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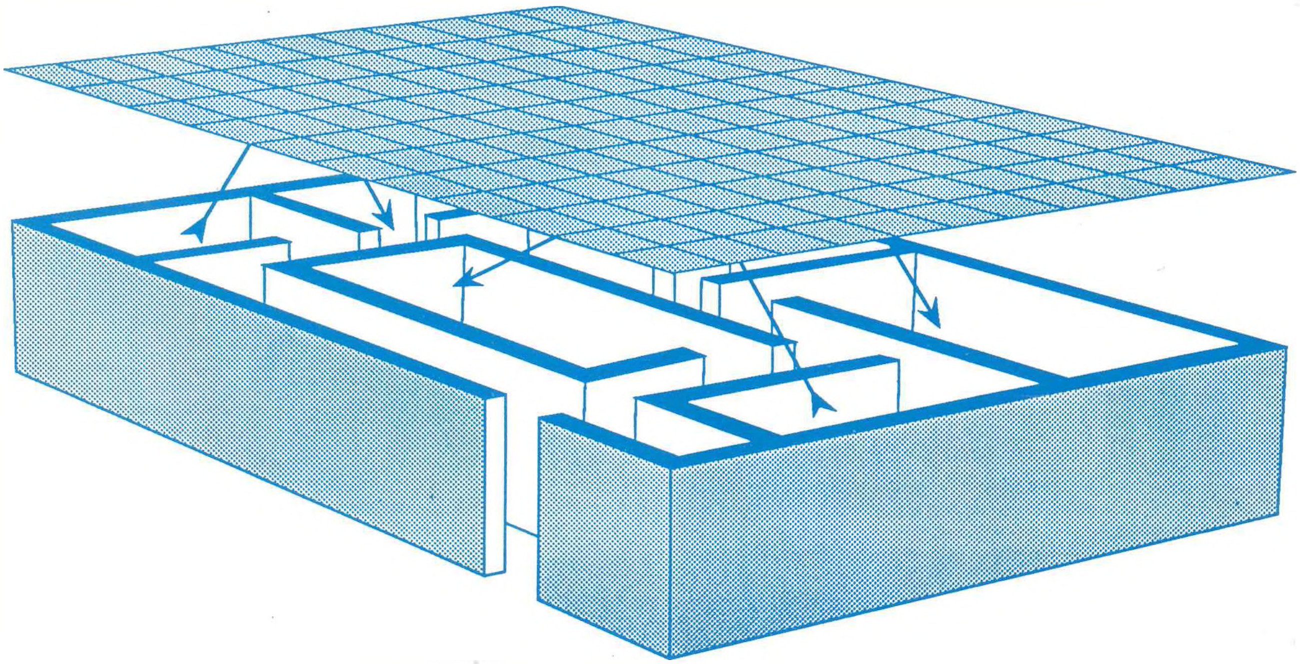

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EDITOR-IN -CHIEF /REDACTEUR EN CHEF
Raymond Hétu
Groupe d'acoustique
de l'Université de Montréal
C.P. 6128, Montréal H3C 3J7
(514) 343-7559, 343-7841

EDITOR / REDACTEUR
Murray Hodgson
Groupe d'acoustique
de l'Université de Sherbrooke
Université de Sherbrooke
Génie mécanique
Sherbrooke (J1K 2R1)
(514) 821-7157

ASSOCIATE EDITORS / REDACTEURS ASSOCIES

Advertising / Publicité:
Paul Gonsalves
19 MacDonell
Toronto, Ontario M6R 2A3
(416) 530-4423

News / Informations:
Alberto Behar
Ontario Hydro
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Pickering, Ontario L1W 3C8
(416) 683-7516

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EDITORIAL

As I often find myself saying to people who ask me about acoustics, it's a funny subject. Sound is everywhere, involved with every aspect of life, yet is taken for granted, ignored. Thus, the subject is highly multidisciplinary, yet studied by few, considered esoteric, not a proper discipline in its own right (how many acoustics departments are there?). Regarding research in acoustics, the chance of finding funds varies considerably. You're OK if you want to study sonar for detecting submarines, but try to fund a study of acoustic conditions in classrooms, which affect the learning of every Canadian. This latter research problem concerns the environment. And environmental research, as we all know, costs money instead of making it. In our society research which doesn't ovbiously make money, even if it improves quality, doesn't attract much interest. Another "problem" with the acoustic environment is that it doesn't kill anyone. Imagine how quickly research funding would flow if acoustic waves caused cancer! But do I perceive a whiff of change in the air? In the heady 60's we worried about the environment on principle (oh, that horrible word!). In the 70's and early 80's this concern turned into a total lack of interest (with the notable exception of the quasi-socialist Parti québécois, which established, for example, the Québec Research Institute for Health and Safety at Work). Now suddenly, there's a resurgence of talk, and even some action, concerning the environment - and it seems to be out of necessity and not on principle. There's worry over depletion of the ozone layer. They're talking about cleaning up the St-Clair River. They're pressuring the U.S. over acid rain. They're questionning logging policy in B.C. Three Montreal suburbs have asked their citizens to sort their garbage for recycling. Something is happening. All you, environmental-acoustic researchers, take heart, and warm up your sound level meters. Maybe the acoustic environment will be next.

Comme je le dis souvent à ceux qui me questionnent au sujet de l'acoustique, il s'agit d'une matière bizarre. On trouve le son partout, dans tous les aspects de la vie,mais on le prend pour acquis et on l'ignore. Ainsi, on est en présence d'un champ de connaissance hautement multi-disciplinaire bien qu'étudié par peu de gens, considérée comme étant ésotérique et non pas comme une discipline en soi de plein droit (combien y a-t-il de départements d'acoustique?). En ce qui concerne la recherche en acoustique, les chances de trouver un financement sont très variables. Tout va bien si vous voulez étudier le sonar pour détecter des sous-marins, mais essayez donc de financer une étude des conditions acoustiques dans les salles de classe, lesquelles affectent toute la population canadienne. Cet objet de recherche traite de l'environnement. Et la recherche en environnement, comme chacun le sait, suscite des coûts plutôt que des gains financiers. Dans notre société, la recherche qui ne génère pas à l'évidence des avantages financiers, même si elle apporte des gains en qualité, ne suscite pas beaucoup d'intérêt. Un autre "problème" lié à l'environnement sonore réside dans le fait qu'il ne tue personne. Imaginez l'avalanche de fonds de recherche si les ondes sonores causaient le cancer! Mais, est-ce que je perçois des signes de changements dans l'air? Dans les impétueuses années 60, nous nous préoccupions de l'environnement par principe (Oh, quel vilain mot!). Dans les années 70 et au début des années 80, cette préoccupation s'est transformée en manque total d'intérêt (à l'exception notable du Parti québécois quasi-socialiste, qui créa par exemple l'Institut de recherche en santé et sécurité du travail du Québec). Et maintenant, subitement, il y a resurgence de discours et même de certaines actions concernant l'environnement - et cela semble découler de nécessités et non par principe. On s'inquiète de l'épuisement de la couche d'ozone. On parle de d'assinissement de la rivière St-Clair. Des pressions sont exercées sur les américains concernant les pluies acides. La politique d'abattage en Colombie britannique est remise en question. Trois banlieues montréalaises ont demandé à leurs citoyens de trier leur rebus pour fins de recyclage. Il se passe quelque chose. Vous tous-tes, chercheurs-es en acoustique de l'environnement, reprennez courage et réchauffez vos sonomètres. Ce sera peut-être le tour de l'environnement sonore.

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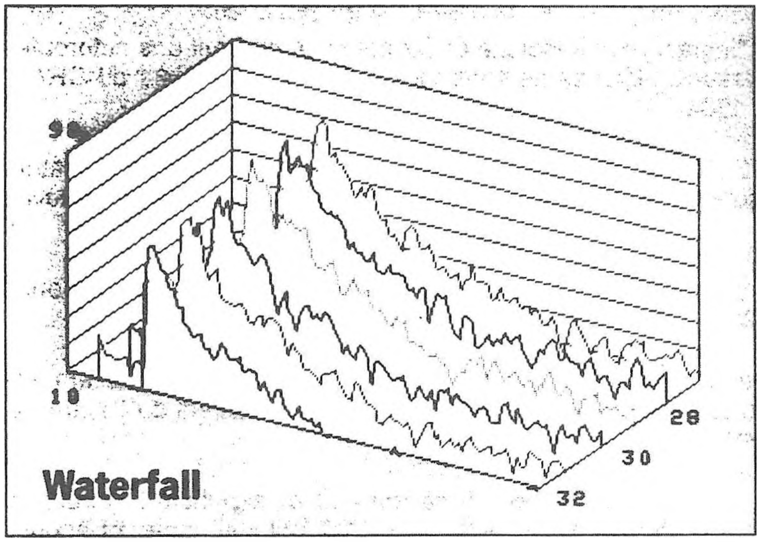

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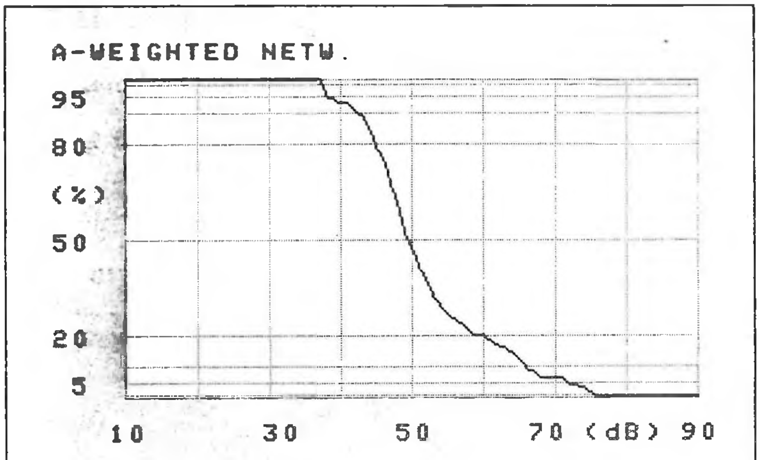

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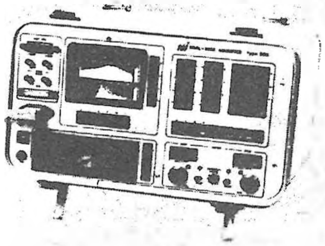

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AUDITORY PHYSIOLOGY RESEARCH IN TORONTO: AN OVERVIEW

Robert V. Harrison *

Department of Otolaryngology
The Hospital for Sick Children
555 University Avenue
Toronto, M5G 1X8

Introduction

The Canadian Acoustical Association encompasses a wide spectrum of research interests, all linked by the common factor, acoustics, (but perhaps not all soundly linked!) The activities of the CAA parallel in many ways those of its big brother/sister the Acoustical Society of America, but compared to the ASA one area has been largely (but not totally) unrepresented in the CAA, namely auditory physiology. However, recent years have seen the maturation of a number of physiological research groups throughout Canada. One of the main functions of the CAA is to promote interactions between groups or individuals with similar research interests, and the vehicle for such communication is this journal, Canadian Acoustics. To assist the spread of information I have agreed to the request of the editor-in-chief to provide a summary the research in auditory physiology being carried out in laboratories in Toronto, at the Hospital for Sick Children, and at the University.

Two basic auditory physiology research laboratories are currently operational in Toronto. The first is in the Research Institute of the Hospital for Sick Children (HSC), associated with the Hospital Department of Otolaryngology[1], and the second is part of the university Department of Otolaryngology[2] located in the Institute of Medical Science,the Medical Sciences Building, at the University. Both laboratories are closely linked to the Department of Physiology[3]; the author lectures in auditory physiology at undergraduate and postgraduate levels, in that department, and the laboratories are training grounds for research students in physiology.

The emphases of our basic research are the structure and function of the normal and of the pathological auditory system. The study of structure, (anatomy, histology, light and electron microscopy) is the main activity in the first laboratory (HSC), and auditory function (electrophysiology, and most recently behavioural psychophysics) is the thrust of the second laboratory (U of T). However, it should be noted that rarely do any of our research projects include only one type of investigation (we always attempt to correlate structure and function). In the following, a description of the facilities of each laboratory is presented followed by a brief summary of some of our ongoing projects. The reference list at the end is a small, representative sample of research publications from members of our research group.

---

* *Associate Professor,*
Departments of Otolaryngology and Physiology,
University of Toronto,
Director Otological Research,
Hospital for Sick Children, Toronto.

Otological Research Laboratory, Hospital for Sick Children

This laboratory[4] is devoted to anatomical, histological and microscopical studies of the inner ear and the central auditory pathways. The lab is managed by an experienced histologist/electron microscopist[5]. Here, biological material is processed for a variety of morphological studies. Some of the procedures are routine, such as fixation, embedding, and sectioning of specimens, although even those vaguely familiar with the anatomy of the ear will recognise that some specialised techniques are required, to cut or remove the very hard temporal bone surrounding the inner ear without damaging the very delicate sensory structures of the cochlea.

One technique which has proved very useful for observation of cochlear structures has been the micro-dissection of the cochlea followed by special preparation for observation using the scanning electron microscope. Figures 6 and 7 show some views of cochlear structures using this technique. This method has been used to great advantage to study the damage to stereocilia and other hair cell structures which result from various types of cochlear pathology (eg acoustic trauma, ototoxic poisoning, cochlear hypoxia, etc).

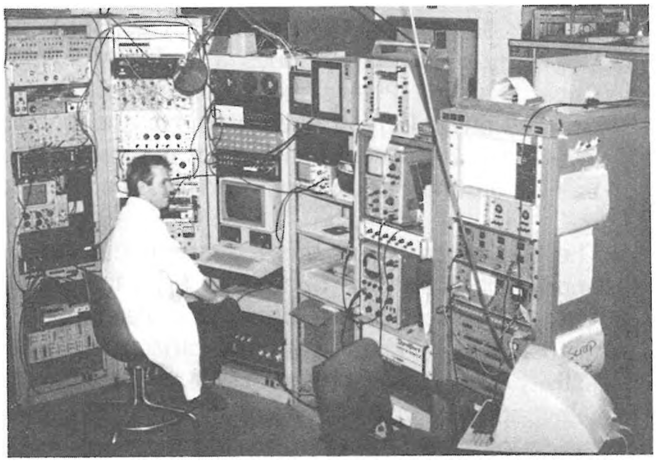

Figure 1: In the Auditory Physiology Lab, U of T, the author decides which button to press next.

Serial sectioning of the cochlea is carried out to allow other types of observation, using light microscopy, or transmission electron microscopy. For example, the study of possible ultrastructural changes to hair cells or sensory nerve fibres requires sectioning techniques; cochlear sectioning is currently being used to investigate endolymphatic hydrops, and spiral ganglion cell degeneration in animal models of deafness, (see below).

In addition to studies of the hearing organ, we also have an interest in the vestibular sense organs (e.g. ref 11).

Studies in the laboratory are not confined to the ear, but extend to the central auditory pathways where a different range of techniques is being applied. Anatomical techniques for tracing and assessing the functional integrity of neural pathways of the auditory system include autoradiography (the study of the uptake of radioactive substances into auditory neurones) and labelling of neurones with enzymes such as horse-radish peroxidase.

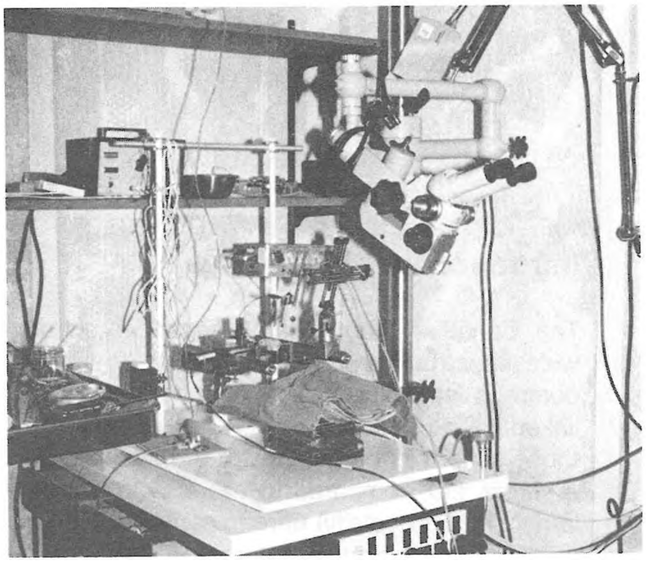

Figure 2: Stereotaxic equipment to record from single nerve cells in the auditory areas of the brain.

The laboratory is currently experimenting with new techniques for the quantitative analysis of microscopic images, and for three dimentional reconstruction of cochlear and brain tissue specimens. One example is shown in figure 4.

