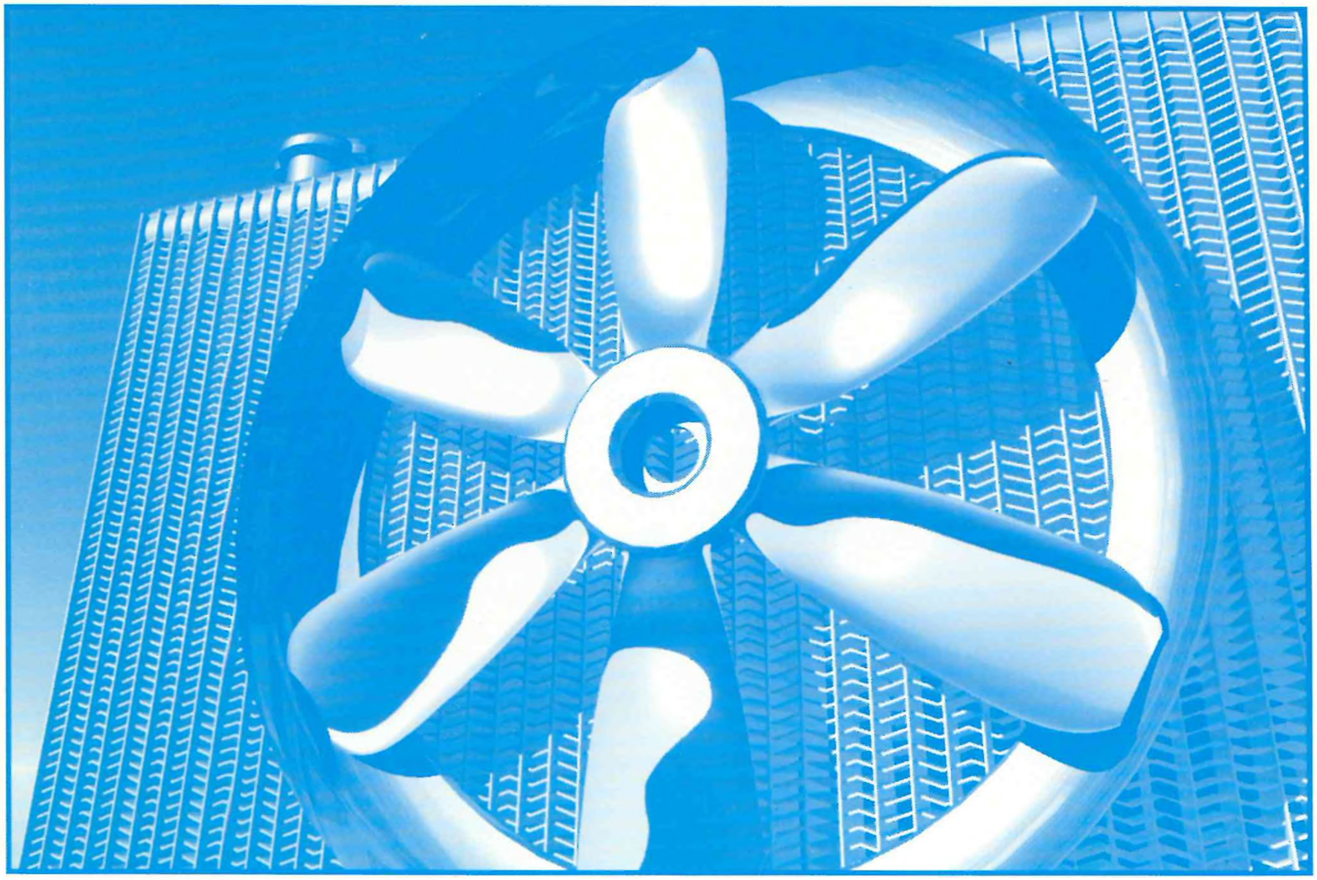
ISSN 0711-6659

# canadian acoustics
# acoustique canadienne

DECEMBER 1996 DECEMBRE 1996
Volume 24 — Number 4 Volume 24 — Numéro 4



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**P.O. BOX 1351, STATION "F"**
**TORONTO, ONTARIO M4Y 2V9**

**L'ASSOCIATION CANADIENNE D'ACOUSTIQUE**
**C.P. 1351, SUCCURSALE "F"**
**TORONTO, ONTARIO M4Y 2V9**

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# ÉDITORIAL / EDITORIAL

Dans ce numéro, vous trouverez trois articles intéressants portant sur divers sujets: la prédiction du bruit émis par les ventilateurs d'automobile, les propriétés acoustiques du fond de marin et la prédiction du bruit dans les locaux industriels. Je ressens une certaine satisfaction à publier ces trois articles, retombée directe du bon travail du comité éditorial. Pouvons-nous maintenir ce rythme?

Notre comité éditorial en est à sa deuxième année d'existence. Je crois qu'il est temps d'évaluer son travail. J'ai écrit à tous les membres du comité à ce propos. Je m'attends à ce qu'il y ait quelques changements dans la constitution du comité. Si quelqu'un est intéressé à s'impliquer ou a des commentaires à formuler, faites-moi signe.

Je présentes mes excuses à tous les lecteurs pour l'arrivée tardive du numéro de septembre (Actes du congrès) et pour tous les incovénients que cela a pu causer. Il s'agit d'une retombée directe du changement récent d'imprimeur. Je crois que les problèmes expliquant ce délai ont été résolus.

L'année 1996 tire à sa fin. J'espère que ce fut une bonne année pour vous. Meilleurs voeux à chacun pour la période des fêtes et pour 1997.

