canadian Acoustics/Acoustique canadienne**.

Nicole M. Lalande, Ph.D.,
director of CAA
For Directors and Members of the
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Human Communication Canada is the official journal of the Canadian Association of Speech-Language Pathologists and Audiologists/L'Association canadienne des orthophonistes et audiologistes. Its purpose is to disseminate knowledge pertaining to human communication and human communication disorders. It is of particular interest to spech-language pathologists, audiologists, and other professionals from disciplines that impact on the broad areas of human communication and its disorders. Human Communication Canada publishes clinical and research articles, reviews of professional resources. practice and technical notes. and professional commentaries anddebates all of which reflect the braod interests of these professionals.

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HALIFAX-DARTMOUTH REGIONAL CHAPTER
CANADIAN ACOUSTICAL ASSOCIATION

7:30 - 9:30 p.m., Thursday, September 29, 1988
Tupper Building, Theatre C, main floor
Dalhousie University Campus, Corner Carlton and College

PROGRAMME

Opening Remarks
Annabel Cohen, Department of Psychology
Dalhousie UniversityAn Overview of Acoustics in Canada

This educational audiovisual slide presentation is an ongoing project under the auspices of the Canadian Acoustical Association. It provides basic information about many fields of acoustics and focuses in particular on work in Canada on wanted sound (speech, music, audiology, sound recording), unwanted sound (noise control, seismology), and other applications such as echolocation, and underwater acoustics.

Sound Generation by Ship Propellers
Neil Sponagle
Defence Research Establishment of the Atlantic, Dartmouth

The noise from ships often interferes with the operation of sonars and other underwater acoustic equipment. For modern surface ships operating at higher speeds, cavitation bubbles produced by the propeller are the dominant noise source. These cavitation bubbles form by vapourization of the liquid in areas of low pressure near the propeller, and then collapse when they return to areas of higher pressure. This produces impulsive broad bandwidth noise. Also, periodic changes in the total amount of cavitation leads to low frequency narrow bandwidth noise. This talk described propeller cavitation, as well as how it produces broad and narrow bandwidth noise.

Update on the Planning of the 1989 Annual Meeting in Halifax
Bob Cyr
Atlantic Acoustical Associates

The Annual Meeting of the Canadian Acoustical Association will take place in Halifax in the fall of 1989. Preliminary plans have been announced. After the official close of the meeting, anyone interested in working on the 1989 planning committee was welcome to attend a brief further discussion. Phone Bob Cyr for additional information at 425-0044 or 434-5434.

Other Business and Closing Remarks
Peter Terroux
Atlantic Acoustical Associates

The meeting was convened by Annabel Cohen (424-8888) and Peter Terroux (425-3096). The cooperation of the Dalhousie School of Human Communication Disorders, and of Mr. Bob Cross of the Dalhousie Audiovisual Department, Tupper Building, is gratefully acknowledged.

SPOTLIGHT ON MEMBERS

Chantal Laroche

Receives Director's Award for Best Student Paper, 1987

Chantal Laroche was born in 1962, in Montreal. She has received degrees in health sciences in 1981 from the College Bois-de-Boulogne, and in Speech and Hearing from the University of Montreal in 1984. Her Masters Degree in Speech and Hearing was completed in 1985. Her studies have been supported by awards from the University of Montreal, and the Quebec Research Institute of Occupational Health and Safety.

She has had considerable research and clinical experience working in the field of pediatric audiology, industrial noise, and psychoacoustics. Most of this work has been conducted at institutes in Montreal under such supervisors as Lourna Dowson, Ginette Filion, and Nicole Lalande. Recently, she worked at Northeastern University in Boston, under the supervision of Georges Canevet. She is currently working part-time at the Raymond Dewar Institute where she is evaluating hearing impairment of infants wearing auditory prosthetic devices. She has co-authored publications on reversible effects of noise (to be published by Acustica), a digitally controlled impulse-noise generation system for the study of the ear response to impulses (to be published by the Journal of the Acoustical Society of America), and the effect of spectral characteristics of impulse noise on auditory fatigue. The latter article was published in CANADIAN ACOUSTICS, 14, and received the Director's Award, for the best student article in 1986. Her doctoral dissertation, supervised by Raymond Hétu, will be defended in the fall of 1988. She will then be working in research under the direction of Raymond Hétu on the problem of Noise and Safety in the Workplace.