Auditory Physiology Laboratory, University of Toronto

This research lab is equipped to carry out a variety of electrophysiological studies into auditory function, (and dysfunction). The techniques currently used include evoked potential studies, for example the auditory brainstem evoked response (ABR) and cochlear action potential (CAP), in animals with various types of impaired auditory systems. One of our experimental subjects is shown in figure 5.

More detailed information about the function of the cochlea and higher auditory pathways is obtained by inserting recording electrodes directly into the part of the brain under investigation (in fully anaesthetized animals). Micro-electrodes can be used to record from small groups of nerve cells, or from single neurones. Such single unit recording techniques are used to investigate the detailed processing of signals in the auditory pathways, and the deterioration of the same in various types of deafness in our animal models.

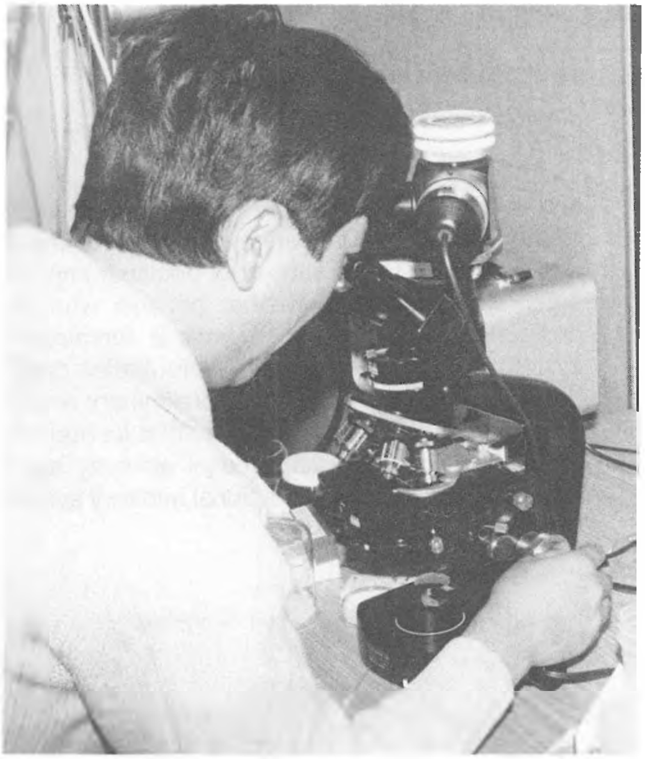

Figure 3: In the Otological Research Lab, HSC, Dr. N. Fukushima (research fellow from Hiroshima, Japan) studies a cochlear specimen.

These "animals models of human deafness[6]" include animals exposed to ototoxic drugs, or acoustic trauma, or with surgically induced cochlear dysfunction such as endolymphatic hydrops, or with some genetic disorder such as hereditary nephritis (see below).

In addition to the objective electrophysiological measures of auditory function outlined above, we are also training experimental animals in behavioural psychophysical tasks such that auditory thresholds, masked thresholds, difference limens etc. can be reported by the experimental animals[7]. Such studies are an important link in relating physiological data to hearing disorders in humans where the only real source of scientific information (at least pre mortem) is psychophysical.

Animal Models of Deafness

For many years we have been using animal models of deafness in an attempt to obtain more insight into the nature and cause of the disease. In the following sections some of our studies with these animal models are briefly described.

1) Acoustic trauma

We are interested in how damage to the cochlea, resulting from intense acoustic stimulation, correlates with functional deficits including threshold elevations and other altered aspects of hearing such as frequency selectivity and intensity coding. Most recently, we have started to investigate some of the factors which may be important for optimal recovery of hearing after acoustic trauma. For all these studies it is convenient to use small animals such as the chinchilla or the guinea pig (e.g. refs 1,4).

2) Ototoxic drug poisoning

The cochlea is vulnerable to a variety of "ototoxic" drugs. In some studies we take advantage of this fact and use drugs (eg kanamycin) to produce predictable damage to the cochlea, and then assess the specific effects that this damage has on cochlear function using a range of electrophysiological methods (eg. refs 3,4). We also study newly developed drugs which are possibly damaging to the ear, assessing their potential ototoxicity by measuring functional, and anatomical changes caused by the drug (eg. refs 9,10).

3) Meniere's disease

In experimental animals, for example guinea pigs, it is possible to induce some of the symptoms of Meniere's disease by a surgical operation which blocks the endolymphatic system of the ear, producing an endolymphatic hydrops. In these "hydrops" animals we are investigating the time-course of changes to the auditory system (eg. fluctuation in low frequency

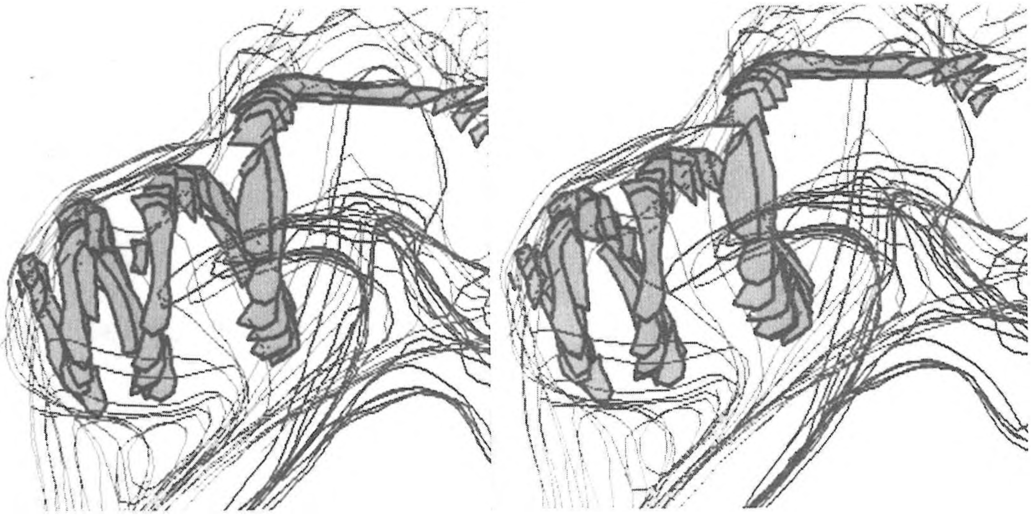

Figure 4: Computer generated 3-d reconstruction of the cochlear endolymphatic system. (Observe this stereo-pair with a viewer for 3-d image.)

thresholds of hearing) as well as trying to determine the underlying cause of symptoms in humans. In this respect we are asking whether the spontaneous firing rates of auditory neurones could be a possible underlying cause of tinnitus ("ringing in the ears"). In such animals models of Meniere's disease, functional changes are being compared with any anatomical changes, in particular the volume expansion of the endolymphatic system.

4. Hereditary deafness

There are many types of hereditary deafness in man. Unfortunately such types of deafness are difficult to investigate experimentally because they do not often occur in non-human species. We have, however, been monitoring auditory function in dogs with hereditary nephritis, a disease often associated with progressive hearing loss in man (e.g. Alports syndrome). One of the experimental subjects is shown in figure 5. So far, however, we have been unable to characterize a genetically determined hearing loss (ref 13).

5. Profound deafness

Animal models of profound deafness can be produced by causing total cochlear degeneration using ototoxic drugs or surgical ablation. Profound hearing loss is not easy to study electrophysiologically (or behaviourally) because, of course, acoustic stimuli cannot be used in experiments to activate the auditory system. However it is possible to determine the integrity of the auditory pathways by a combination of direct electrical stimulation of the cochlea, and evoked potential or single unit recordings, for example from the brain stem or midbrain. Our studies in this area relate to the subject of cochlear implants (ref 7). Thus, we are asking whether patients who have been profoundly deaf from birth have a functional auditory system that can use the limited information provided by a cochlear implant device. Our preliminary results in deaf from birth animal models indicate that an auditory system which has not been activated at an early age may not have developed a fully functional auditory system.

Figure 5: An experimental subject relaxes for ABR assessment of auditory thresholds.

Research Funding

The research lab spaces have been established by the Hospital for Sick Children Research Institute and the University Department of Otolaryngology. Research funding is provided through external agencies, in particular from peer reviewed research grants from the Medical Research Council. Important financial support has also been provided from local agencies, and in particular by the generosity of the Masonic Foundation of Ontario.

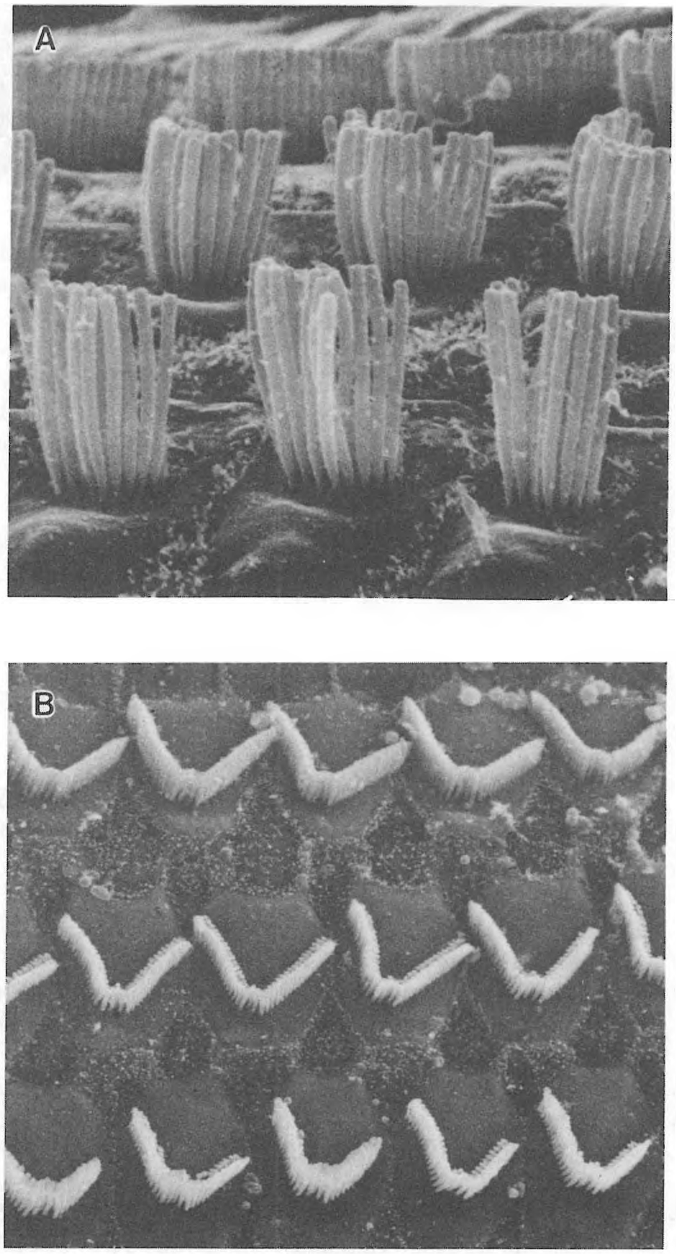

Figure 6: Scanning electron micrographs of hair-cell stereocilia from the apical (a) and basal (b) regions of the cochlea.

Research Training

The research laboratories provide research training to science graduates working toward higher degrees, and to post-docs, for example, MD residents in otolaryngology seeking research experience.

Applied Research

The major emphasis in our laboratories is basic physiological research. However, being based in a clinical department (otolaryngology) there is sometimes an opportunity to apply some of our techniques and knowledge to clinical problems. Thus for example we have been involved with the provision of cochlear implants to profoundly deaf patients[8] (ref 7) and the development and testing of new implant devices[9] (ref 8).

Evoked potential electrophysiology in humans is now a widely used technique for objective assessment of hearing and other neurological disorders. We have implemented such evoked potentials (ABR, AP) during surgical operations involving the cochlear nerve or auditory brainstem (eg acoustic neuroma removal) to monitor the function of the auditory pathways with the aim of conserving hearing[10] (ref 12).

Thus the basic physiological laboratories described herein enjoy a close relationship with the clinical Department of Otolaryngology, and the related Audiology divisions. The labs serve to promote interaction between clinicians and laboratory scientists, bringing scientific techniques to bear on clinical problems, and allowing new knowledge and techniques generated on the bench to permeate into practical applications.

---

[1] Head of Department: Dr. W.S. Crysdale.

[2] Chairman of Department: Dr P.W. Alberti.

[3] Chairman of Department: Dr H. Atwood.

[4] Historical note: the lab was largely established by Dr. Ivan Hunter-Duvar who is now retired, but alive and well, hunting and fishing in Nova Scotia.

[5] Mr. Richard Mount.

[6] The term "deafness" is used here not in its specific sense of total hearing loss but in a general sense to cover all degrees of hearing impairment.

[7] In charge of this research is Dr. David Smith.

[8] In collaboration with Drs. S.M. Abel and J.M. Nedzelski.

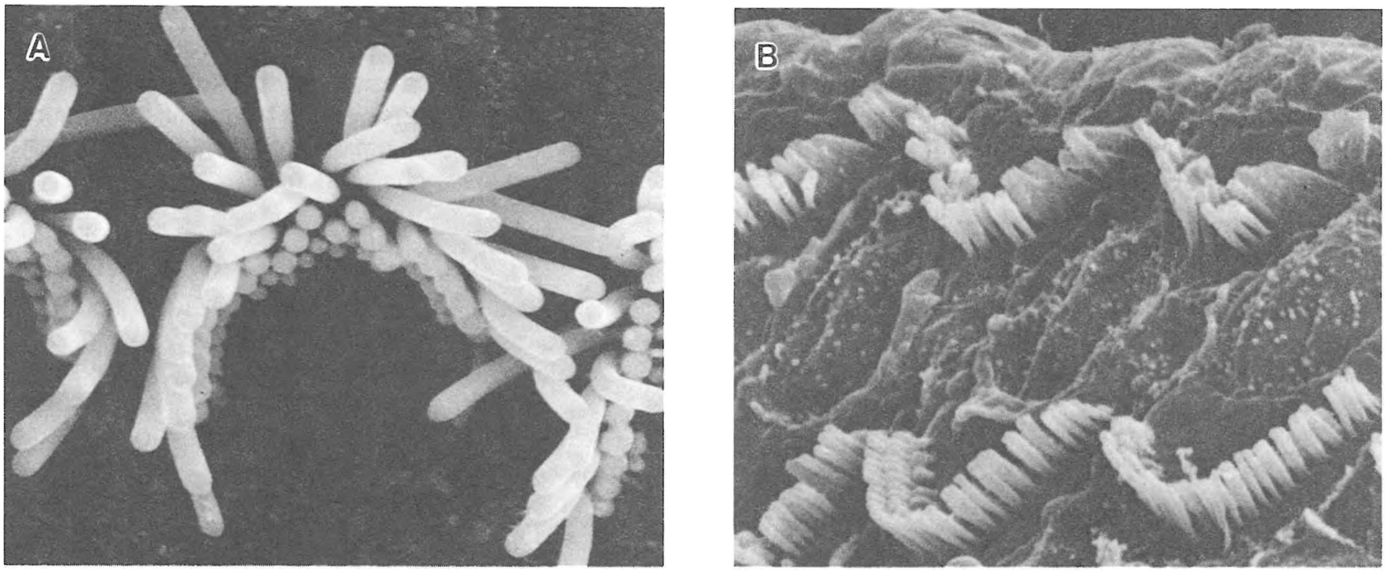

Figure 7: Some of the effects of acoustic trauma on the stereocilia of hair-cells. Note the splaying (in A) and the fusion of stereocilia (in B).

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This is a small sample of some recent publications from our research group:

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[9] In collaboration with Drs. H. Kunov, R. Morris, P. van der Puije and F. Duval.

[10] In collaboration with Dr. J.M. Nedzelski, Dr. D.W. Rowed, Susan Stanton, and Marlene Z. Cashman.

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1988, 16(2): 9-23*

THE EFFECT OF VARIOUS PARAMETERS ON THE SOUND ISOLATION BETWEEN OFFICES WITH SUSPENDED CEILINGS

K. Kruger, Building Sciences Branch
Alberta Public Works, Supply & Services
12th Floor, 8215 - 112 Street
Edmonton, Alberta T6G 5A9

ABSTRACT

There is very little practical information available on the acoustical performance of suspended ceilings used in an office environment. It is very difficult to determine the influence of specific elements through a comparison of field measurements since there are many unknown conditions that change from one site to the next. The purpose of this study was to evaluate the importance of various common parameters associated with suspended ceilings in a realistic but controlled manner. Effects of ceiling panel STC, return air openings, plenum absorption, plenum barriers and ceiling sandwich construction were measured.