In this issue are published three interesting papers on very diverse subjects: prediction of automotive fan noise, determining the acoustical properties of the sea-bottom, and predicting noise in industrial workrooms. It is satisfying to be able to publish three papers in one issue, a direct result of the Editorial Board's hard work - can we keep it up?

Regarding the Editorial Board, it has now been in existence for almost two years. I think it is time to evaluate whether it has been effective. I have written to all Board members on this subject. I expect there will be some changes in the Board membership - if anyone is interested in becoming involved (or has comments about the Editorial Board), let me know.

I sincerely apologize to all readers for the late arrival of the September (proceedings) issue of the journal, and for any inconvenience caused. This was a direct result of the recent change in printer. I believe that the problems at the origin of the delay have now been resolved.

1996 is drawing to an end. I hope it has been a good year for you. Best wishes to everyone for a happy holiday period and for 1997.

*Canadian Acoustics / Acoustique Canadienne 24(4) 3-9 (1996)* ***Technical article / Article technique***

# MODIFICATION AND EVALUATION OF AN AUTOMOTIVE COOLING AXIAL FLOW FAN NOISE PREDICTION MODEL

**David Roth**
University of Waterloo
Waterloo, Ontario, Canada, N2L 3G1

**Haran K. Periyathamby**
**William Gallivan**
Siemens Electric Ltd.
London, Ontario, Canada, N6E 1R6

**C. W. S. To**
University of Western Ontario
London, Ontario, Canada, N6A 5B9

## ABSTRACT

The intention of this paper is to demonstrate the feasibility of a noise prediction model recently proposed for use in determining the sound pressure level spectrum of axial flow fans for an automotive cooling application. The predictions of the noise model, based solely on blade geometry and operating conditions, were compared with numerous empirical studies, one of which is presented here. The model is shown to be very effective in the absence of secondary sources of noise, such as blade corner details and the fan hub, while being totally ineffective when these sources are not negligible. Furthermore, in a fractional design of experiment, the model is used to predict the three most important geometrical parameters to consider in fan design. From the point of view of quietness, these parameters are overall fan radius, chord width and rotational speed.

## SOMMAIRE

L'intention de cet article est de démontrer qu'un modèle de prédiction de bruit, produit dernièrement pour prédire le spectre de niveau de pression sonore d'un ventilateur employé dans une application de refroidissement dans l'industrie automobile, est réalisable. Les prédictions du modèle, établi seulement sur la géométrie des pâles du ventilateur et les conditions de fonctionnement, ont été comparées en vue de plusieurs études empiriques, dont l'une d'elle est présentée ici. On a montré que le modèle en éfficace en l'absence de bruit de sources secondaire tel que les détails des coins des ailes et le moyeu du ventilateur, cependant le modèle est totalement inefficace lorsque ces sources ne sont pas négligeables. De plus, dans une fraction du design de l'expérience, le modèle a prédit les trois paramètres les plus importants à considérer dans le design d'un ventilateur du point de vue niveau de bruit, le rayon du ventilateur, la largeur de la corde et la vitesse de révolution.

## 1. Introduction

Except for Gutin (1936), the most substantial theoretical investigation into aerodynamically generated sound is given by M. J. Lighthill [1]. In this historical paper, Lighthill derives a second order partial differential equation which characterizes the propagation of sound in a homogenous and isotropic medium. Many others, since then, have made significant contributions to noise theory, including Curle [2], who investigated, with respect to a sound field, the issue of solid, stationary boundaries , Morfey [3] and Longhouse [4], who researched the mechanisms of sound generation and Fukano *et al.*[5] who attempted to model turbulent noise generation. Two more recent investigators, specifically dealing with the topic of axial flow fan noise, are Quinlan [6], who discusses the application of active control as a means of reducing radiated noise and Lee *et al.*[7], who present an analytical model for predicting the vortex shedding noise generated from the wake of axial flow fan blades.

Kent Clark Bates developed a method of predicting axial flow fan sound pressure spectrums from simplified blade geometry and fan operating conditions. Based on the work in his thesis [8], a computer program has been produced at Siemens Electric Ltd. with the intention of applying Bates' noise prediction theory to engine cooling fans. The objective of this project is fan development time optimization through the integration of the computer code into the design process. It was felt that this course of action would prove to be effective through minimizing the time spent with prototypes and empirical evaluation. In order to accomplish this task, a two part plan was developed. First, a series of validation tests to substantiate the computer model. Second, a fractional factorial design of experiments (DOE) to identify key design parameters. The computer model is written in Microsoft Visual C++ 1.0, and is designed to run in a Windows 3.1 environment. It was the hope of management to be able to harmonize the technologies of computational fluid dynamics (CFD) and noise prediction to produce an economical axial flow fan that maximizes efficiency while minimizing noise.

## 2. Nomenclature

| | |
|---|---|
| $C_m$ | the m^th^ complex Fourier coefficient of the radiation sound pressure relative to ambient pressure |
| $d_m''$ | the m^th^ complex Fourier coefficient of the second derivative of the fan displacement function |
| f | frequency [Hz] |
| $f_0$ | fan rotational frequency [Hz] |
| F(f) | frequency response weighting function |
| G(f) | one sided mean-square pressure spectral density function $[N^2/m^4]$ |
| $I(r_s)$ | Intermediate integral in the calculation of $C_m$ |
| m | Fourier coefficient index |
| n | number of defining fan blade cross sections |
| N | fan rotational speed [RPM] |
| Nb | number of fan blades |
| $P_{ref}$ | decibel reference pressure, $20[\mu N/m^2]$ |
| r | radius [m] |
| $R_f$, | receiver radial location [m] |
| s | subscript denoting the current element being considered |
| SPL | sound pressure level [dB] |
| V | relative velocity of air (m/s)<br>$(V \approx 2\pi(N/60)r)$ |
| w | blade chord width [m] |
| $Z_f$, | receiver axial location [m] |
| $\phi$ | angular coordinate [rad] |
| $\gamma$ | blade pitch angle [rad] |
| $\theta$ | blade camber angle [rad] |
| $\rho$ | blade radius of curvature [m] |
| $\rho_0$ | ambient air density $[kg/m^3]$ |
| $\upsilon$ | kinematic viscosity of air $(m^2/s)$ |

The basic parameters for an arbitrary fan blade cross section are below, in Figure 1.