ACOUSTICAL STANDARDS - CANADIAN STANDARDS ASSOCIATION

The Canadian Standards Association (CSA) is composed of several standards writing groups. One of them is the committee Z107, Acoustics and Noise Control. This committee has 24 members on its main committee and over 50 on its subcommittees and Canadian Advisory Committees. The main committee meets at least once a year (usually during Canadian Acoustics Week) and its executive committee at least once as well. The subcommittees meet as frequently as is necessary to complete their work.

The responsibilities of the main committee are to vote on all proposed acoustic standards, review actions of its subcommittees, determine in consultations with interested parties whether new acoustic standards are required, review up coming government regulations and provide comments when requested on acoustical subjects.

The subcommittees that are part of the committee are as follows;

Editorial: Reviews all proposed standards to be sure they are consistent with each other and maintains the standard Z107.0 "Definitions of Common Acoustical Terms Used in CSA Standards".

Hearing Measurement: Develops standards or proposes endorsement of standards relating to the measurement of hearing and maintains the standards Z107.4 "Pure Tone Air Conduction Audiometers for Hearing Conservation and for Screening" and Z107.6 "Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation".

Transportation Noise: Develops standards or proposes endorsement of standards relating to the measurement of noises from transportation and maintains standards Z107.21 "Procedure for Measurement of the Maximum Exterior Sound Level of Pleasure Motorboats", Z107.22 "Procedure for Measurement of the Maximum Exterior Sound Level of Stationary Trucks with Governed Diesel Engines", Z107.23 "Procedure for Measurement of the Maximum Interior Sound Level in Trucks with Governed Diesel Engines", Z107.24 "Method for the Measurement of the Exterior Sound Level of Railway Bound Vehicles" and Z107.25 "Procedure for the Measurement of the Exhaust Sound Level of Stationary Motorcycles".

Powered Machines: Develops standards or proposes endorsement of standards relating to the measurement of noises from powered equipment and maintains standards Z107.31 "Test Procedure for the Measurement of Sound Levels from Agricultural Machines" and Z107.32 "Test Procedure for the Measurement of Sound Emitted from Construction, Forestry, and Mining Machines to the Operator Station and Exterior of the Machine".

Industrial Noise: Develops standards or proposes endorsement of standards relating to the measurement of noises emanating from industry and maintains standards Z107.51 "Procedure for In-Situ Measurement of Noise from Industrial Equipment", Z107.52 "Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources", Z107.53 "Procedure for Preforming a Survey of Sound Due to Industrial, Institutional or Commercial Activities", Z107.54 "Procedure for the Measurement of Sound and Vibration Due to Blasting Operations", Z107.55 "Recommended Practice for the Prediction of Sound Levels Received at a Distance from an Industrial Plant" and Z107.56 "Procedures for the Measurement of Occupational Noise Exposure".

Instrumentation: Develops standards or proposes endorsement of standards relating to the design or use of instrumentation and presently has no standards to maintain.

Consumer Products: Develops standards or proposes endorsement of standards relating to consumer products and maintains the standard Z107.71 "Measurement and Rating of the Noise Output of Consumer Appliances.

Building Acoustics: Develops standards or proposes endorsement of standards relating to building construction or the use of building elements and presently has no standards to maintain but does have a collection of endorsed ASTM standards to continuously review.

The Canadian Advisory Committees (CAC) that are part of the committee as follows:

CAC Acoustics:

The International Standards Organization (ISO) has a Technical Committee (TC) 43 on Acoustics. This committee produces internationally accepted standards on acoustics measurement methods, guidelines for associated acoustical criteria and descriptions of acoustics effects on people. The CAC receives all such documents to review and is responsible for formulating the Canadian position on each. The Committee is active in the working groups of TC 43, and undertakes to inform CSA Z107 of all their activities. The committee also ensures that the appropriate Canadian expertise is solicited when choosing representatives for working groups and when balloting is carried out. In these ways harmony is strived for between International and Canadian vibration standards.

There are two subcommittees of ISO TC43. These are ISO/TC43/SC1 on Noise and ISO/TC43/SC2 on Building Acoustics. The former is part of the CAC on the main TC43 committee while the latter is a separate CAC that is fully harmonized with the Building Acoustics subcommittee.