SOMMAIRE

Peu d'information pratique de l'isolation acoustique des plafonds rapportés dans le local des bureaux existe. Puisque les conditions, d'un bâtiment à l'autre, sont très variables, il est difficile de déterminer l'influence d'éléments spécifiques a partir d'essais sur place. Le but de cette étude est d'évaluer plusieurs parametres associés aux plafonds rapportés dans une situation réaliste mais contrôlé. L'effet de la perte de transmission sonore de differents panneaux, des grilles de ventilation, de l'absorbtion et des barrières dans l'espace interstitielle du plafond, ansi que des panneaux sandwich ont été mesuré.

INTRODUCTION

Office construction in modern buildings typically consists of drywall partitions terminated at the underside of a continuous suspended ceiling. A large and open space above the ceiling is usually provided to create a return air plenum and to conceal mechanical and electrical equipment. Although there are only two primary building components separating offices, the prediction of sound isolation is nevertheless complex. The theory of plenum transmitted sound, as developed by Mariner[1], describes the effect of several important variables such as plenum depth, ceiling transmission coefficient and absorption coefficients for the various ceiling and plenum surfaces. The theory has been found to agree reasonably well with measurement where the acoustic properties of all the surfaces are homogeneous and readily defined. More realistic ceilings cannot be described in such explicit terms. Ceilings are often penetrated by numerous ventilation openings and light troffers making the transmission loss difficult to determine. Acoustic conditions above the ceiling can also be somewhat nebulous if a plenum contains a barrier or if absorptive material is unevenly distributed. To gain an insight on the importance of various parameters that are routinely encountered in designing offices for speech privacy, an extensive test program has been undertaken.

TEST FACILITY AND PROCEDURE

A reverberation chamber was modified to create two offices and an adjacent corridor. This provided a convenient and controlled environment to systematically investigate various ceiling configurations. Initially, a heavy gypsum board and plaster surface was installed at 3400 mm above the floor to represent a roof or upper floor structure. A conventional T-bar suspension grid was hung from this ceiling at 2400 mm above the floor leaving a 1 m plenum depth. A plan view and section through the test chamber are shown on Figure 1.

Three of the plenum walls were lined with 150 mm thick rigid glass fibre. The fourth surface, adjacent to both offices, was the untreated reverberation chamber wall. The intent of the absorption was to simulate a plenum which was open in three directions. This condition would be found above offices located along the perimeter of a building and away from any corners. Lining the plenum walls also tends to leave the ceiling performance substantially independent of plenum depth.[2]

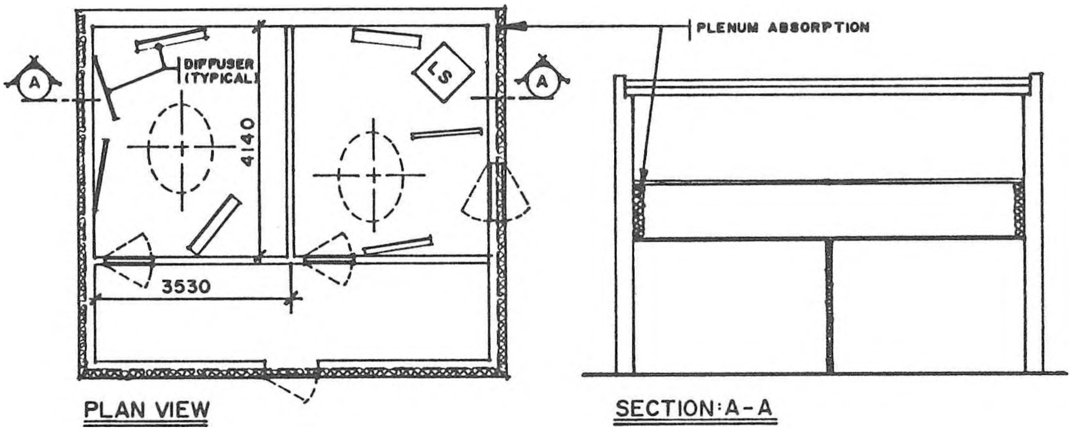


fig.1

The office partitions were constructed of 92 mm steel studs with 12 mm drywall applied to each side and insulated with 50 mm thick glass fibre batt. The transmission loss of the dividing wall was very similar to that of a good quality demountable partition. A 3 mm thick closed cell foam tape was used to seal the junction between the top plate of the wall and the suspended ceiling. The partitions were sealed to the chamber floor and walls with caulking. The rooms did not contain any absorptive material except the ceiling. Several plywood panels were placed in each room to create a more diffuse sound field.

The test procedure generally followed ISO 140/IV.[3] A single loudspeaker was placed in a corner opposite to the common office partition and directed toward the corner. The loudspeaker was fed broad band pink noise. A rotating microphone with a sweep time of 16 seconds and a sweep radius of 865 mm was positioned so that the traverse was not nearer than 500 mm to room boundaries. The boom was inclined approximately 40 degrees from horizontal and positioned as far from the source as possible. Space average levels for one complete revolution were determined using the mean squared pressure.

Level difference values were standardized to a reverberation time of 0.5 seconds. The equivalent absorption area was determined from an ensemble average of fifteen reverberation time analyses with a moving microphone.

Results are expressed in terms of the Derived Articulation Index (DAI) which is defined as follows[4]:

$$DAI = 30 \times \sum_{f_i} A(f_i)\ W(f_i)$$

where f_i is the centre frequency of the bands from 200 to 5000 Hz, $A(f_i)$ is the standardized level difference measured in the one third octave band with centre frequency f_i , $W(f_i)$ is the standard Articulation Index[5] weighting for that band given in ANSI S3.5. Conversion to the recently adopted Articulation Class[6] (A.C.) can be obtained by simply multiplying DAI by 10.

The DAI was chosen over the conventional measure of field sound isolation, the Normalized Noise Isolation Class (NNIC), because it was found to correlate much more closely to the Articulation Index. No attempt was made to measure the actual sound insulation of the ceiling. Since the intent of this investigation was to simulate field conditions as closely as possible, a typical dividing wall was used. Under some conditions and at certain frequencies, the overall isolation was dictated by the wall.

SPEECH PRIVACY

Neither the DAI or the AC are yet commonly used to describe sound isolation between cellular offices, so a comparison to the NNIC may be helpful. Approximately 400 tests were conducted on different ceiling and wall conditions. The level difference spectra are thought to be quite realistic for a wide range of office construction methods. Figure 2 shows the comparison between the NNIC and DAI for all of the data; the bars indicate one standard deviation. The best fit line is given by the following expression:

$$DAI = 1.26 + 1.06 * (NNIC)$$

The relationship between DAI and speech privacy is shown more specifically on Figure 3. Articulation Index values were calculated for every test at each of the background noise levels indicated on the graph. The resulting curves are best fit polynomials. Male speech at a normal voice effort was used as the source. The assumed spectral distribution of the background noise is that of the standard NC curve. Although this noise characteristic is not too common for real building mechanical noise sources, the graph does indicate the sensitivity of the DAI to privacy. A change in DAI of 5 can be quite significant. Confidential privacy is achieved when the sum of the DAI and the NC exceeds 70.

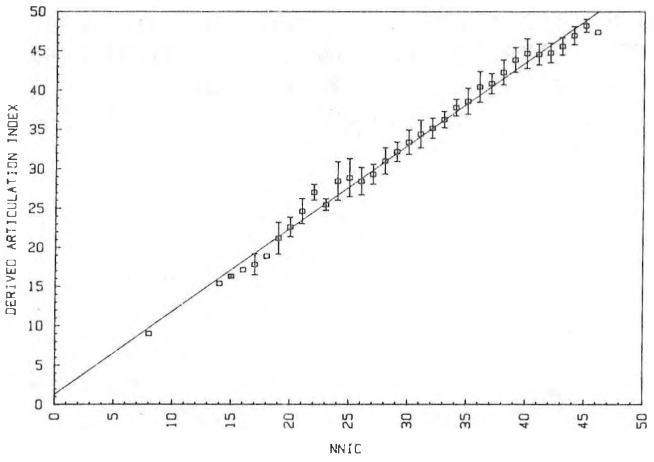


fig.2 relationship between DAI and NNIC for all tests in the study

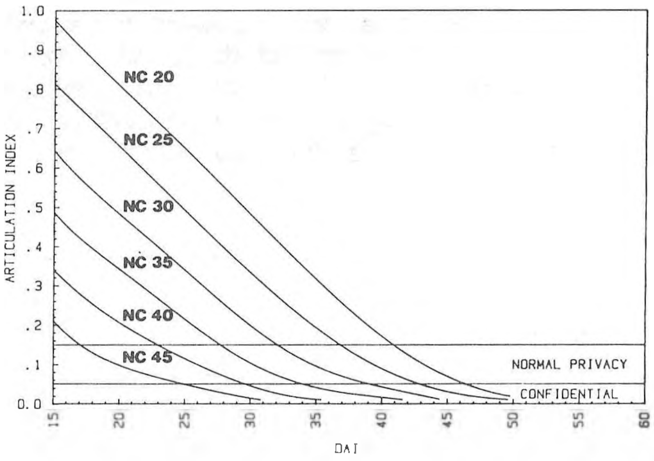


fig.3 speech privacy as a function of background noise and sound isolation

CEILING BOARD STC

The two-pass STC, measured according to AMA 1-II[7], is commonly used to establish the performance of ceiling panels. Manufacturers often publish the results quoting the appropriate STC range. The laboratory standard allows for the evaluation of ceiling systems representing field conditions, but typically samples are tested using a more ideal configuration consisting of an exposed suspension system that is continuous, well sealed over the common partition, and is without penetrations except those inherent to the product's design.

Table I indicates the ceiling panels that were tested in this study. Panel #9 is not actually a manufactured product although comparable products are available. The list includes panels intended for a wide range of applications. Specific products were selected on the basis of their popularity in commercial office space familiar to the author.

TABLE I CEILING PANEL CHARACTERISTICS

PANEL NO.	PANEL COMPOSITION	NOMINAL THICKNESS (mm)	SURFACE DENSITY (kg/m^2)	ADVERTISED STC RANGE
1	Glass Fibre	25	2.2	15 - 19 *
2	Glass Fibre & Foil Back	25	1.5	20 - 24
3	Glass Fibre & Foil Back	38	2.3	25 - 29
4	Mineral Wool & Backing	25	2.9	25 - 29
5	Mineral Fibre	22	6.6	30 - 34
6	Mineral Fibre	16	3.8	35 - 39
7	Mineral Fibre	16	3.1	35 - 39
8	Mineral Fibre	16	3.8	40 - 44
9	Drywall	6	5.8	40 - 44 *

* estimate

The sound isolation measured with the various ceilings is shown on Figure 4, where the DAI is plotted against the STC range for each product. Measurements were made using the typical ceiling configuration as described previously. The line drawn through the measured points indicates the best fit linear relationship between DAI and NNIC obtained from the entire body of data in this study. In order to plot the line, the NNIC was simply substituted with the median STC value for each range. This substitution is not strictly valid because the measurement standard used to obtain the NNIC (ISO 140-IV) is quite different from that used for the STC (AMA 1-II). However, many designers assume that the STC is representative of field performance and so the line gives an approximate indication of the isolation that might be anticipated when the ceiling is the dominant transmission path.

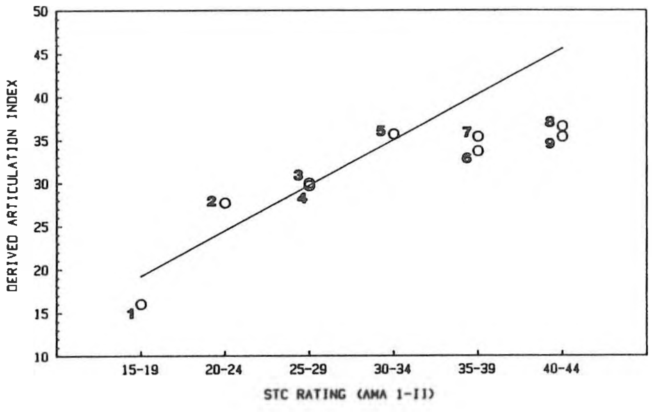


fig.4 comparison between transmission loss rating for various ceiling panels and sound isolation between offices

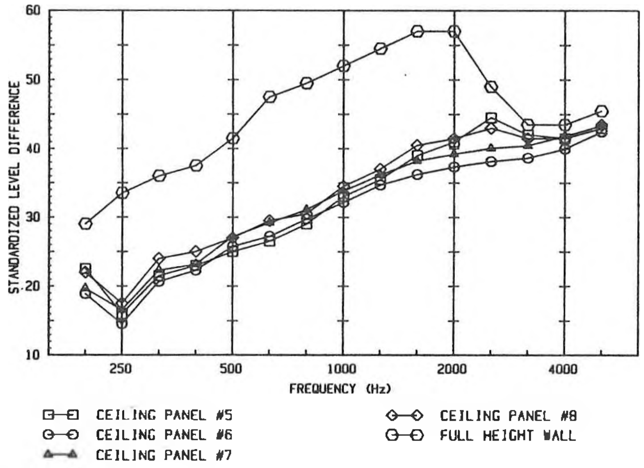


fig.5 level difference between offices with various mineral fibre ceiling panels

The glass fibre panels (1-4) perform as expected. These products have a low transmission loss and thereby minimize any differences that might occur when comparing measurements performed to different standards and conditions. A distinct plateau is found at approximately DAI 35 corresponding to all of the mineral fibre composition products. Since these panels have a relatively high transmission loss, it is not surprising that specific differences between test procedures become much more significant and lead to different results. For example, the AMA standard requires the plenum to be lined on all four sides. Removing absorption from one wall, as in this test facility, can reduce the isolation provided by a high transmission loss panel by as much as 4 dB at 1 KHz.[8] In addition, the transmission loss of the common wall, according to the AMA standard, must be at least 10 dB greater than the ceiling for all frequency bands. The more typical wall, used in these tests, does not meet this criterion for the mineral fibre panels and contributes to limiting the performance of the overall construction.

The similarity between the mineral fibre panels is further indicated by the level difference curves shown on Figure 5. Again, there does not appear to be a consistent correlation between the STC rating and the isolation over any part of the frequency range. In fact, panel #5, which has the lowest STC of this group, exhibits the best performance around the critical 2000 Hz region. Variation between products diminishes even more when openings through the ceiling or less than perfect seals are introduced. Influence of the wall begins to be seen for frequency bands above 2500 Hz where coincidence effects dominate.

The implication here is that, for typical office construction, there is little to be gained by selecting a ceiling panel with an STC above approximately 33 (Panel #5). This conclusion is probably somewhat tenuous considering that this test series is far from a comprehensive evaluation of the total number of products available. None the less, the variation in performance is remarkably small considering that the mineral fibre panels all have quite distinct physical characteristics and are produced by three different manufacturers.

Because of the similarity between the mineral fibre panels under relatively ideal conditions, it was decided that the behavior of many other ceiling configurations could be reasonably well represented by just one of the products. Even if the results of a specific test cannot be applied absolutely to the performance of other panels, at least the trends are expected to remain the same. Ceiling panel #7 was chosen as the standard.

RETURN AIR OPENINGS

Suspended acoustic ceilings are rarely installed without any penetrations. The most common unobstructed openings are those created to allow for return air to pass into the plenum. Two types of openings are typically found in offices; several long narrow slots which are integral to the light fixtures or a larger rectangular opening cut into a ceiling panel. The minimum area required to provide adequate ventilation varies approximately between 0.032 m^2 for an average size office located in an interior zone to 0.064 m^2 for an office on the building perimeter. This open area is typically equivalent to 3 return air slots and 6 slots respectively. Larger openings and especially more slots, are common.

The effect of return air slots was investigated by progressively increasing the number of slots in both rooms. The first two slots were part of a light fixture installed in each room. Additional slots were formed by leaving a gap between two closely spaced tees resulting in a free opening of 12 mm x 1025 mm. The slots were distributed evenly throughout the ceiling plane and placed symmetrically about the common office partition. A comparison between slots formed by the fixture and those created by the tees showed no difference outside the limits of repeatability. Similarly, there was no measurable effect of the fixture (with the slots blocked) compared to a ceiling without any fixtures.

Single return air openings were formed by cutting a 600 mm wide hole in a ceiling panel located near the center of each office and gradually increasing the length of the opening. The openings were spaced 3600 mm apart at the nearest edges.

Figure 6 shows the result of this series where return air open area in each office is plotted against the DAI. Several narrow slotted aperatures distributed over the ceiling have a significantly greater influence on sound isolation than a single aperature with an aspect ratio much closer to 1. From a practical perspective, consider that a DAI reduction of 5 can result in a significant change in speech privacy. Only 8 return air slots would be necessary for this to occur, whereas a single rectangular opening would have to be approximately 600 mm x 750 mm to have the same effect. An opening of this size is six to seven times larger than necessary for ventilation requirements.