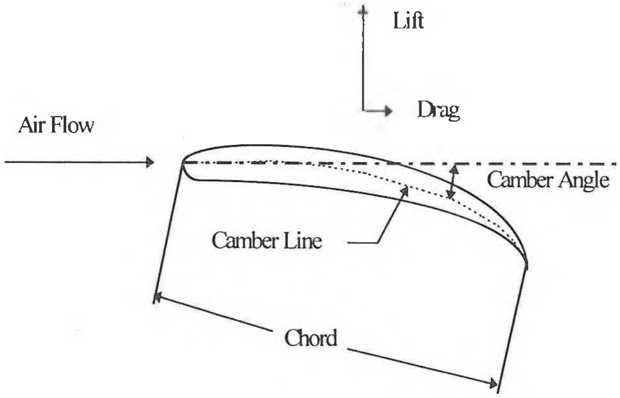

**Figure 1** - basic airfoil cross section

## 3. Mathematical Foundation

**Overview.** To familiarize the reader with the basic concepts of Bates' noise prediction theory, the key equations are summarized below. The general idea of the mathematics is to calculate the non-zero complex Fourier coefficients that predict the blade passage frequency tone levels and then estimate the broadband components thereafter.

**Basic Equations.** It has been shown by Bates that the SPL within a frequency band having center frequency $f_c$, and bounded by a lower and upper frequency, $f_1$ and $f_2$ respectively, is given by:

$$(SPL)_{f_c} = 20\log_{10}\left(\frac{\sqrt{\int_{f_1}^{f_2} F(f)G(f)df}}{P_{ref}}\right) \qquad (1)$$

It may also be shown that G(f) can be expressed as an infinite summation of complex Fourier coefficients, $C_m$, where $C_m = C_m(N, Nb, r, R_f, w, Z_f, \phi, \gamma, \theta, \rho, \rho_0)$. From the number of parameters that $C_m$ is a function of, the reader may deduce that the main computational effort of the noise prediction model involves calculating these coefficients.

**Constraints and Assumptions of the Bates' Original Theory.** While the accuracy of the predictions is of the utmost importance, certain assumptions are made in an effort to reduce the mathematical complexity of the model (please note: in the modified theory used in the noise model being presented herein, the effect of some of these assumptions have been attempted to be minimized. In the following list, these shall be noted, for reference, in *italics*,

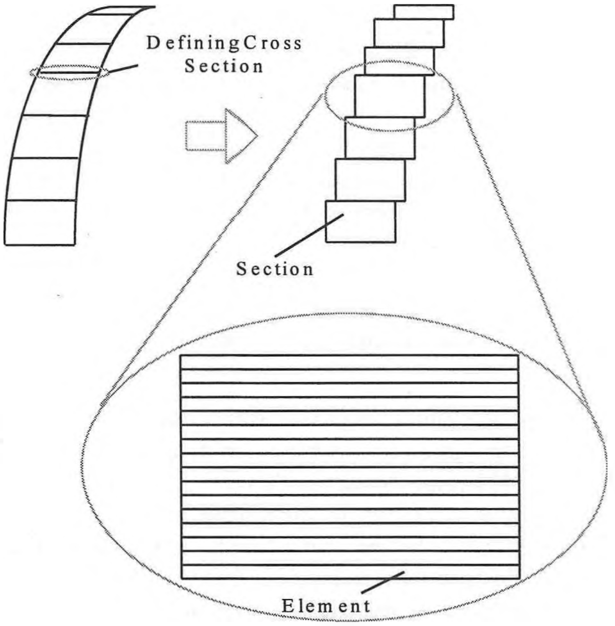

**Figure 2** - schematic detailing the method in which Bates' constant fan blade assumption may be modified to more accurately resemble axial flow fans.

since they will be discussed again later). First and foremost, the noise prediction model is not wholly independent of experimental correlation. Bates neglects the significant applied force and stress source terms (the dipole and quadrupole terms respectively) of the wave equation in the development of his noise prediction theory. To partially compensate for these omissions, and in an effort to match experimentally measured autocorrelation functions, Bates adds a correctional term to his own theoretically derived autocorrelation function. The second approximation assumes a particle of air in the path of the blades is displaced only in the interval of time in which it is in contact with the fan blades. The third maintains an equivalent air displacement pattern may be generated by an infinite array of acoustical monopole sources located evenly in the plane circular band bounded by the extremities of the fan blades. *Fourth, the cross section of every blade, at any radial point, is constant. It is in the shape of a circular arc and possesses fixed values of pitch, camber, chord width and radii of curvature.* Fifth, all blades are rigidly connected to a central hub, but the effects of the hub as well as any rivets, blade thickness, blade corner detail or blade vibrations are neglected. Finally, the predicted field sound pressure is a stationary random process.

**Modifications to Bates' Theory.** While little may be done about many of the assumptions, a remedy exists for that of the fourth listed above . Bates' theory was modified to allow an arbitrary number of defining fan cross sections to be input and a representative fan be constructed from sections whose parameters are the average of the bounding cross sections (Figure 2).