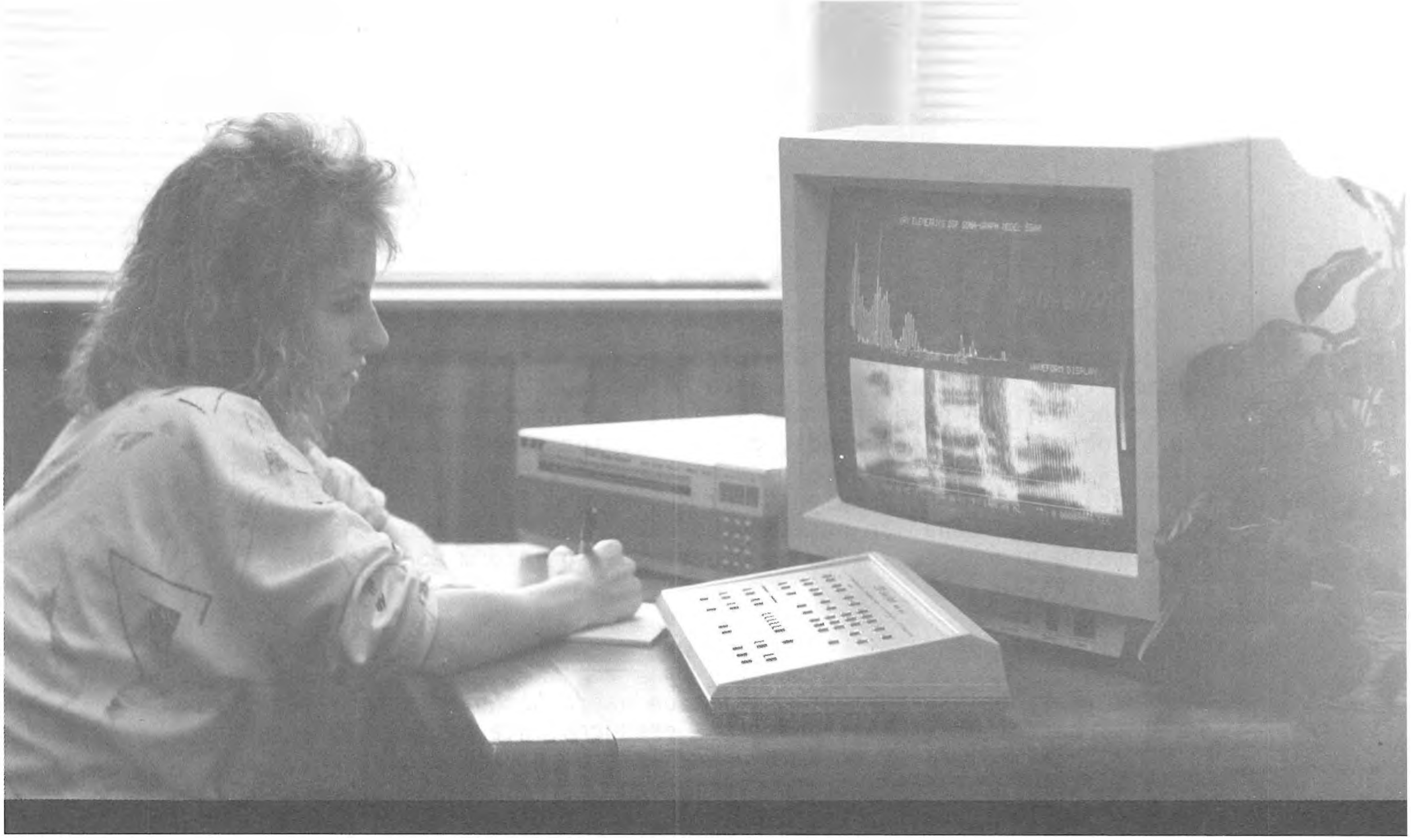
CAC Vibration:

The International Standards Organization has a technical committee 108 subcommittee 4 on Human Exposure to Mechanical Vibration and Shock. This subcommittee produces internationally accepted standards on vibration measurement methods, guidelines for associated vibrational criteria and a description of the effects of vibration on people. The CAC receives all such documents for voting and is responsible for formulating the Canadian position on each. The committee is active in the working groups of TC108 and undertakes to inform CSA Z107 of all their activities.

CAC Instrumentation:

The International Electrical Commission has a technical committee 29 on Electroacoustics. This committee produces internationally accepted standards on acoustic terminology and instrumentation. The CAC receives all such documents for voting and is responsible for formulating the Canadian position on each. The committee is active in the working groups of TC29 and undertakes to inform CSA Z107 of all their activities. The committee ensures that the appropriate Canadian expertise is solicited when choosing representatives for working groups and when balloting is carried out. In these ways harmony is strived for between International and Canadian instrumentation standards.

In addition, the CAC also reports on ANSI acoustic standards activities and participates in same.



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