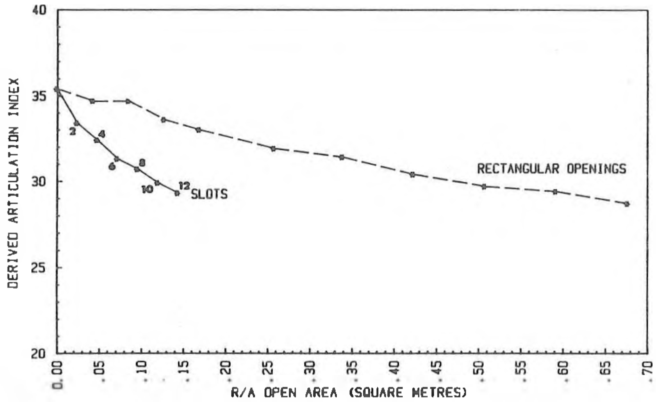


fig.6 effect of return air open area on sound isolation for two types of openings

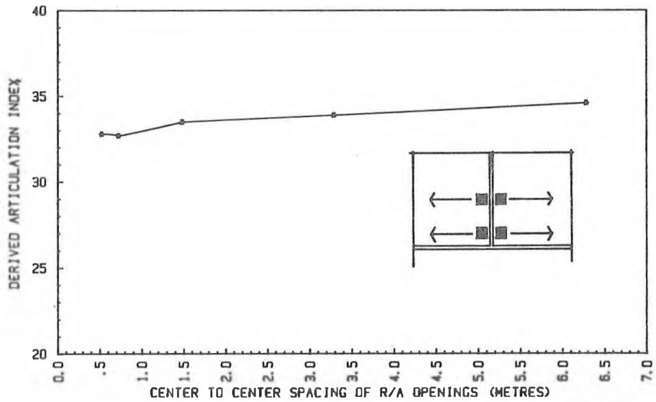


fig.7 effect of separation between square return air openings on sound isolation

Reducing sound propogation through a single large opening is a straight forward procedure requiring only a short section of lined duct on the back of the grill. But even this measure does not seem worthwhile in the case of a suspended lay-in ceiling since a typical opening of .09 m^2 only reduces the DAI by approximately 1.

The surprisingly small effect of a large return air opening was at first thought to be influenced by the room to room distance between openings. Proximity of the opening to the sound source could also have been a factor, since a diffuse sound field could not be established in such small rooms. Some indication of the importance of these parameters was determined by positioning return air openings on three different grid lines and gradually increasing the separation. Openings were located in a line directly above the source, along the office centre line and along the wall opposite from the source. Results indicate that proximity to the source does have a small influence. When the openings are in a line on the source side, isolation is reduced by an average of 2dB compared to a corresponding location on the opposite side of the room. Another factor that may have contributed to the poorer performance along the source grid line was the influence of the adjacent reflective plenum wall.

Figure 7 shows the effect of distance between 300 mm x 300 mm return air openings versus the DAI averaged for the two grid lines remote from the source. Generally, it appears that increased separation is beneficial but the improvement for practical purposes is minimal. In situations where there may be a row of offices, the separation would be maximized by locating the openings near the center of each office. However, this spacing (approximately 4 m), improves the DAI by less than 1 compared to when the openings are placed back-to-back with only the width of the partition separating them.

Of much greater concern, is the sound propogation through return air slots. A very simple method of controlling this flanking path was investigated. An open ended hood was placed above a light fixture, straddling the return air slots. The hoods were constructed from mineral fibre ceiling panels with the fissured surface facing the fixture.

Figure 8 shows the effect of the hood on level difference. For this test, three actual fixtures were used in each office, resulting in a total of 6 slots per room. Interestingly, the hoods not only eliminate flanking through the openings but also offer an additional improvement over the unpenetrated ceiling. This excess gain is thought to be caused by the increased absorption in the plenum provided by the exposed hoods.

Another, somewhat less common but more problematic, method of accommodating for return air near windows is through a continuous slot (typically 75 - 150 mm wide) which runs along the building perimeter. The slot is formed by terminating the suspended ceiling short of the exterior wall. When interior partitions are installed in this situation, a large opening between two offices is created.

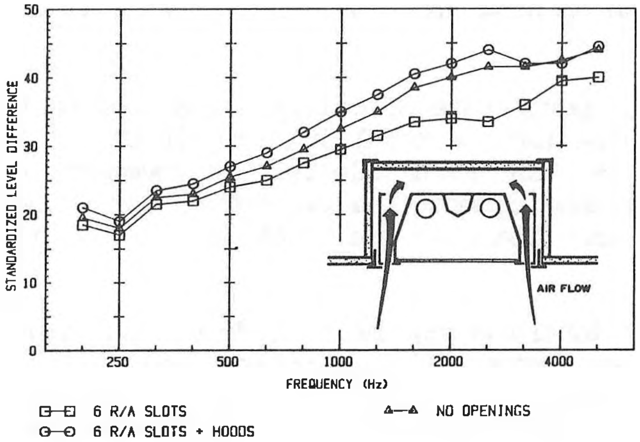


fig.8

level difference between offices indicating the effect of hoods placed above slotted light fixtures

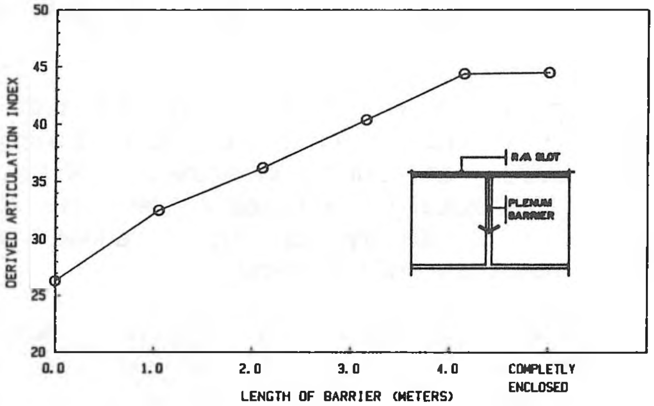


fig.9

effect of plenum barrier length on sound flanking through perimeter return air slot

One means of dealing with this flanking path is to introduce a partial barrier in the plenum starting at the exterior wall. The effect of such a barrier as a function of length is shown on Figure 9. Initially, a low value of isolation occurs because of the perimeter slot. The DAI decreases from 35 for an unpenetrated ceiling to 26 with the introduction of the slot. This type of return air opening has the most detrimental effect on sound isolation of all those investigated. However, a significant improvement takes place as a barrier is installed and extended along the wall.

Diffraction losses around the barrier are great enough at approximately the 2 m length to completely eliminate the effect of the return air slot. Sound isolation continues to increase as the barrier is carried across the entire length of the common partition. A negligible improvement is found when the barrier is further extended so as to enclose the entire plenum space of the receiving room.

PLENUM ABSORPTION

The addition of sound absorptive material to the plenum is a common method of reducing sound transmission between offices. Typically, batt insulation is laid directly on top of the suspended ceiling. It is improbable that this additional layer has a significant effect on the actual transmission loss of the ceiling panels. More likely, the presence of absorption helps to attenuate sound propogating along the plenum and controls flanking through cracks between the ceiling panels and the T-bar grid.

Plenum spaces that are crowded with ducting and other mechanical components may exhibit a somewhat similar effect by virtue of the diffusion and absorption that is present. Because the density and nature of the equipment differs tremendously, even within the same building, this variable was not investigated. Instead, a worst case situation was simulated where the plenum space was virtually empty.

The effect of absorption located directly above a suspended ceiling was determined by systematically increasing the number of batts placed symmetrically about the common partition. Standard RSI 2.1 insulation batts, 89 mm thick, were used. Measurements were made with and without return air slots in the ceiling. When slots were present, the batts were kept approximately 50 mm from the edge of the opening creating a 100 mm wide tunnel for the return air path.

Figure 10 plots the DAI against the percentage of ceiling area covered by absorption. For a ceiling without penetrations, a total increase in DAI of 10 occurs at 100% coverage. With slots, an even greater improvement of approximately 13 takes place. The difference between the two curves diminishes as more absorption is a added but the flanking due to the slots is still evident at full coverage.

Figure 11 shows an alternate way of interpreting the same data. The graph compares the change in DAI per square meter of absorption against the percentage of the ceiling area covered. This more directly relates to the cost effectiveness of this technique. As might be expected, for an unpenetrated ceiling, the effectiveness is greatest for the initial quantity of absorption and it continually diminishes as the coverage increases. When return air slots are present, plenum absorption is generally more effective than is the case for the unpenetrated ceiling and there appears to be an optimum coverage at approximately 40% - 60% of the ceiling area.

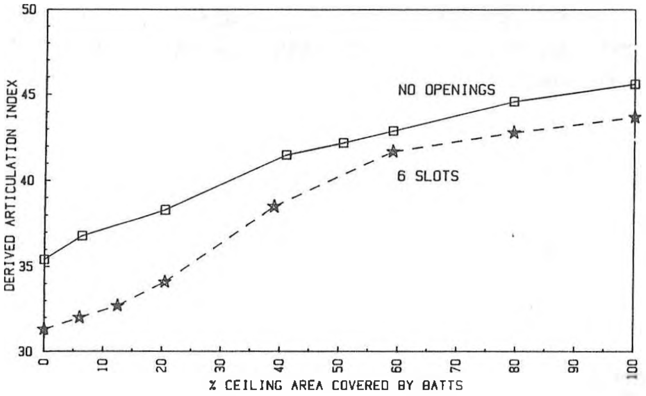


fig.10 sound isolation of mineral fibre ceiling versus area of batt insulation placed above panels

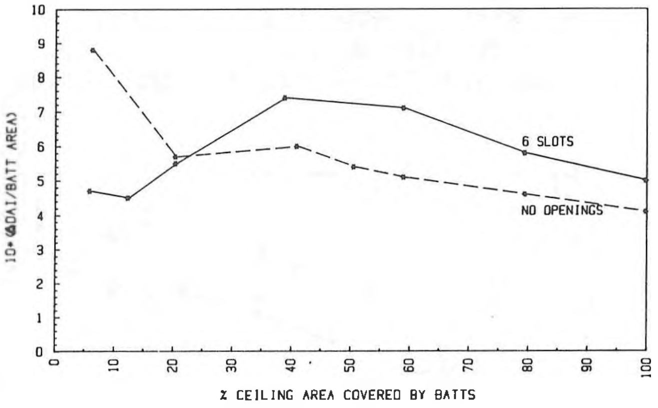
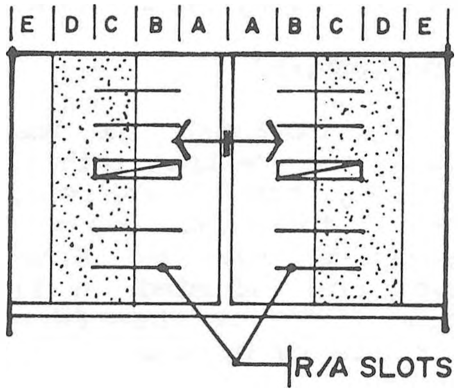


fig.11 effectiveness of absorption placed above suspended ceiling as a function of the quantity

Further testing, the results of which are summarized on Table II, revealed that the maximum effectiveness was actually more closely related to the relative location of the absorption with respect to the return air slots and the common wall rather than an optimum quantity. Initially, $10m^2$ of batt, representing approximately 40% ceiling coverage, was placed in a close array centered over the partition. The area of absorption was held constant but it was split into two equal sections and gradually separated. In the case with no slots there is a clear relationship between performance and location of absorption. Concentrating the absorption near the common partition appears to be the optimum arrangement. A similar trend occurs when return air slots are added to the ceiling, but the effect of placement is more pronounced. The DAI can vary by as much as 6 depending on location of the absorption. Figure 12 shows the level difference for two extremes in placement when slots are present.

TABLE II EFFECT OF BATT LOCATION

SLOT LOCATION	BATT LOCATION	DAI
-	-	35.4
-	AB (close array)	41.5
-	CD	38.6
-	DE	37.5
BC	-	31.2
BC	AB (close array)	38.5
BC	BC (2 areas)	38.5
BC	CD (2 areas)	34.1
BC	DE (2 areas)	32.2



A related test series, where the position of the slots was varied and absorption remained centered, showed that slot location is not very important. Although there was a slight improvement noted when the separation between return air slots in each room was maximized, the differences were typically less than 1dB in the critical frequency bands.

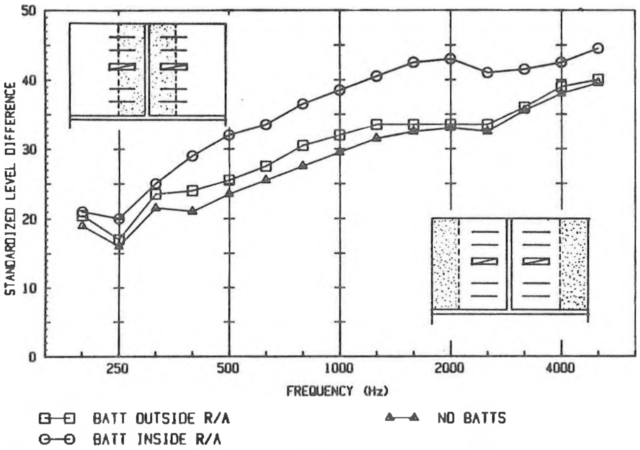


fig.12 level difference between offices indicating effect of extremes in batt location relative to position of return air slots

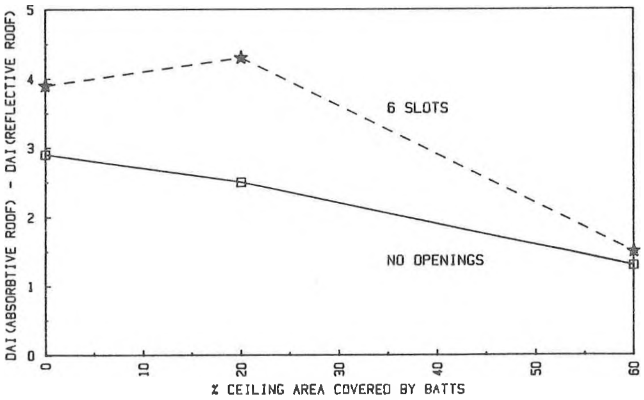
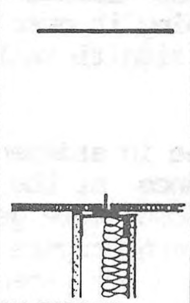
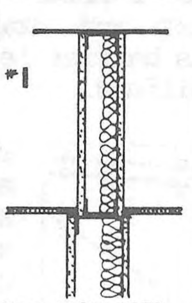
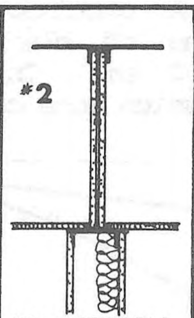
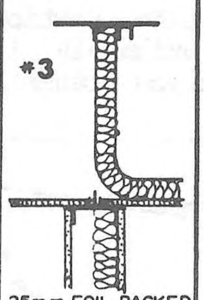


fig.13 improvement in sound isolation due to an absorptive plenum ceiling

Absorption in the plenum can also be found on the underside of a roof or floor slab in the form of a spray-on fireproofing material. Many of these products have reasonably good mid and high frequency sound absorption coefficients. A spray-on was simulated by attaching 25mm thick rigid insulation directly to the plenum ceiling. For some tests, batt insulation was also placed on top of the suspended ceiling to determine the combined effect of absorption at both locations. Results shown on Figure 13 indicate the direct improvement due to the addition of roof deck absorption for two ceiling configurations. Absorption applied to the upper surface of the plenum was not as effective as when it was placed on top of the suspended ceiling. Complete coverage of the plenum ceiling increased the DAI by a maximum of approximately 4. As indicated on Figure 10, this same increase can be achieved by covering only 25% of the ceiling panels with batt insulation. However, since the spray-on is likely to be installed for reasons other than sound isolation, any acoustic benefits derived from it are without cost. Combining absorption from the spray-on with a batt insulation overlay can give very substantial improvements, especially when the ceiling is ventilated.

PLENUM BARRIERS

In many instances, the most effective method of reducing sound transmission through the ceiling path, is to introduce a barrier into the plenum. This is especially helpful for ceilings with a very low transmission loss. DAI values obtained for three common types of barrier construction in combination with various ceilings are shown on Table III. The corresponding level difference curves are indicated on Figure 14 for the mineral fibre ceiling panels and Figure 15 for the glass fibre panels. Test results shown were obtained without any return air openings.