Furthermore, Bates employs a circular arc blade cross section in his model, so its radius of curvature is readily available. However, the cross section of a fan blade at Siemens Electric is a C4 airfoil and therefore this parameter is non-existent. Nevertheless, the camber line contour equation used in computing the airfoil shape of each defining cross section is based on a circular arc and is a function of the blade camber angle. It is therefore postulated that the cross sectional shape may be modeled after this base curve. Please note: because the noise prediction model is intended for use with a fan in the design stage, the blade camber angle, for each cross section, is easily obtainable. Therefore, the camber angle substitutes as an input parameter and the blade element radius of curvature is calculated from each separate value.

**Superposition of Blade Elements.** The above modification naturally necessitates the need of a method for the effects of all the blade elements to be combined mathematically. Since the complex Fourier coefficients are calculated by integration in the radial direction, this allows for the superposition of the noise contributions of each fan blade section (for the purposes of the NOISE application, each section was further broken down into sixteen smaller elements). It may be shown that the m$^{th}$ complex Fourier coefficient may be rewritten as :

$$C_m = \frac{Nb \cdot \rho_0 \cdot f_0^2}{2} \sum_{j=1}^{n-1} \sum_{l=1}^{16} \left[ r_s^2 \cdot d_m'' \cdot I\left(r_s\right) \cdot \Delta r_s \right]_{j,l} \quad (2)$$

Using equation (1), and other principals described by Bates, the axial flow fan sound pressure spectrum may now be predicted for realistic fan blade geometry.

## 4. Validation Test Methods and Evaluation

**Main Equipment.** In addition to the regularly used noise measurement equipment, the following special items are to be noted:

- NOISE application
- the Volvo 390F-1.3.0 fan and its associated table of geometrical parameters.

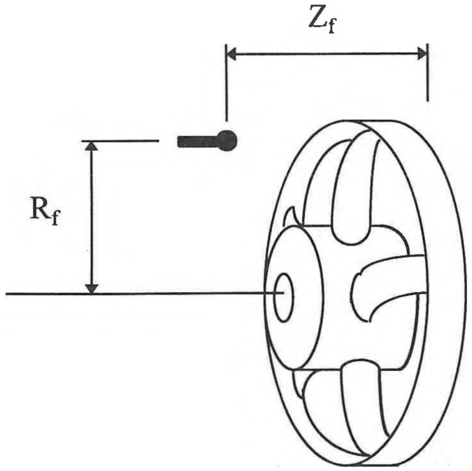

**Figure 3-** Typical placement of microphone, including measuring reference points on the fan

**General Procedures, Experimental.** ISO 3744 describes a procedure that may be used for measurements in the near field. A number of different car manufacturers make reference to this standard but generally prescribe noise tests be done at a distance of 1m (far field). However, because of the limitations imposed by the assumptions listed above, this distance, although desirous, could not be used (see section 5). The experimental procedure observed was as follows:

1. Set up the apparatus in the standard configuration for noise measurement of fans, as detailed in Figure 3.
2. Set the initial placement of both microphones in line with the fan axis of rotation at a specified radial ($R_f$) and axial ($Z_f$) distance.
3. Adjust the power supply until the desired rotational speed is set.
4. Measure both the overall noise and discrete frequency noise levels simultaneously.
5. Save all data electronically.
6. Plot the data.
7. Repeat steps 2-6 for each axial and radial position required and for each desired speed.

**General Procedures, Theoretical:** The theoretical procedure observed was as follows:

1. Start the NOISE application
2. Input all the geometrical parameters.
3. Input all the ambient condition parameters.
4. Guess at the values of the correlational parameters, Z and $\zeta$.
5. Plot the 'A' Weighted SPL versus Frequency graph.
6. Compare the broad-band noise levels to that of the experimental results.
7. If the broad-band noise does not correlate closely with that of the experimental results, repeat steps 4-7.
8. Note the values of the overall noise level, the tonal frequencies and the correlational parameters.
9. Save the information to a file.
10. Repeat steps 2-9 for each axial and radial position required and for each desired speed.

**Experimental Validation of the NOISE Application.** The axial flow fan given above has been tested, at speeds of 1800 and 2400 rpm. Noise levels were measured at radial distances of 0 - 20 cm, in increments of 5 cm, at two experimental axial distances of 10 and 15 cm (with respect to the NOISE program, these two distances are 6 and 11 cm). The results are summarized above in Table 1.

## 5. Discussion

**The Correlation Experiment, Comparison of Relative Error.** The error calculations, relative to the experimental SPL results, show three distinctive trends. The first indicates the NOISE application's prediction accuracy increases with a decreased receiver axial distance. This trend agrees well with Bates' constraint of a near field

| Speed | (Rf, Zf) | Experimental Overall SPL | NOISE v.2 Overall SPL | Relative Difference |
|---|---|---|---|---|
| 1800 | (0,.06) | 83.7 | -80.791 | 196.524 |
| 1800 | (0.05,.06) | 83.6 | 49.018 | 41.366 |
| 1800 | (0.1,.06) | 82.7 | 79.855 | 3.440 |
| 1800 | (0.15,.06) | 83.3 | 84.889 | 1.907 |
| 1800 | (0.2,.06) | 82.4 | 87.822 | 6.580 |
| 1800 | (0,.11) | 75.9 | -97.074 | 227.898 |
| 1800 | (0.05,.11) | 75 | 8.491 | 88.679 |
| 1800 | (0.1,.11) | 74.8 | 36.524 | 51.172 |
| 1800 | (0.15,.11) | 74.5 | 63.575 | 14.665 |
| 1800 | (0.2,.11) | 74.2 | 69.816 | 5.908 |
| 2400 | (0,.06) | 91.9 | -76.811 | 183.581 |
| 2400 | (0.05,.06) | 90.1 | 56.599 | 37.182 |
| 2400 | (0.1,.06) | 90 | 87.433 | 2.852 |
| 2400 | (0.15,.06) | 90.5 | 92.513 | 2.224 |
| 2400 | (0.2,.06) | 89.3 | 95.460 | 6.898 |
| 2400 | (0,.11) | 81.7 | -86.001 | 205.264 |
| 2400 | (0.05,.11) | 80.9 | 16.090 | 80.111 |
| 2400 | (0.1,.11) | 80.9 | 44.205 | 45.359 |
| 2400 | (0.15,.11) | 81.3 | 71.282 | 12.322 |
| 2400 | (0.2,.11) | 81.9 | 77.547 | 5.316 |

Table 1 - Results of the validation experiments

| Factor Name | Low | High | ALIAS |
|---|---|---|---|
| Number of Profiles (P) | 6 | 11 | |
| Stagger Angle [°] ($\zeta$) | 55 | 75 | |
| Stagger Taper ($T_\zeta$) | NONE | Increasing | |
| Camber Angle [°] ($\theta$) | 15 | 30 | |
| Chord Width [mm] (W) | 30 | 80 | |
| Chord Taper ($T_W$) | NONE | Decreasing | |
| Number of Blades (B) | 2 | 11 | $P\zeta T_\zeta \theta$ |
| Rotational Speed [RPM] (N) | 2000 | 3000 | $PT_\zeta W T_W$ |
| Overall Radius [mm] (R) | 280 | 460 | $T_\zeta \theta W T_W$ |

Table 2 -- Factors and settings for the parametric study on noise

prediction model, where he states "the theoretical solution was concluded to be invalid at distances greater than approximately one fan radius..."[Bates p. 79]. It should be noted that the values used for $Z_f$ in the NOISE simulations was not equal to the experimental value, since, as Bates states in his thesis $Z_f \neq Z_{exp}$ [Bates p. 77]. For these experiments, $Z_{exp}$ is calculated as $Z_{exp} \approx Z_f$ + hub thickness.

The second trend implies the NOISE model is most acceptable for radial receiver locations of approximately 75% of the maximum radial distance. This does not collaborate well with Bates' results who found adequate prediction accuracy along the entire width of the fan blades. The most probable source of error in this case is the simplification wherein the blade shape is modeled as a circular arc and the effects of the blade thickness and corner details are neglected. Since this trend held true for all fans tested, and therefore different blade section geometry, the only other change is the relative velocity of the air passing over the blade. Considering the blade sections nearer to the blade tip encounter greater relative velocities than those closer to the hub, the flat plate, circular arc blade section assumption must only be valid above a certain threshold speed value.

The final trend is the accuracy of the model increases with increased fan rotational speed. It should be noted that this observation again strongly suggests that Bates' circular arc model is only valid above a certain speed, when dealing with airfoil cross sections.

Careful investigation of the Reynolds number of the fan blade indicates the flow for the innermost fan cross sections is almost certainly laminar while that of the outermost sections is likely turbulent. The Reynolds number for an airfoil is calculated as:

$$\mathrm{Re} = \frac{Vw}{\upsilon} \qquad (3)$$

Since Bates maintains "acoustic source distributions...are created by both blade geometry and turbulent flow" [Bates, p. 16], it is expected the threshold relative velocity value will prove to be that at which the transition Reynolds number occurs ($Re_{transitional} \cdot \approx 10^6$ [9]). This has yet to be proven.

It should also be noted that the trends exhibited by the relative error results were independent of the type of fan tested. That is to say, the relative error of the NOISE prediction model is independent of blade geometry or sweep.

## 6. Fractional Factorial Design of Experiment

**Overview.** As stated above, $C_m = C_m(N, Nb, r, R_f, w, Z_f, \phi, \gamma, \theta, \rho, \rho_0)$. From the point of view, however, of fan blade design criterion, obviously not all of these parameters may be influenced. After some discussion, nine parameters were chosen to be investigated (Table 2).

**Method.** The design of experiment (DOE) was carried out as an eighth replicate of a $2^9$ factorial design. The design followed that recommended by J.C. Young [10]. As a $2^{9-3}$ design, three design parameters were aliased (see Table 2) with three extremely unlikely four factor interactions. This translates to, as described by Young, a resolution IV experiment and as such, some two factor interactions will also be confounded with some other (hopefully negligible) two factor interactions (the terms "aliased" and "confounded" are statistical terms and are meant to convey the idea that the results of the experiment could be attributed either of the factors or interactions the results are confounded or aliased with). The various levels of the parameters were estimated to represent a fair spread of realistic design parameters, as experienced at Siemens Ltd.. Table 2, below, describes the experimental set-up.

The assumptions made in the experiment were as following:

1. All interactions greater than two are unlikely, and as such are ignored.
2. All interactions with the number of design profiles are irrelevant with respect to noise generation (these will only affect the prediction accuracy), and as such are ignored.
3. Ignore the interaction between the overall radius and the rotational speed. This is reasonable since

this interaction shows the effect of tip speed, which is shown by N alone. The change in the overall radius will exhibit the effect of the hub radius (which was held constant at 150mm).

It can be proven that, from the method in which this experiment was set up, the only confounded two factor interaction is between N and R (interaction NR) aliased with the P and θ (Pθ) interaction. Since both interactions are being ignored for this study, this experiment becomes in reality a resolution V experiment.

All sixty-four experiments were run on the NOISE application over a course of three days. The receiver axial and radial locations were kept constant at 75% of the fan radius and 6cm respectively. This was determined to be the ideal location in terms of the accuracy of the NOISE program, as detailed above. Furthermore, the autocorrelation parameters were also selected on the basis of past experience.