TABLE: III				
EFFECT OF VARIOUS PLENUM BARRIERS.	 NO BARRIER	 #1 91mm INSULATED DRYWALL	 #2 25mm DRYWALL	 #3 25mm FOIL BACKED INSULATION
CEILING PANEL TYPE.	DAI	DAI	DAI	DAI
MINERAL FIBRE PANEL # 7	35.4	48.3	46.5	39.8
GLASS FIBRE PANEL # 1	16.0	—	39.6	23.7
GLASS FIBRE PANEL #2	27.7	—	45.2	—

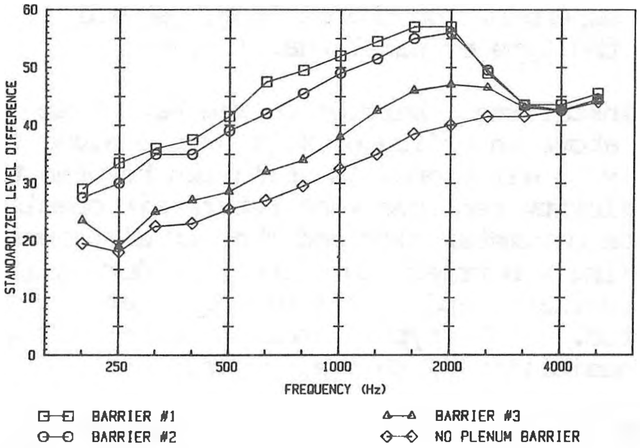


fig. 14 level difference between offices for various plenum barriers and mineral fibre ceiling panel #7

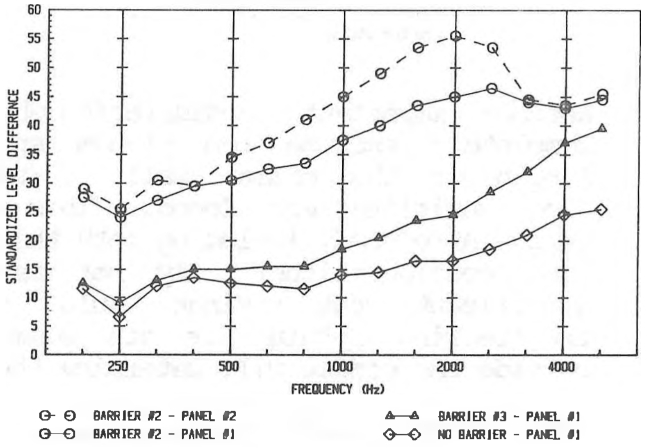


fig. 15 level difference between offices for various plenum barriers and glass fibre ceiling panels

Barrier #1 essentially transformed the dividing partition into a full height wall. The performance of this construction defined the upper limit of sound isolation for all test series. The prominent coincidence dip is typical of many offices but is not usually too serious since ambient noise levels in buildings are usually adequate to mask transmitted speech in these frequency bands.

Barrier #2, consisting of two layers of drywall placed back-to-back, is a more practical design where there may be a moderate amount of mechanical equipment to contend with. Joints can be offset and smaller pieces of drywall can be used for patching and fitting tightly up to ducts and conduit that penetrate the barrier. The drywall rested directly on the top track of the partition in order to avoid flanking through the ceiling panel or suspension system. Strips of insulation batt were used to caulk cracks between the barrier and abutting surfaces. This barrier was only slightly less effective than a full height wall when used in conjunction with the mineral fibre ceiling. With a glass fibre ceiling, the improvement afforded by the barrier is substantial but the poor performance of the ceiling panel limits the isolation over most of the frequency range. The slightly higher transmission loss of the foil backed glass fibre panel is beneficial and approximately defines the point at which further increases in ceiling performance have a minimal effect on overall isolation.

Foil faced insulation, used as Barrier #3, is desirable due to its ease of installation. A continuous barrier was formed by taping joints between separate sections of blanket and draping it over the top of the ceiling for approximately 300 mm. This barrier is significantly more effective when used with low transmission loss ceilings.

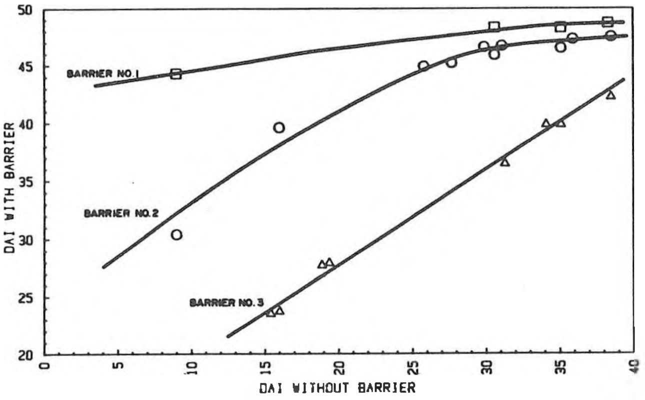


fig.16 sound isolation obtained with various plenum barriers as a function of the ceiling performance

The interdependance between the performance of the ceiling and the barrier is shown more generally on Figure 16. The graph compares numerous ceiling configurations measured with and without a barrier. It can be seen that the sound isolation with Barrier #1 is nearly independent of the ceiling. Isolation with Barrier #2 is reasonably constant when used in conjunction with a ceiling that provides a DAI of approximately 28 or more. This includes most of the mineral fibre ceiling configurations. The low transmission loss of Barrier #3 makes the overall isolation very dependent on the ceiling, regardless of the type of panel that is used.

Another important consideration when installing a barrier is whether it should completely enclose the plenum space above an office or just extend along the length of the common wall. Virtually no difference in isolation between the two conditions was found. This similarity remained when return air openings were introduced, including both the wide perimeter slot and the six distributed slot configurations. By not installing a barrier above the corridor wall, a significant cost savings would be realized and problems associated with transferring return air are eliminated. The type of occupancy immediately outside the office will determine the feasibility of this approach.

All of the above tests were performed with well-sealed plenum barriers. In practise, achieving a tight barrier is often a problem, particularly in buildings with open web joists and metal decking. Numerous openings occur when a barrier butts up to the metal deck and runs perpendicular to the direction of the flutes. The importance of flanking at this joint was measured using Barrier #2 and the mineral fibre ceiling. Six return air slots were introduced into the ceiling to make the effect of barrier flanking more sensitive. As shown on Figure 17, a substantial reduction of 5 - 10 dB over much of the frequency range is noted as a result of the unblocked openings.

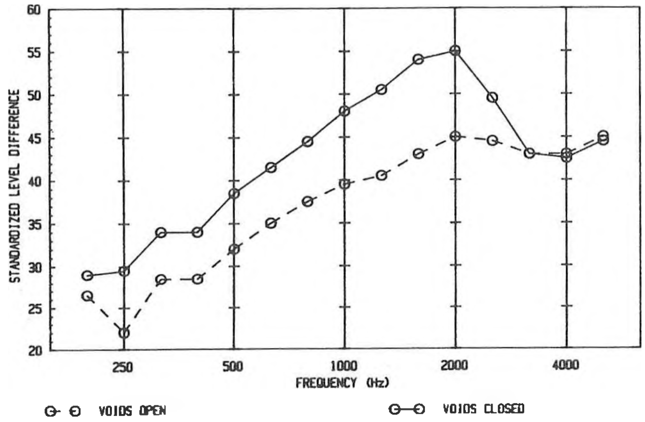
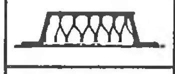
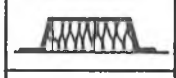
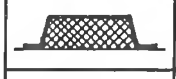
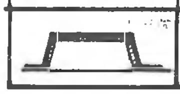


fig.17 level difference between offices indicating importance of flanking through deck flutes above plenum barrier

TABLE IV EFFECT OF FLUTE FILLERS

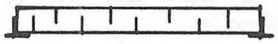
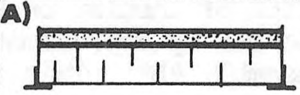
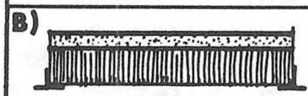
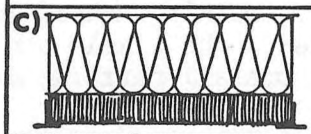
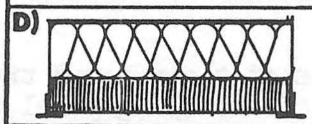
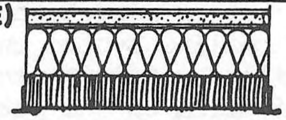
	FILLER	DAI
	NONE	39.8
	LOOSE BATT	42.7
	PACKED BATT	45.6
	FOAM CLOSURE	45.5
	SHEET METAL	41.0
	SHEET METAL (CAULKED)	45.6

Many materials can be used to fill these voids. The effectiveness of several common ones is indicated on Table IV. Low density glass fibre loosely fitted into the voids increased the DAI by approximately 3 but the voids were still a weak point. The same type of insulation, tightly compressed, nearly eliminated sound flanking. More elaborate fillers, actually intended to be used as air seals for this location, are comprised of preformed sheet steel or closed cell foam strips matching the profile of the metal decking. Insertion of the foam closures requires some compression thereby ensuring a good seal. This material proved to be very effective. The sheet steel closures were initially simply butted up to the metal decking, but small continuous cracks between closures and decking remained and consequently prevented an improvement in DAI. Caulking the joint along the entire profile of the decking restored full performance to the barrier.

SANDWICH CEILINGS

In a very crowded plenum, the construction of any kind of barrier becomes extremely difficult and time consuming. In these instances, it may be more practical to apply a backing to the suspended ceiling. Results for several sandwich assemblies are shown on Table V. DAI values are given for each assembly measured without any return air openings as well as with six return air slots.

TABLE V EFFECT OF VARIOUS SANDWICH CEILINGS

SANDWICH ASSEMBLIES		NO OPENINGS	6 R/A SLOTS
		DAI	DAI
	GLASS FIBRE PANEL #1.	16.0	15.4
	MINERAL FIBRE PANEL #7.	35.4	30.6
A) 	6mm DRYWALL GLASS FIBRE PANEL	36.9	32.6
B) 	6mm DRYWALL MINERAL FIBRE PANEL	40.6	33.1
C) 	89mm BATT MINERAL FIBRE PANEL	45.6	43.7
D) 	50mm BATT WITH FOIL BACK MINERAL FIBRE PANEL	46.9	40.2
E) 	6mm DRYWALL 25 mm BATT MINERAL FIBRE PANEL	44.3	36.6

The least expensive backing considered here was drywall. Full sheets were cut to size and placed on top of the ceiling panels. A 6 mm thick drywall was chosen so that the weight restriction for the suspended ceiling grid was not exceeded. The drywall increased the surface density of assembly "B", threefold. The corresponding increase in performance of 5 dB was not nearly the improvement that might be expected from the mass law. This shortfall was in part due to the fact that the drywall did not form a tight continuous backing leaving numerous small cracks between the ceiling panels and the T-bar. Some loss of plenum absorption also occurs since drywall is more reflective than the back side of the ceiling board. The effect of reduced back absorption is substantial, as indicated by a reduction in DAI of 7.5 when return air slots were introduced.

When drywall is used to back a glass fibre panel, as in assembly "A", the improvement is dramatic. The additional mass and flow resistance provided by the drywall accounts for an increase in DAI of approximately 21. Lack of absorption in the plenum is again evident from the results of the test with return air slots, although the improvement due to the backing is still substantial.

Results for assembly "C" indicate that glass fibre insulation is a much more effective backing for mineral fibre panels than is the drywall. Although the insulation batts do not significantly increase the mass of the ceiling, their benefit is derived from the substantial absorption that is added to the plenum. An absorptive backing is also beneficial in minimizing the effect of flanking through return air openings since the introduction of return air slots only reduced the DAI by about 2.

Foil faced insulation with the foil towards the plenum, as in assembly "D", provides a small further improvement in DAI compared to ordinary batt. Like the drywall backing, the foil also reduces absorption in the plenum, especially for frequency bands above 500 Hz and the effect of return air slots now becomes significant, causing a reduction in DAI of approximately 7.

Sandwich "E" combines batt insulation and drywall as backing materials. The transmission loss of this assembly is quite high, but because of a more reverberant plenum and the inevitable gaps which remain between drywall panels, the overall performance is actually slightly worse than assemby "C" which uses only insulation as a backing. However, the insertion of insulation between the ceiling board and the drywall does improve the DAI by approximately 4 when compared to the drywall-backed ceiling shown as assembly "B". This improvement is maintained even when return air openings are present.

Many of these sandwiches offer a substantial improvement over the basic suspended ceiling and perform nearly as well as a plenum barrier. The importance of avoiding even moderately reflective backing materials is quite obvious, especially if the ceiling is ventilated. The simple addition of a batt insulation backing appears to provide the best overall performance.

CONCLUSIONS

Suspended ceilings are often selected on the basis of their sound transmission loss rating. Attempting to simply match the STC of a ceiling panel to that of a wall system can lead to disappointing results. It is important to know the combined effect of the wall, plenum conditions and ceiling system including any flanking that might be introduced because of ventilation requirements. Return air slots, in particular, can impose a severe limitation on the performance of a ceiling. Practical methods of eliminating their effect have been described. Performance of the ceiling transmission path can be further improved by adding sound absorptive material to the plenum. Absorption was found to be most effective when placed directly on the back of the ceiling panels and centered about the common partition. This placement is especially important when return air slots are present. Various other backing materials can also be used to increase sound isolation when applied over the entire ceiling. The performance of these sandwich assemblies exhibited a marked dependence on their absorptive properties, as seen from the plenum, in order to minimize the effect of flanking through return air slots. Plenum barriers offer the greatest potential for increasing sound isolation especially when used in conjunction with low transmission loss ceilings. Barriers must be reasonably massive and well-sealed to realize their full benefit but they do not necessarily need to completely enclose the plenum space above an office.

ACKNOWLEDGMENTS

The considerable participation of Mr. Martin F. Fayers in initiating this study and assisting with the planning and execution of the testing, is gratefully acknowledged.

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May 11-12	Thunder Bay, Ont.	Machine Health Monitoring

DATE	PLACE	TITLE
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May 26-27	St. John's, Nfld.	Intensity Measurements
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June 1-2	Ottawa, Ont.	Signal Processing
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1988, 16(2): 27-37*

Prédiction des conditions sonores dans les salles de classe au moyen des caractéristiques physiques de l'environnement

Sylvie A.Bilodeau, Raymond Hétu,
Groupe d'acoustique de l'Université de Montréal
C.P. 6128, Succursale "A"
Montréal, Qué. H3C 3J7

SOMMAIRE

Une recherche-terrain a été menée dans 50 classes de six écoles primaires de l'île de Montréal dans le but d'identifier des conditions physiques susceptibles de prédire l'intelligibilité de la parole dans les classes. Un modèle empirique fondé sur l'évaluation du rapport signal-bruit en dBA et de la durée de réverbération à 1000 Hz [Bradley, J.Acoust. Soc. Am., 1986: 846-854] a été utilisé. Trois variables ont été identifiées comme étant prédictives d'une intelligibilité de la parole optimale dans les classes soient l'absence de bruit de ventilation, la fermeture des aires par des cloisons complètes et la présence de tuiles acoustiques au plafond.

ABSTRACT

A field study has been conducted in 50 classrooms from 6 primary schools in Montreal in order to identify physical characteristics that would predict speech intelligibility in classrooms. An empirical model founded on the evaluation of the signal-to-noise ratio in dBA and of the reverberation time at 1000 Hz [Bradley, J. J. Acoust. Soc. Am. 1986, 80: 846-854] has been used. Three variables have been identified as predictors of an optimal speech intelligibility in classrooms, namely the absence of ventilation noise, the enclosure of the rooms by complete partitions and the presence of acoustic tiles on the ceiling.

INTRODUCTION

En raison des activités d'enseignement qui se déroulent dans les salles de classe, il est essentiel d'y trouver d'excellentes conditions de propagation de la parole. Pour une intelligibilité de la parole favorable aux apprentissages des enfants, le niveau de bruit doit être faible et la réverbération de courte durée.

Plusieurs auteurs[1,2] rapportent que l'exposition à un niveau de bruit élevé peut entraver le développement de la parole et du langage chez l'enfant, pouvant ultérieurement se traduire par des difficultés au niveau de la lecture et des habiletés d'écoute. D'autre part, on sait que la discrimination de la parole décroît avec l'augmentation de la durée de la réverbération dans un local et ce, de façon plus marquée chez les enfants que chez les adultes [3,4].