## 7. Results

The factors, in order of importance, were found to be: R, W, N, $T_W$, B and $T_\zeta\zeta$. This is shown in Table 3 and Table 4:

From the above tables, we see the need for two definitions: Std. ERROR and 95% CONFIDENCE INTERVAL. The first is an estimation of the standard error for the variable, which is a measure of the degree to which an effect varies from the mean. The last in the list is the expected range of *change*, with 95% certainty, of the overall noise level, as predicted by NOISE, at the specified position, if the factor is varied from its low level (-) to its high level (+).

## 8. Conclusions

Based on this experiment, from the point of view of noise reduction, and in order of preference:

1. A smaller radius is preferable to a large radius
2. A shorter chord length is preferable to a longer chord length
3. A slower rotating fan is preferable to a faster rotating fan
4. Having a decreasing chord length at greater radial distances is desirable
5. A smaller number of blades is preferable to a greater number of blades
6. A constant, high stagger angle is preferable to one that is low and increases linearly in the radial direction.

## ACKNOWLEDGMENTS

The authors would like to thank the Management of Siemens Electric Ltd., London, Canada for permission to publish this paper. The authors also gratefully acknowledge the support of fellow colleagues and co-workers in the work described in this paper.

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| ANALYSIS of: | Std. ERROR | 95% CONFIDENCE INTERVAL | |
|---|---|---|---|
| R EFFECT | 0.761 | 11.808 | 14.922 |
| W EFFECT | 0.761 | 10.492 | 13.605 |
| N EFFECT | 0.761 | 8.708 | 11.822 |
| $T_W$ EFFECT | 0.761 | -8.496 | -5.383 |
| B EFFECT | 0.761 | 5.177 | 8.290 |

Table 3 -- Statistical analysis of the major factors

| ANALYSIS of $T_\zeta\zeta$ EFFECT | Std. ERROR | 95% CONFIDENCE INTERVAL | |
|---|---|---|---|
| $\zeta$ (no $T_\zeta$) Effect | 1.076 | -7.995 | -3.592 |
| $\zeta$ (with $T_\zeta$) Effect | 1.076 | -4.096 | 0.307 |

Table 4 -- Statistical analysis of the major two factor interaction

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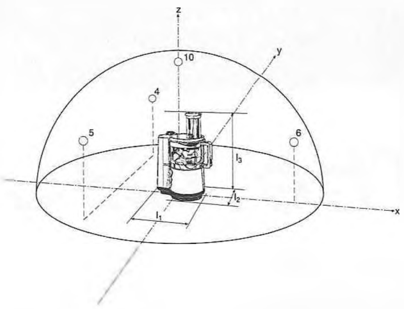

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# SEISMO-ACOUSTIC DETERMINATION OF THE SHEAR-WAVE SPEED OF SURFICIAL CLAY AND SILT SEDIMENTS ON THE SCOTIAN SHELF

**John C. Osler**[*] **and David M. F. Chapman**

Defence Research Establishment Atlantic
P.O. Box 1012, Dartmouth
Nova Scotia, B2Y 3Z7, Canada
email: dave.chapman@drea.dnd.ca

## ABSTRACT

The Defence Research Establishment Atlantic has determined the shear-wave speed profile of the unconsolidated surficial clay and silt sediments at two locations on the Scotian Shelf—the shallow water continental margin of Nova Scotia, Canada. An ocean bottom seismometer detected the passage of interface waves which were generated by detonating small explosives on the seabed. Profiles of shear speed as a function of depth were determined by repetitive forward modelling of the measured dispersion of the interface waves. The shear speed of the approximately 25 to 40 m thick Quaternary succession of clay and silt ranges from approximately 10 m/s at the seabed to 120 m/s at 40 m depth. The shear speed profiles are consistent with a power-law relationship of the form $c_s(z) = c_0 z^{\nu}$, with $\nu$ in the range 0.60-0.65 and $c_0$ in the range 16-22 m/s re 1 m. The shear speeds encountered in this study are among the lowest that have been reported for any marine sediment in the literature, while the strength of the gradient, $\nu$, is approximately twice that which is typically observed.

## SOMMAIRE

Le Centre de recherches pour la défense Atlantique a determiné le profil de vitesse des ondes de cisaillement dans des sédiments superficiel meuble d'argile et de limon à deux emplacements sur le plateau continentale écossais (les eaux continentales peu profondes au bord de la Nouvelle-Ecosse, Canada). Un sismomètre de fond d'océan détecte le passage d'ondes d'interface qui sont produites en détonant de petits explosifs sur le fond marin. Les profils de vitesse de cisaillement en fonction de la profondeur ont été déterminé en modélisant de façon répétitive la dispersion des ondes d'interface qui ont été mesurée. Dans la succession de couche d'argile et de limon du quaternaire qui est d'environ 25 à 40 m de profondeur, la vitesse des ondes de cisaillement varie entre approximativement 10 m/s sur le fond marin à 120 m/s à 40 m de profondeur. Les profils de vitesse de cisaillement sont consistants avec une relation de puissance de la forme $c_s(z) = c_0 z^{\nu}$ où $\nu$ varie entre 0.60 et 0.65, et $c_0$ varie entre 16 et 22 m/s re 1 m. Les vitesses de cisaillement obtenues dans cette étude sont parmies les plus basses qui ont été rapporté pour un sédiment marin, tandis que l'intensité du gradient, $\nu$, est approximativement le double de ce qui est typiquement observé.

## 1. INTRODUCTION

The shear-wave speed in unconsolidated surficial marine sediments and its dependence on depth is a physical property which is of interest to a broad community of researchers including acousticians, marine geophysicists, and geotechnical engineers. The shear speed of a sediment is a function of its shear strength—a property which is relevant to problems concerning seabed stability, such as earthquake risk assessment and the construction of offshore structures. For acousticians, conversion of compressional waves in the water to shear waves in the seabed has been identified as a significant propagation loss mechanism, particularly at lower frequencies and in shallow water [*e.g.* Akal, 1980]. In some seabeds, the shear speed profile dominates over other parameters (such as shear-wave attenuation, compressional-wave speed and attenuation, and density) in controlling propagation loss [*e.g.* Dosso and Brooke, 1995].

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[*] Current address: SACLANT Undersea Research Centre, Viale San Bartolomeo 400, 10138 San Bartolomeo (SP), Italy.

DREA's interest in shear wave effects in ocean acoustics is motivated by a desire to understand the influence of the seabed on the low-frequency performance of passive sonar systems, which endeavour to detect, locate, and classify submarines using the sounds that these vessels radiate naturally as a consequence of operating and transiting underwater [Chapman *et al.*, 1992]. Of secondary interest is the relation of shear speed to sediment stiffness and the ease with which anti-ship mines might be buried in Canadian shallow waters.

Direct measurements of shear-wave speed may be conducted *in situ* using probes (*e.g.* shear wave transducers or cone penetrometers) inserted into the sediment, in the laboratory by inserting probes into cores, or using vibrational techniques such as the resonant column test [Bennell and Smith, 1991]. The *in situ* measurements are typically limited in depth [*e.g.* Muir *et al.*, 1991], are time consuming, and often require support from divers or submersibles [*e.g.* Hamilton *et al.*, 1970]. Laboratory measurements have consistently shown lower values than *in situ* measurements [*e.g.* Richardson *et al.*, 1989; Stoll *et al.*, 1988] due to disturbance during collection, transportation, storage, and mechanical manipulation and reduction in confining pressure. Both methods, in particular the laboratory techniques using probes, make measurements at frequencies which are higher than those at which conversion to shear waves is identified as a significant propagation loss mechanism in field experiments.

Indirect measurements can use impulsive sources located at or near the seabed to generate interface waves on the water-sediment boundary and shear body waves within the sediment. These are detected by receivers located on or below the seabed. Sources include explosive charges and compressed air guns (summarized in Stoll *et al.* [1991] and Dodds [1995]), which may be configured into "shear-wave sleds" [Ewing *et al.*, 1992; Davis *et al.*, 1989] and torsional sources which generate horizontally polarized shear waves (SH) [Stoll *et al.*, 1994]. Receivers are typically geophone sensors although hydrophones located in proximity to the seabed are capable of detecting the compressional component of an interface wave. The underlying shear speed profile may be determined through a process of forward modelling to model the dispersion characteristics of the interface wave [*e.g.* Dosso and Brooke, 1995; Ali and Bibee, 1993] or in a more automated fashion through an inversion algorithm [*e.g.* Stoll *et al.* 1994; Caiti *et al.*, 1993]. The advantages of the indirect techniques are that they sample a larger volume, use more realistic frequencies, do not disturb the structural integrity of the sediment, and can resolve the shear speed to a greater depth.

The experiment described in this paper uses small explosive charges as sources to generate interface waves and the DREA ocean bottom seismometer (OBS) as a receiver. Two sites on the Scotian Shelf with clay as the surficial sediment were selected for the experiment. To our knowledge, this is the first publication presenting shear speed profiles for the surficial sediments on the Scotian Shelf collected using this seismo-acoustic inversion technique. The interface waves generated in this experiment propagated at group velocities and frequencies which are among the lowest—if not the lowest—that have been reported in the literature [Snoek, 1990; Stoll *et al.*, 1994]. Using this technique, the shear speed of the approximately 40 m of clay and silt in the Quaternary succession on the Scotian Shelf is determined to vary from approximately 10 m/s at the seabed to 120 m/s at 40 m depth, increasing as a power-law function of depth with an exponent in the range of 0.60 to 0.65.

## 2. GEO-ACOUSTIC ENVIRONMENT OF EXPERIMENTAL SITES

The prominent physiographic features of the Scotian Shelf are shallow banks (~100 m depth) and deeper basins (150-300 m depth). The unconsolidated surficial sediments on the Scotian Shelf were deposited during the late Quaternary period (the last 25,000 years before present). The sediment types and their distribution are linked to two related events: the Wisconsinan Glaciation, the most recent episode of glaciation on the Scotian Shelf, which covered most of the Scotian Shelf with ice; and relative sea level changes, up to 115 m lower than present, which led to sub-aerial exposure of the shallower areas. On average, the thickness of the Quaternary succession is 50 m. Following King [1970], the lithostratigraphy for the banks is typically sand underlain by glacial till, while the basins have clay and silt overlying the glacial till. (The information and nomenclature of the following two paragraphs is also based on King [1970].)

The glacial till, "Scotian Shelf Drift Formation", is deposited from grounded ice. In water depths >120 m, it overlies much of the bedrock on the Scotian Shelf in the sub-surface as a continuous blanket of relatively uniform thickness (10–15 m). It is a cohesive poorly sorted sediment generally containing angular fragments in the pebble / cobble / boulder range. It is dominantly sandy but contains abundant silt and clay. (This formation is found in water depths up to 260 m, but its maximum extent is not known.) The "Emerald Silt Formation" overlies and interfingers with the Scotian Shelf Drift. While similar in composition to the Scotian Shelf Drift, it was formed from subglacial meltout debris from a stable but floating ice shelf. The stratigraphy has a banded nature because of the differential sorting of material settling through the water column. Accordingly, there is a strong contrast in the acoustic character of the two formations which serves a basis to distinguish them. The "Sable Island Sand and Gravel Formation" is comprised of well-sorted and well rounded sand and gravel particles. It is