Au plan pratique, il est nécessaire de savoir si les nombreux locaux d'enseignement de notre système scolaire satisfont des critères optimaux d'intelligibilité. L'intelligibilité de la parole dans un local peut être mesurée de façon directe en appliquant une épreuve de discrimination auditive auprès d'un groupe d'individus. Pour évaluer l'intelligibilité de la parole dans plusieurs locaux tels les salles de classe, les tests de discrimination auditive doivent être effectués auprès de groupes homogènes d'individus, soient des enfants dont l'âge, l'origine socio-économique, les habiletés d'apprentissage et l'acuité auditive sont similaires. Ainsi, nombreux sont les facteurs à contrôler dans l'application d'une mesure directe d'intelligibilité de la parole.

Une estimation de l'intelligibilité de la parole peut être faite en s'appuyant sur les résultats d'études mettant en relation des mesures d'intelligibilité de la parole et des descripteurs d'ambiances sonores nuisibles.

On dispose ainsi de six prédicteurs de l'intelligibilité de la parole:

- le niveau de pression acoustique pondéré A du bruit[5],
- le niveau perturbateur de l'intelligibilité (Speech Interference Level)[6],
- l'indice d'intelligibilité (Articulation Index)[7],
- le rapport signal-bruit en dBA (S/N (A))[8],
- la fonction de transfert de modulation (Speech Transmission Index)[9],
- le ratio utile/nuisible du signal (useful/detrimental ratio)[8].

Lors d'une étude comparative, Bradley[10] a mis en évidence une efficacité pratiquement équivalente de plusieurs prédicteurs de l'intelligibilité de la parole dans les salles de classes. Dans ce contexte, le prédicteur le plus facile d'application est le rapport signal-bruit en dBA couplé à une mesure de la durée de réverbération. Bradley a obtenu une corrélation de 0,81 entre, d'une part, le rapport S/B en dBA associé à une mesure de la durée de réverbération dans la bande d'octave de 1kHz et, d'autre part, les pourcentages d'intelligibilité de la parole obtenus auprès d'enfants de 12-13 ans. Pour des enfants de cet âge, Bradley a de plus relevé qu'un niveau de bruit de fond inférieur à 35 dBA et une durée de réverbération entre 0,4 et 0,5 seconde dans la bande d'octave centrée à 1 kHz sont nécessaires pour une intelligibilité de la parole excellente (100%) dans les salles de classe.

Bien qu'il soit facile pour un acousticien d'évaluer la conformité d'un local avec ces critères, il faudrait un temps et des investissements importants pour évaluer l'ensemble des locaux d'un système scolaire donné. C'est pourquoi nous avons, dans la présente étude, cherché à déterminer des caractéristiques des locaux à la fois faciles à identifier pour un non-acousticien et prédictives de bonnes conditions d'intelligibilité verbale.

BUT DE LA RECHERCHE

L'étude avait pour but d'éprouver l'hypothèse selon laquelle, dans les classes, l'identification des conditions d'aménagement et des sources de bruit intrusif (circulation, activités des locaux adjacents, etc.) permet de prédire l'intelligibilité de la parole telle qu'évaluée au moyen du rapport signal-bruit et de la durée de réverbération.

METHODOLOGIE

Locaux visités

Cette recherche exploratoire fut menée entre les mois de janvier et avril 1987 dans 50 classes réparties en six écoles primaires de l'île de Montréal. Le choix des écoles a été effectué en tâchant de maximiser les différences en termes de conditions d'aménagement et d'exposition à des sources de bruit extérieur. Le Tableau I résume les principales caractéristiques des écoles recrutées. Ainsi, l'échantillon comptait notamment deux écoles à aires ouvertes construites récemment et une école âgée de plus de 60 ans, ces dernières étant localisées près d'artères jugées achalandées par la direction de l'école; les trois autres écoles étaient peu exposées au bruit de circulation urbaine, mais l'une d'elle était située dans l'axe d'un corridor aérien. Une seule école déservait une clientèle socio-économiquement favorisée (tel que définie selon la classification de la Commission scolaire). La taille des écoles variait pour les extrêmes par un facteur légèrement supérieur à deux, soitent 550 enfants par rapport à 235.

Tableau I. Caractéristiques des écoles visitées en termes d'âge de la construction, d'ouverture ou de fermeture des aires, de taille et de classification socio-économique de la clientèle ainsi que de l'achalandage routier et aérien environnant.

Ecole	Age (ans)	Aires	Milieu socio-économique	Nombre d'enfants	Circulation routière	Circulation aérienne
A	16	ouvertes	faible	450	achalandée	négligeable
B	16	ouvertes	faible	250	achalandée	négligeable
C	47	fermées	favorisé	235	négligeable	négligeable
D	69	fermées	faible/moyen	300	achalandée	peu achalandée
E	24	fermées	faible/moyen	334	négligeable	achalandée
F	64	fermées	hétérogène	550	peu achalandée	peu achalandée

Dans chaque école recrutée, trois types de données furent recueillies soient: (a) des commentaires des enseignants sur les conditions sonores de leur classe et l'aménagement habituel du local lors des périodes d'enseignement, (b) des observations sur les caractéristiques visibles des parois (e.g. présence de tuiles acoustiques au plafond), sur l'aménagement du local (e.g. disposition du mobilier) et sur les sources de bruit audible (e.g. bruit de conduite d'eau) et (c) des mesures du niveau de bruit de fond, de la durée de réverbération, des dimensions des locaux et des distances maximales entre le locuteur et le récepteur.

Mesures acoustiques

Les niveaux de bruit de fond furent mesurés à l'aide d'un sonomètre intégrateur Brüel and Kjaer (BK 2225) muni d'un microphone à condensateur d'un demi pouce (BK 4175), le tout calibré à l'aide d'une source étalon (BK 4230) avant et après chaque série de mesures. Le sonomètre était opéré en fonction $L_{Aeq,60s}$ et tenu à l'horizontal à un mètre du sol.

Dans un premier temps, entre 5 et 15 relevés de bruit furent effectués dans chaque classe afin d'obtenir une mesure fiable du bruit de fond, le critère étant une différence moyenne d'au plus 2 dB entre les relevés. Si des mesures réalisées une semaine plus tard montraient un écart supérieur à ± 2 dB, des mesures supplémentaires étaient effectuées afin d'obtenir une estimation représentative du bruit ambiant.

Pour éviter que la mesure du bruit de fond ne soit entachée par l'influence du type d'activités en cours dans les classes, les mesures de bruit furent recueillies dans des conditions sonores optimales, c'est-à-dire en l'absence des enfants dans le local mais pendant que des activités normales d'enseignement se déroulaient dans les locaux adjacents à la classe visitée.

Les durées de réverbération ont été obtenues lorsque les enfants étaient absents de l'école. Elles ont été mesurées au moyen d'un analyseur BK-4418, d'une source de puissance normalisée (BK-4224), d'un pré-amplificateur (BK-2619) et d'un microphone à pression (BK-4134). Ce dernier était placé au centre de la pièce à 1,55 mètre du sol alors que la source sonore était installée successivement dans au moins deux coins de la salle, dans un angle de 45° par rapport au sol. Les durées de réverbération étaient recueillies dans les bandes de tiers d'octave centrées à 800, 1000 et 1250 Hz, la moyenne de ces valeurs étant retenue pour caractériser la durée de réverbération dans la bande d'octave centrée à 1 kHz.

Traitement des données

Les rapports S/B en dBA furent déterminés dans chaque classe pour l'enfant le plus éloigné du professeur en estimant le niveau de pression acoustique de la voix de l'enseignant à cette distance et en y soustrayant le niveau de bruit de fond moyen relevé dans le local étudié.

Le niveau de pression acoustique de la voix du professeur était obtenu selon l'équation suivante:

$$L_S = L_W + 10 \log \left[\frac{Q}{4 \Pi r^2} + \frac{4}{A} \right] \text{ en dB} \qquad [1]$$

où L_S en dB est le niveau de pression acoustique de la voix du locuteur lorsque mesurée à une distance r en mètres, L_W est la puissance acoustique de la voix en dB (re: 10^{-12} Watts/m^2), Q est le facteur de directivité du locuteur, et A, l'aire d'absorption équivalente du local évaluée en m^2.

La directivité moyenne de la voix mesurée dans un angle de 0° à 0,5, 1, 2 et 4 kHz est généralement évaluée à Q=2,5 pour un locuteur situé à l'avant d'une salle tel un professeur dans une classe[12,13]. Dans les salles de classe quasi-cubiques, l'aire d'absorption équivalente s'évalue à partir de l'équation de Sabine fondée sur l'hypothèse d'un champ diffus:

$$A = \frac{0{,}161\ V}{TR} \text{ en m}^2 \qquad [2]$$

où V représente le volume de la pièce en mètres-cubes (m^3) et TR, la durée de réverbération en secondes. Dans la présente étude, une valeur de 10 m^2 a été ajoutée à l'aire d'absorption équivalente de chaque classe pour tenir compte de l'absorption par les enfants lorsqu'ils sont dans la classe. Ce correctif est obtenu en évaluant à 25 le nombre moyen d'enfants par classe et à 0,4 m^2 l'aire d'absorption équivalente pour chaque enfant[14]. La durée de réverbération TR a été estimée à partir des mesures pour la bande d'ocatve centrée à 1 kHz.

Par des mesures en chambre anéchoïque où l'absorption équivalente est très grande, Pearsons et al. [11] ont établi que le niveau de la voix normale mesuré à un mètre est de 58 dBA pour un homme et de 55 dBA pour une femme, ce qui représente des puissances acoustiques respectives de 65et 62 dBA.

Sur la base de ces données, il est possible de calculer le niveau de pression acoustique de la voix d'un enseignant en tout point de la classe.

Quant au niveau de bruit de fond moyen, il a été obtenu pour chaque classe d'après l'équation 3:

$$L_B = 10 \log 1/T \sum_{i=1}^{n} 10^{(L_i/10)} \cdot t_i \quad \text{en dBA} \qquad [3]$$

où T représente le temps total de mesure, L_i le niveau de bruit de fond mesuré en $L_{Aeq,60s}$ durant le temps t_i.

Les rapports S/B en dBA ont donc été obtenus pour chaque classe par le calcul suivant:

$$S/B = L_S - L_B \qquad [4]$$

où L_{pS} est la résultante de l'équation 1 et L_{pS}, la résultante de l'équation 3. Connaissant les rapports S/B en dBA et les durées de réverbération à 1 kHz, les pourcentages d'intelligibilité de la parole ont été calculés pour chaque classe à l'aide de l'équation 5 telle que définie par Bradley[10]:

$$IP = 2{,}26\ S/B - 0{,}0888\ S/B^2 - 13{,}9\ TR_{1kHz} + 95 \quad \text{en \%} \qquad [5]$$

dans laquelle IP représente le pourcentage d'intelligibilité de la parole, S/B est le rapport signal-bruit en dBA et TR_{1kHz}, la durée de réverbération à 1 kHz telle que mesurée dans une classe.

RESULTATS

Parmi les six écoles visitées, une seule présentait des conditions sonores conformes au critère proposé par Bradley[10] en termes de niveau de bruit de fond et de durée de réverbération. L'intelligibilité de la parole pour la moyenne des classes est de l'ordre de 70% à l'école A, de 90% aux écoles B, C, D et E et elle s'avère excellente pour toutes les classes de l'école F comme le montrent les résultats présentés à la Figure 1.

Des mesures d'association ont été effectuées entre les caractéristiques physiques identifiant dans les classes (conditions d'aménagement et sources de bruit intrusif) et les conditions sonores mesurées (niveau de bruit de fond et durée de réverbération). Le Tableau II montre le résultat des tests de X^2 dans le cas les variables nominales ou ordinales décrivant le milieu visité. Trois variables nominales éventuellement importantes n'ont pas été considérées parce que décrivant des conditions à toutes fins utiles identiques pour toutes les classes visitées. Il s'agit des bruits audibles provenant d'autres classes, des bruits provenant du corridor et du bruit provenant de l'éclairage au fluorescent. Le degré d'association avec les caractéristiques physiques définies sur des échelles numériques a été évaluée au moyen du coefficient de corrélation de Pearson dont les résultats sont présentés au Tableau III.

Tableau II. Résultat des tests d'association (X^2) entre les caractéristiques physiques des locaux, les niveaux de bruit de fond (L_{Aeqn}) et les durées de réverbération (TR).

Caractéristiques physiques	Conditions sonores			
	L_B		TR	
	X^2	d l	X^2	d l
Présence d'animaux dans les classes	0,12	2		
Bruits de conduites d'eau	6,69	2		
Bruits des horloges	3,80	2		
Bruits des urinoires	3,23	2		
Bruits des micro-ordinateurs	1,41	2		
Bruits des autos	7,45	2		
Bruits des avions	7,44	2		
Achalandage routier	24,52*	4		
Achalandage aérien	3,12	2		
Bruits audibles de ventilation	25,04*	2		
Milieu socio-économique	43,82*	6		
Bruits audibles provenant de l'extérieur de l'école	15,83*	2		
Tapis au sol	28,64*	2	13,43*	2
Tuilles acoustiques au plafond	8,17	2	40,88*	2
Rideaux devant les fenêtres	7,54	2	5,20	2

* associations statistiquement significatives au seuil de 0,01.

Tableau III. Coefficients de corrélation linéaire entre les caractéristiques physiques de type numérique et les conditions sonores mesurées dans les classes. La probabilité "p" que la corrélation soit significativement différente de zéro est également indiquée.

Caractéristiques physiques	Conditions sonores			
	L_B		TR	
	r	p	r	p
Nombre d'enfants par école	0,005	0,49	-0,007	0,21
Age de l'école	-0,66	<0.01	0,27	0.03
Volume des classes	-0,18	0,45	0,17	0,11
Distance entre locuteur et récepteurs	-0,004	0,67	-0,005	0,49

Il ressort de ces deux tableaux que les variables "achalandage routier", "bruit de ventilation", " milieu socio-économique", "bruits provenant de l'extérieur", "présence de tapis au sol" et "âge de l'école" sont significativement associées au niveau de bruit de fond alors que la dernière de ces variables ainsi que les variables "tapis au sol" et "tuiles acoustiques au plafond" sont associées à la réverbération.

De nombreux liens de colinéarité pouvant exister entre ces différentes variables, il fut nécessaire d'isoler les facteurs confondants. En effet, le milieu socio-économique faible était confondu avec la présence de bruit de ventilation et d'un achalandage routier important. Les bruits provenant de l'extérieur de l'école n'étaient audibles qu'en l'absence de bruit de ventilation. Le tapis au sol était confondu avec la présence de bruit de ventilation et n'était présent que dans les écoles à aires ouvertes. L'âge de l'école était systématiquement associé aux variables milieu socio-économique et présence de bruit de ventilation.

Nous avons donc introduit une nouvelle variable, soit "l'ouverture des aires", permettant de distinguer les classes en aires ouvertes des locaux en aires fermées. Après épurement de l'analyse, les variables statistiquement associées aux conditions sonores dans les classes étaient les suivantes: l'achalandage routier, le bruit de ventilation, les tuiles acoustiques au plafond et l'ouverture des aires.

A partir de ces caractéristiques physiques, nous avons tenté de définir un modèle prédictif des conditions sonores dans les 50 classes visitées au moyen d'analyses de régression multiple.

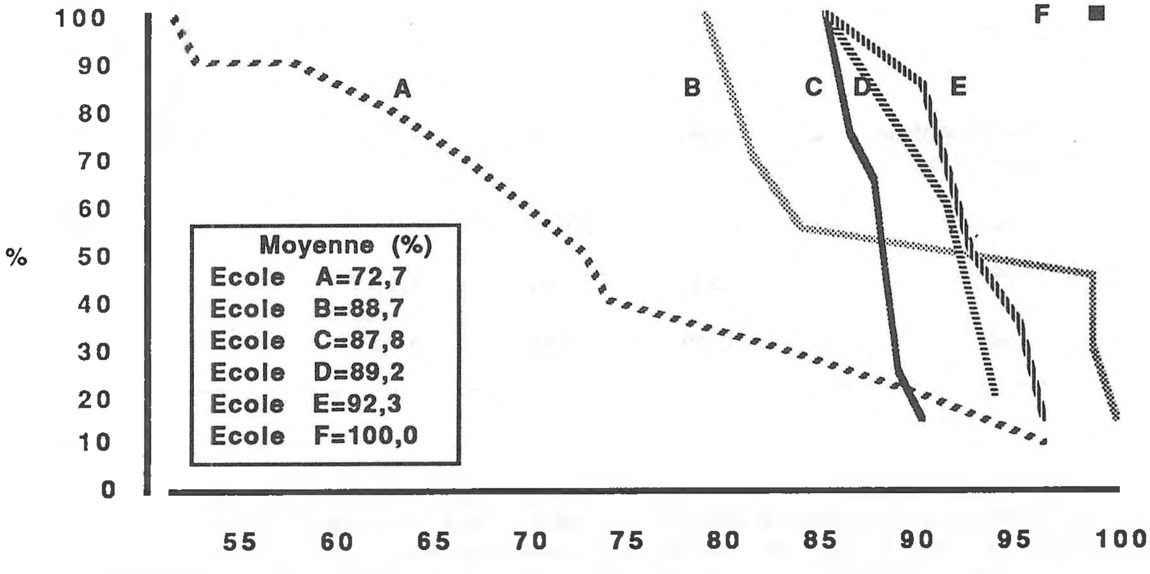

Figure 1 : Distribution cumulative des indices d'intelligibilité de la parole calculés dans chacune des écoles.

Tableau IV. Résultats des analyses de régression multiple permettant la prédiction des conditions sonores dans les locaux de classes. Les variables prédictirices ont été traitées comme variables factices ("dummy"). Les rapport F, les degrés de liberté correspondant (dl) et le coefficient de détermination R^2 sont indiqués pour chacune des trois régressions.

Conditions sonores			Variables			Ordonnée à l'origine
			Ventilation	tuiles acoust.	ouverture des aires	
L_B	Coefficient de régression	=	7,86	-2,64	3,79	40,24
	Rapport F	=	61,4	35,0	26,6	
	Degrés de liberté	=	1,48	2,47	3,46	
	R^2	=	0,56	0,60	0,63	
TR	Coefficient de régression	=		- 0,85		1,35
	Rapport F	=		288,5		
	dl	=		1,48		
	R^2	=		0,86		
IP	Coefficient de régression	=	-9,96	10,19	- 16,76	89,77
	Rapport F	=	25,0	30,0	46,7	
	dl	=	3,46	2,47	1,48	
	R^2	=	0,62	0,56	0,49	

Les résultats présentés au Tableau IV montrent que l'ouverture des aires contribue à l'augmentation du niveau de bruit de fond et par le fait même, à une diminution de l'intelligibilité de la parole dans les classes. Dans les écoles à aires ouvertes, les classes sont séparées les unes des autres par des cloisons partielles, situation qui favorise la propagation des bruits et des voix entre les aires et l'élévation du niveau de bruit de fond.

De même, le bruit produit par les systèmes de ventilation contribue à réduire l'intelligibilité de la parole dans les classes. Ce bruit est généralement introduit de façon intentionnelle dans les écoles à aires ouvertes dans le but de masquer les bruits des activités adjacentes pouvant interférer avec l'enseignement. Les données de la présente étude montrent au contraire que le bruit de ventilation mesuré dans les classes visitées est nuisible à l'intelligibilité de la parole.

En dernier lieu, la présence de tuiles acoustiques au plafond permet, comme on pouvait s'y attendre, de réduire la réverbération et ainsi d'améliorer l'intelligibilité de la parole dans les classes.

Il est à noter que la contribution de la variable achalandage routier à la prédiction des conditions sonores s'est avérée non-significative lorsque les autres variables étaient prises en compte simultanément.

DISCUSSION

Au minimum, trois conditions devraient être respectées afin d'offrir des conditions optimales d'intelligibilité de la parole dans les classes visitées, soient l'absence de bruit de ventilation, des locaux à aires fermées et un plafond recouvert de tuiles acoustiques.

Il convient toutefois d'apporter des réserves à la généralisation de ces résultats en raison du modèle empirique utilisé. L'application du modèle de Bradley[10] comporte en effet certaines limites, notamment les suivantes:

1- L'équation de prédiction de l'intelligibilité de la parole à partir des conditions sonores a été établie pour des enfants de 12-13 ans. Puisque des enfants de niveau primaire (6-12 ans) ont besoin de conditions sonores encore plus favorables, les valeurs d'intelligibilité de la parole de la présente étude ont probablement été surestimées.

2- Aucune école à aire ouverte n'était comprise dans l'échantillon de Bradley alors que le nôtre en comptait deux. En appliquant le modèle de Sabine dans ces écoles, le volume total de l'aire dans laquelle la durée de réverbération était mesurée a été pris en compte dans le calcul de l'absorption équivalente. La valeur de l'absorption sonore équivalente a donc d'être surestimée. L'influence de ce facteur est toutefois peu importante pour le calcul de l'intelligibilité de la parole.

3- Pour les classes ayant une durée de réverbération inférieure à celle recommandée (0,4-0,5 secondes), aucun terme correctif n'a été introduit ne connaissant pas l'influence exacte de telles conditions; cependant, dans ces conditions, l'intelligibilité de la parole risque d'être diminuée.

4- Le modèle empirique ne prend pas en compte le caractère perturbateur des divers bruits perçus dans les classes. Puisque les bruits porteurs d'information masquent davantage la parole que d'autres bruits non-significatifs[15], il est plausible que les voix provenant d'autres classes soient très perturbatrices pour l'enseignement, en particulier en situation d'aires ouvertes.

Pour généraliser l'application du modèle prédictif de l'intelligibilité de la parole dans les salles de classe, celui-ci devrait, à notre avis, prendre en compte l'âge des enfants, la nuisance des divers bruits pour l'enseignement ainsi que les effets éventuels de durées de réverbération à 1kHz inférieures à 0,4 seconde.

La portée des résultats de la présente étude est par ailleurs limitée par les conditions spécifiques dans lesquelles les données ont été recueillies. Ainsi, les résultats obtenus sont valables pour la saison d'hiver, au Québec, alors que les fenêtres des classes fermées limitent la contribution des bruits provenant de l'extérieur de l'école. Les pourcentages d'intelligibilité de la parole ont de plus été obtenus pour des conditions optimales, sans considérer le bruit généré par la présence des enfants dans les classes. Enfin, la contribution éventuelle de variables telles que la circulation urbaine, aérienne ou ferroviaire et les bruits provenant des autres classes ou du corridor ne peut être exclue même si nos résultats n'ont pu en dégager l'influence sur le niveau de bruit de fond mesuré dans les classes.

Un élargissement de notre échantillon ou la redéfinition de certaines de ces variables aurait éventuellement permis d'expliquer une portion additionnelle de la variance des conditions sonores et des estimations de l'intelligibilité. Il y aurait lieu notamment d'éprouver d'autres descripteurs du bruit généré par la circulation urbaine au voisinage de l'école et de la transmission sonore entre les locaux de classe, lesquels descripteurs ne seraient pas issus de mesures acoustiques. Ceux-ci pourraient être, pour l'un, la fréquence et la proximité des véhicules automobiles circulant à proximité de l'école en un temps donné et, pour l'autre, la description des matériaux composant les parois entre les classes de façon à estimer leurs propriétés insonorisantes.

CONCLUSION

La présente étude montre qu'il est possible pour un non-acousticien d'évaluer la qualité de l'intelligibilité verbale des locaux de classe à partir de caractéristiques physiques du milieu. Dans la majorité des écoles recrutées, nous avons identifié des conditions inadéquates d'intelligibilité de la parole. Bien que les résultats de cette recherche ne soient pas généralisables à l'ensemble des écoles primaires du milieu urbain québécois ou canadien en raison du faible échantillon considéré, il est peu probable que nous ayons rejoint les seules écoles réunissant les conditions sonores les plus défavorables. Nos résultats sont dans ce sens une bonne indication à l'effet que l'intelligibilité de la parole n'est pas optimale dans plusieurs écoles. Ils démontrent la nécessité d'entreprendre une vaste enquête conduisant à une description représentative des conditions d'intelligibilité de la parole dans le milieu scolaire.

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ACOUSTICS WEEK 1988
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ACTIVITY CALENDAR

Monday, October 3	–	Seminars
Tuesday, October 4	–	Seminars
Wednesday, October 5	–	Workshops
Thursday, October 6	–	Symposium
Friday, October 7	–	Symposium

Programmes, registration forms, and hotel reservation cards will be mailed to all members before August 15, 1988. Please register as soon as possible so that we can plan properly. Students who want to register should give their summer address to the Secretary of the Organizing Committee:

Mrs. Francine Parry,
c/o Bilsom International,
1 St. Clair Ave. E., Suite 503,
Toronto, Ontario M4T 2V7
Telephone: 416-922-4567
Fax: 416-922-4616
Telex: 06-217746

SYMPOSIUM NEWS

Abstract should be submitted before June 1, 1988. Full paper should be submitted before August 15, 1988 to the Technical Programs Chairman:

Mr. Alberto Behar,
c/o Ontario Hydro,
757 McKay Road,
Pickering, Ont. L1W 3C8
Telephone: 416-683-7516
Fax: 416-683-7516 Ext. 286

SOCIAL EVENTS

Toronto offers many attractions. Those accompanying members, but not attending the Technical Sessions, will be entertained by John Kowalewski, our Social Chairman and his group.

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Limited space available, please reserve early.

SEMINARS AND WORKSHOPS

Details of the seminar curriculum and the workshop topics will be made available and distributed as soon as possible. The Chairman is:

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Toronto Ont.
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During Acoustics Week the ISO/TC43/IEC/TC29 will also be meeting in Toronto and are registered in the Westbury Hotel. This should offer opportunities to meet our colleagues from other countries. We suggest that you stay in the Westbury during your stay in Toronto. The hotel is close to all downtown activities. Our group rate for facilities rental depends on how many are registered in the hotel. The corporate rate is $89.00 per day (average downtown Toronto hotel rates are $135.00 per day). By staying in this hotel we keep our registration costs low, thus supporting ourselves.

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NEWS / INFORMATIONS

Seminars and courses / Séminaires et cours

Inner Ear Biology Workshop. September 4th-7th, 1988, University College, London. Contact: Andrew Forge, Institute of Laryngology and Otology, 330 Gray's Inn Road, London WC1X8EE, United Kingdom. [tel. (44-1) 837 8855 ext 4169.]

International Symposium on "Clinical Applications of Otoacoustic Emissions" (Satellite Symposium, of the Ist European Congress of Ot-Rhino-Laryngology). September 30 - October 1, 1988. Contact: Ms A. Bara, Symposium Secretariat, INSERM-U.254, Hôpital St-Charles, 34059 Montpellier Cedex, France. [tel. 67.33.65.15]

Institute of Acoustics - One-Day Meeting: Noise Control in Factory Buildings, June 27, 1988, University of Salford. Contact: Dr R. J. Orlowski, Department of Applied Acoustics, University of Salford, Salford M5WT, United Kingdom. [tel. (061) 736 5843 ext 7145]

13th International Seminar on Modal Analysis, September 19-23, 1988, Leuven, Belgium. Contact: Prof. P. Sas, K.U. Leuven, Afdeling Mechanische Konstruktie en Produktie, Celestijnenlaan 300b, 3030 Leuven, Belgium (tel. (32) 016 286211 ext 2480; Fax. 016 23.99.07]

Conferences / Congrès

History of Ultrasound Symposium, October 15-16, 1988, Washington, D.C., prior to the 1988 World Meeting of Ultrasound (Oct. 18-21). Contact: AIUM, 4405 East-West Highway, Suite 504, Bethesda, MD 20814. [tel. 301 656-6117]

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.

From another journal in acoustics.../ D'un autre périodique en acoustique...

BULLETIN D'ACOUSTIQUE

ABSTRACTS from N^{o} 3, December 1987

Prediction of sound pressure levels in open space: Application of the sound ray techniques
by P. NOEL

In this paper, the sound ray simulation method is applied to the determination of sound pressure levels in open space. It is described how to modelise some characteristic phenomena of outside propagation: refraction due to wind or temprerature gradients (stratification of atmosphere at fixed ray length), diffraction on barriers and spherical receptors.

Prognosis of sound levels near road tunnels.
Second part: Efficiency of an acoustical treatment of the walls.
by J. LECLERC

This article is the second part of a general investigation of the sound field generated outside a road tunnel by the traffic flow inside. A mapping of equivalent levels L_{eq} is obtained for moving sources and the efficiency of an acoustical treatment of the walls is evaluated. A full parametric study is also conducted and confirmed by scale models and 'in situ' measurements.

Conference Proceedings

Prospects in Modern Acoustics - Education and development
Gdansk - Jastrzebia Gora, Poland, 19-21 May 1987

The conference, held in Gdansk - Jastrzebia Gora, Poland on 19-21 May 1987, was sponsored by the International Union of Pure and Applied Physics - Commission on Acoustics, the Polish Academy of Sciences - Committe on Acoustics, the Polish Acoustica l Society, and the Polish Noise Abatement League. The University of Gdansk and the Technical University of Gdansk supported the activities of the Organizing Committee. The International Advisory Committee consisting of 49 outstanding acousticians helped in the preparations for the conferecne. Most of the Advisory Committee members took part in the conference.

There was a total of 94 participants. Many countries of the world were represented: Canada, Czechoslovakia, Denmark, France, FRG, GDR, The Netherlands, Hungary, India, Italy, Norway, Poland and USA.

The program of the conference devoted the fisrt and the last day to debates and discussions, while during the second day there were visits to the Gdansk Universities and acoustical laboratories, as well as for a sightseeing tour in the old city of Gdansk. There were 44 papers preesented during the debates: 25 invited lectures, seven contributed papers and 12 poster presentations. In addition to the discussions which followed the presentations of papers, two general discussions were organized. The discussions were recorded and a concise abstract has been written for inclusion in the Proceedings of the conference.

Although the main theme of the debates was education in acoustics, many aspects were presented and discussed with consideration to various fields of acoustics, as well as acoustical applications. The interdependence between physics and applied acoustics and their inseparable relations were strongly emphasized. However, the role of acoustics as applied to engineering, medicine, environmental control, music, etc., was also stressed. Thus, several contributions might be grouped under the same subjects, e.g. physical acousits, utrasonics, sound engineering, musical acoustics, computer applications, noise and vibrations. Differences among appropriate teaching curricula are unavoidable and self-evident. However, there are many common subjects to be taught and many valuable methods to be employed in the teaching process.

Several inspiring demonstrations were presented during the debates. They gained a vivid interest and were greatly appreciated. It is impossible to report these presentations here, however they are included in the Proceedings, which are also accompanied by a videocassette. The video (VHS system) report was recorded during the conference and it contains fragments of all the presentations and discussions. The report is being edited and is available from the Organizing Committee.

As a result of the final dicussion, the participants decided to send the following: a letter to the International Commission on Acoustics asking for sponsorship for an intended workshop on teaching acoustics and for a series of monographies on acoustics (the letter has now been sent and is also included in the Proceedings); reports to the Editors of renowned scientific journals containing information for broad circles of scientists and academic teachers about the results of the conference (the present report follows that decision).

According to the opinions of all the speakers the conference was successful and a useful contribution ot the process of education in acoustics. The value of direct contact and exchange of experience among acoustic engineers of various countries was emphasized.

The Conferece Proceedings contains 43 submitted papers, summaries of discussions and a list of participants. The Proceedings were prepared by A. Sliwinski and G. Budzynski with the help of the Oranizing Committee members and published by the World Scientific Company.

G. Budzynski
Technical University of Gdansk

A. Sliwinski
University of Gdansk, Poland

New Standard Catalog

Published by the Acoustical Society of America

The Standards Secretariat of the Acoustical Society of America announces the publication of a new catalog of acoustical standards. The catalog covers new standards in four acoustical fields: physical acoustics, mechanical shock and vibration, bioacousitcs, and noise. Thirteen new standards are included among the eighty-four listed in the new catalog, its seventh revision. Included are new standards for outdoor noise barriers, assessment of noise in residential communities, instrumentation, and hearing aids.

For a free copy of the new ASA catalog, or information regarding other ASA standards, contact Dr. Avril Brenig, Standards Manager, 335 East 45th Street, New York, N.Y., 10017 [tel. (212) 661-9404]. This catalog and the standards are published for the Acoustical Society by the American Institute of Physics.

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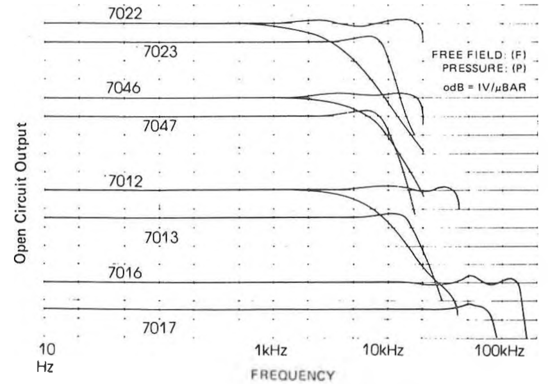

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CALL FOR PAPERS

ACOUSTICAL·SOCIETY·OF·AMERICA

April 1988

To all members:

The 116th meeting of the Acoustical Society of America will be held Monday through Friday, 14-18 November 1988 at the Sheraton-Waikiki Hotel, Honolulu, Hawaii. A very special feature of this meeting is that it will be our second joint meeting with the Acoustical Society of Japan, on the tenth anniversary of our first joint meeting in 1978, also in Honolulu. Acoustical societies of other Pacific rim countries have been invited to participate. Other special features are a banquet, a program for accompanying persons, buffet socials, tutorial lectures, Distinguished lectures, and an equipment exhibit. The language of the meeting will be English.

Contributed papers are welcome in all branches of acoustics. The deadline for receipt of abstracts is 8 July 1988 in Honolulu.

TECHNICAL PROGRAM

Two 2-hour tutorials on digital signal processing in acoustics and adaptive signal processing, by A.V. Oppenheim and M.M. Sondhi, are planned for Monday afternoon, 14 November. A tutorial registration form will be mailed in August. Distinguished Lectures by R. Fettiplace and A.J. Hudspeth on hair-cell transduction and its role in cochlear tuning, a Vern O. Knudsen Lecture on "Concert Hall Acoustics", and a musical demonstration of historical tunings and temperaments by E.L. Kottick are also planned.

Especially for this meeting, the Acoustical Society of Japan has established a Committee with membership corresponding to that of the ASA Technical Council. The two Societies are coordinating many special sessions of joint interest, with invited speakers from both Societies. The following special sessions are being planned. Abbreviations on the right indicate the sponsoring Technical Committees.

Theater acoustics - the performer's point of view	Arch.
Application of the acoustic intensity technique	Arch./Noise
Hand-arm vibration	Bioresp.
Physiological response to vibration	Bioresp.
Graduate programs for education in acoustics (poster session)	Ed.
Modern acoustic transducers	Eng.
Signal processing in noise environments	Eng.
Artificial intelligence in acoustics	Eng./Speech
Digital signal processing in music	Music
Musical instruments, East and West I: piano & percussion	Music
Musical instruments, East and West II: wind & string	Music
Scales and tuning in eastern and western music	Music
Active noise control (see also Active vibration control below)	Noise
Hearing conservation: evaluating and preventing non-occupational and occupational noise-induced hearing loss	Noise
Noise control in automotive design and manufacture	Noise/Arch.

Acoustical microscopy and non-destructive evaluation	Physical
Nonlinear acoustics, general	Physical
Role of acoustics in high-temperature superconductors	Physical
Mechanisms of biological response to ultrasound & vibration	Physical/Bioresp.
Biomedical ultrasound	Physical/Bioresp.
Hair cell transduction and cochlear frequency analysis	P & P
Transduction and tuning in the cochlea	P & P
Ototoxicity of environmental chemicals	P & P
Measurement and modeling of speech articulation and articulators	Speech
Speech processing aids for the handicapped	Speech
Speech processing in human-machine interaction — an international view	Speech
Acoustical imaging of vibrating structures	Strl. & Vib.
Active vibration control (see also Active noise control above)	Strl. & Vib.
Flow-induced sound and vibration	Strl. & Vib.
Structure-borne noise from vibrating structures	Strl. & Vib./Arch.
Wavenumber vector signal processing	Strl. & Vib./UW
High-frequency underwater acoustics	UW
Seismic acoustics of the Pacific basin	UW
Shallow water acoustics	UW
Time-domain methods in underwater acoustics	UW

Lecture, poster, and precis-poster sessions will be scheduled Tuesday through Friday, 15-18 November, within the hours 8 a.m. to 12 noon and 2 to 6 p.m. The number of parallel sessions will be limited to six. Contributed papers will be limited to 8 to 12 minutes, including discussion time. Authors for precis poster sessions will be limited to 3 minutes and 3 slides for the oral precis.

Every effort will be made to schedule contributed papers in accordance with author and Technical Committee preferences. However, authors should be prepared to accept assignment to a poster or precis-poster session. Assignments will take into account (a) program balance, (b) Technical Committee instructions, (c) author preference, (d) whether the author has submitted multiple abstracts, with or without co-authors, and (e) date the abstract is received. If all papers cannot be accommodated within the regular program, the Committee may establish poster sessions and evening sessions. Papers will be rejected if they do not comply with instructions or if scheduling constraints and author preferences are incompatible.

ABSTRACTS

An abstract of not more than 200 words is required for each paper whether invited or contributed. Authors are encouraged to submit only one abstract. An author whose name appears on more than one abstract should indicate the priority for each. Abstracts are to be prepared in accordance with the instructions on the enclosed sheet and in J. Acoust. Soc. Am. 81, 575, (1987). The entire abstract and the information items appended to it, including those identified below, must be double-spaced on one side only of a single page approximately 8-1/2 x 11 inches. Abstracts that are too long will be truncated. For subject classification, see the June or December 1987 issues of the J. Acoust. Soc. Am. The author to be notified of paper acceptance and scheduling should have a complete mailing address in the abstract.

At the bottom of the abstract, in addition to the items required by the instructions, please (a) identify by name the special session, if any, with which you would like your paper associated, (b) state as appropriate "invited paper", "lecture-style only" (Committee will reject paper rather than schedule it for a poster session), or "poster presentation acceptable", and (c) list any special equipment required (see section on audio-visual equipment).

Mail original abstract and three (3) copies to	John C. Burgess (ASA - Abstract) Department of Mechanical Engineering University of Hawaii 2540 Dole Street Honolulu, HI 96822 Telephone: (808) 948-6480 or -7167 (messages)
The deadline for receipt in Honolulu is 8 July 1988.	

The deadline will be strictly observed. Authors are cautioned to allow adequate mail delivery time (at least ten days within the U.S.). Authors of invited papers are expected to send their abstracts as specified above and should send an additional copy to their session organizer for receipt a week earlier, by 1 July 1988. Paper acceptance notices and a preliminary program will be mailed in August. Final programs will be mailed in October.

AUDIO-VISUAL EQUIPMENT

Standard overhead transparency projectors and 35 mm slide carousel projectors for 2 x 2 inch (50 x 50 mm) slides will be provided at all sessions. A 4 x 4 ft. poster board and fastening materials will be provided each author in a poster session. Requests for special facilities (movie projectors, tape playback equipment, etc.) must be identified at the bottom of the abstract. Their costs may be charged to the requester.

PLENARY SESSION, AWARDS, AND SOCIAL EVENTS

A short opening plenary session will be held on Tuesday morning, 15 November. Complimentary buffet socials with cash bar will be held early on Tuesday and Wednesday evenings. There will be a banquet on Thursday evening featuring a seven-course Chinese dinner, awards by both the Acoustical Society of America and the Acoustical Society of Japan, and special entertainment. Banquet tickets should be purchased when registering. A no-host social hour will precede the banquet.

EXHIBIT PROGRAM

An exhibit program is planned for acoustical, shock, and vibration instruments, associated signal processing equipment, books, and noise control products. Organizations wishing to exhibit should contact	Lois Kimmelman Advertising Division American Institute of Physics 335 East 45 Street New York, NY 10017 Telephone: (212) 661-9404

PROGRAM FOR ACCOMPANYING PERSONS

Accompanying persons are welcome. An Aloha Hospitality Room will be open near the conference rooms where information will be available in English and Japanese on a wide variety of activities available in and near Honolulu. Special activities with a local flavor will be scheduled mornings, Tuesday through Friday. Local travel, hotels, and other activities in Honolulu and the Hawaiian Islands may be arranged with commercial tour agents near the Registration area.

TRAVEL AND HOUSING

United Airlines (UAL) has been appointed the "Official Airline" for air travel to and from the meeting within the United States. The agreement with UAL provides for either 40% discount from "Y" or "YN" coach fares or 5% discount from published excursion fares in effect when tickets are purchased. While Mileage Plus upgrades will not apply, enrolled Mileage Plus members will receive mileage credit. Members who wish to use these special fares must (a) book their travel through United's Meeting Trip Desk (1-800-521-4041), (b) use the special Tour Code "411CW", and (c) travel between 4-29 November 1988 inclusive. Members may make reservations and payment directly or through travel agents (fares are commissionable). Excursion fare seats are capacity controlled, and members are urged to make reservations early. Ground transportation in Honolulu is available via Greylines Airporter ($5) and by taxi ($16, four people max).

A variety of rooms and suites has been reserved at the Sheraton-Waikiki Hotel and at the Princess Kaiulani Hotel (7-minute walk). Reservations for all rooms can be made using the enclosed reservation form or directly with Group Reservations Department, Sheraton-Waikiki Hotel, 2255 Kalakaua Avenue, Honolulu, HI 96815, Telephone (808) 922-4422 Ext. 72576. The Acoustical Society name must be used to reserve rooms at the special (non-commissionable) convention rates. Members are urged to make room reservations early.

PAPER COPYING SERVICE

Authors are requested to provide one copy of their projection material and/or paper(s) to the Paper Copies Desk in the Registration Area upon arrival. The copy should have material <u>on one side only</u> on paper approximately 8-1/2 x 11 inches suitable for photocopy reproduction. Copies of available papers will be made for a nominal charge.

COMMITTEE MEETINGS

Meetings of Administrative, Technical, and Standards Committees, including Writing Groups, will be announced in the printed program if requests are received in Honolulu no later than 30 June. Requests should specify the committee needs for space, room arrangement, furnishings, catering, and any special equipment. Send requests to John C. Burgess at the address given on Page 3.

REGISTRATION

Registration will begin Monday afternoon, 14 November, at 2:00 p.m. The registration fee is $50 for members of the Acoustical Societies of America and Japan and all participating Pacific Rim acoustical societies. Invited speakers who are members of the Acoustical Societies of America or Japan are expected to pay the registration fee. The registration fee will be waived for all nonmember invited speakers, students with current identification cards, and emeritus members of the Societies. The registration fee for all other nonmembers is $90; however a nonmember who completes an application for Associate Member in the Acoustical Society of America and pays one year's dues at the time of registration may register at the member rate . There is no registration fee for accompanying persons.

Murray Strasberg
Secretary

CANADIAN ACOUSTICAL ASSOCIATION
MINUTES OF THE BOARD OF DIRECTORS MEETING

March 20, 1988 - Ontario Hydro, 700 University Avenue, Toronto
10:00 a.m. - Mezzanine Level, Room A

Present: S.M. Abel
C. Andrew
A.J. Cohen
L. Cuddy
B. Dunn
R. Hetu
N. Lalande
M.M. Osman
M.V. Sydenborgh

Absent: C. Sherry
J. Nicolas
J.G. Migneron
G. Faulkner

1. Opening Remarks — Sharon Abel

The President thanked the attendees, especially the ones coming from other provinces.

A letter from C. Sherry (Past President) was read on the need to celebrate the 25th anniversary of CAA. The name of Dr. T. Northwood was mentioned for an article in Canadian Acoustics.

Action — Raymond Hetu

A letter from John Manuel was read re help to Yugoslavia to organize 13th ICA. It was agreed that aid will be offered.

A breakdown of current membership after 1988 renewal was distributed to the attendees.

2. Report of the Secretary — Moustafa Osman

Update on 88 renewal forms sent out and returns received was provided. The possibility of a larger P.O. Box was discussed and dismissed. The upkeep and handling of the 12th ICA and Vancouver meeting proceedings, was raised and the need to offer them now at some nominal cost was discussed. Also, an ad in Canadian Acoustics would help prospective acquirers.

Action M.M. Osman and R. Hetu

The 1988 $1,000 secretarial help were not used to date.

3. Report of the Treasurer

The current investments were reported: Two T-Bills from 12th ICA revenues, $23,605 and $41,692 and a certificate for $8,500 from the Montreal meeting.

On the expense side, $5,000 was given to Mrs. D.A. Benwell towards hosting the ISO/IEC 1988 meetings in Ontario and $1,500 was assigned as seed money for Acoustics Week '88 in Toronto. The Treasurer will investigate the pros and cons of being a charitable organization as opposed to non-profit organization.

Action Chris Andrew

4. Report of the Membership Chairman Anabel Cohen

New stationery with a new logo was distributed and appreciated, especially the two-colour scheme.

The issue of seed money for local chapters was discussed and a motion was tabled.

> "That CAA will provide seed money for new local chapters who require up to $50.00 towards their initial meeting".

Moved: Anabel Cohen
Seconded: B. Dunn Defeated.

The first Halifax local chapter meeting will be on April 6, 1988. There is a need to consider the role of CAA as an umbrella organization for other groups who already belong to other organizations.

5. Report of the Editor Raymond Hetu

The subjects of 1st class mail, changes to the cover, editing, a new column (Invited Paper) and the new logo (next year) were discussed. A letter from Tim Kelsall re the need for a new Advertising Editor and suggested replacement was read by the President.

Action Raymond Hetu

6. Acoustics Week '88, Toronto October 3-7, 1988 Winston Sydenborgh

The organizing committee is in place. The venue will be the Westbury Hotel. ISO/IEC meetings will be held at the same place over a two-week period. There will be exhibits and poster sessions. Four parallel sessions are planned including a new one on audio engineering. No registration fee increase over that of 1987 is anticipated.

7. International INCE Sharon Abel

A discussion took place on the issue of CAA representative on International INCE and in particular the communications with Prof. Hugh Jones. The President will write to him again explaining the situation and the opinion of the Board of Directors that they wish Tony Embleton to act as the official representative. It was agreed that Hugh Jones should represent CAA when Tony could not attend.

Action Sharon Abel

8. Directors' Awards

These awards will be mentioned in the journal.

Action Nicole Lalonde/R. Hetu

A thank you letter from Chantal Larouche was read by the President.

9. Students' Prizes Bruce Dunn

There has been some difficulties in identifying, rating and assessing the presentations given by students during the annual meeting. Concerns were also voiced regarding the possible changes in criteria of selection and evaluations from meeting to meeting.

It was agreed that up to three prizes will be offered at each annual meeting. Winston Sydenborgh agred to select a local Student Prize Chairman for CAA '88.

10 Edgar & Millicent Shaw Postdoctural Prize & other Prizes
Sharon Abel

Discussion took place re the time period for the prize (1 or 2 years) and the amount of money ($3,000 vs $6,000).

Motion: "That a total amount of $6,00 be allotted made up of two equal annual installments for this prize to be offered to a Canadian".

Moved: Bruce Dunn
Seconded: Winston Sydenborgh Carried.

Bruce Dunn and Lola Cuddy are requested to work out the details of this prize within one year.

Action Bruce Dunn/Lola Cuddy

Motion: "That a $30,000 fund be created the interest on which would be used for the Edgar & Millicent Shaw prize. This fund can be topped up with any unused portion of the students' prize".

Moved: Bruce Dunn
Seconded: Lola Cuddy Carried.

Action Bruce Dunn/Chris Andrew

Re the Bell prize for a graduate student in the area of speech and communications, the President will write to Paul Mermelstein on the details of the prize (total fund available is $8,500).

Action Sharon Abel

Finally, re possible prizes for undergraduate students, the Membership Chairman will investigate the matter.

11. Other Business

Various subjects were discussed. A Noise Analysis Course may be offered by the Ontario Ministry of Transportation. It was reiterated that CAA could neither sponsor, endorse such courses nor receive any proceeds. Acoustics Week '88 will offer noise seminars. Also Acoustics Week '88 will have a publicity group to promote CAA activities. CAA involvement with the National Consortium of Scientific and Educational Societies was briefly mentioned.

Meeting adjourned at 1:25 p.m.

Prepared by:

M.M. Osman
CAA - Secretary
April 15, 1988

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PRESIDENT / PRESIDENT
Sharon Abel (416) 586-8278
Mt. Sinai Hospital, Suite 843
600 University Avenue
Toronto, Ontario, M5G 1X5

PAST PRESIDENT / ANCIEN PRESIDENT
Cameron W. Sherry (514) 457-6810
Domtar Research Centre
P.O. Box 300
Senneville, Quebec, H9X 3L7

SECRETARY / SECRETAIRE
Moustafa Osman (416) 592-4988
Ontario Hydro
700 University Avenue
Toronto, Ontario, M5G 1X6

TREASURER / TRESORIER
Chris Andrew (403) 268-1621
Transportation Planner
City of Calgary
P.O. Box 2100
Calgary, Alberta, T2P 2M5

MEMBERSHIP / RECRUTEMENT
Annabel Cohen (902) 424-8888
Department of Psychology
Dalhousie University
Halifax, Nova Scotia, B3H 4J1

EDITOR / REDACTEUR
Raymond Hétu (514) 343-7559
Groupe d'acoustique
de l'université de Montréal
Montréal, Quebec, H3C 3J7

DIRECTORS / DIRECTEURS

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