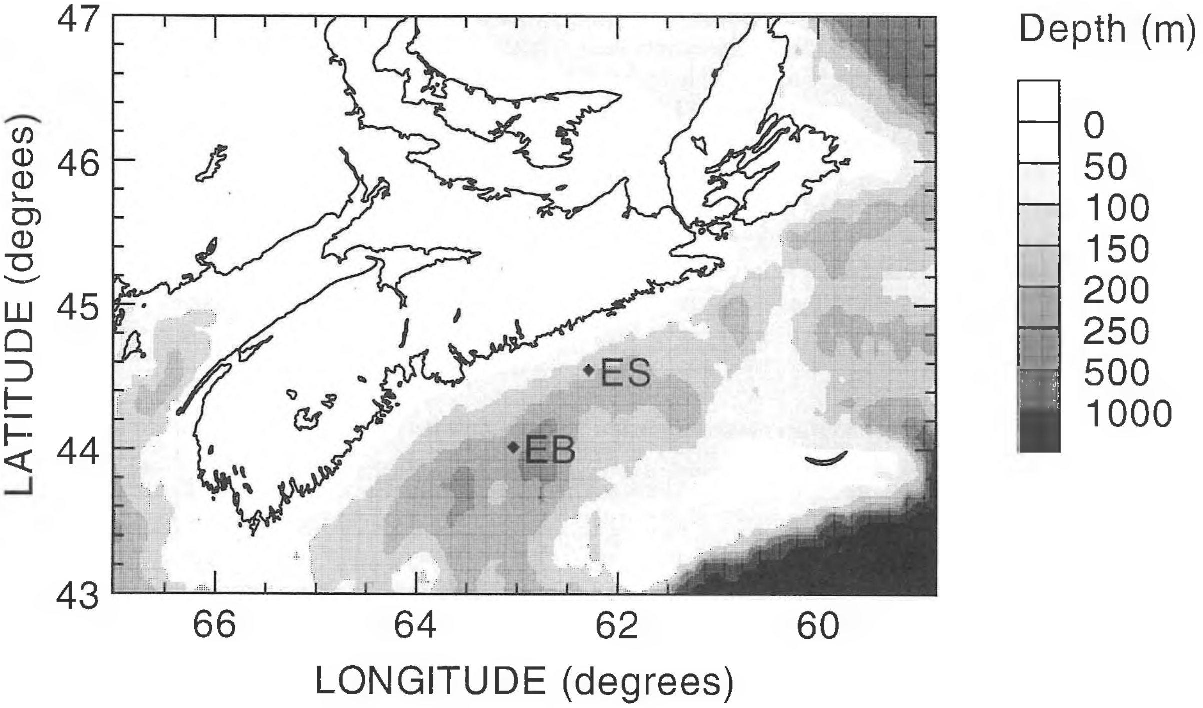

*Figure 1:* *Bathymetry of the Scotian Shelf and locations of interface wave dispersion experiments. EB=Emerald Basin, ES=Eastern Shore.*

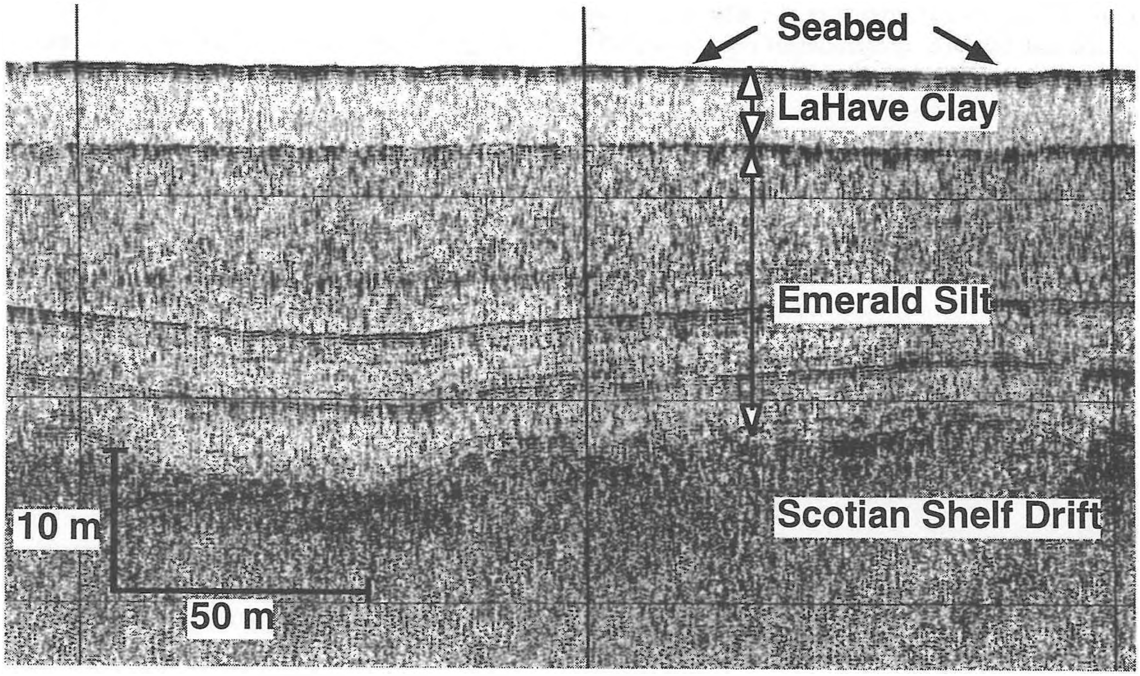

*Figure 2:* *Seismic reflection profile of the Quaternary succession at the ES site obtained with a 3.5 kHz profiler towed approximately 20 m above the seabed [Canadian Seabed Research, Ltd., 1996].*

mainly derived from the erosion of former glacial deposits on the shallow banks. These sediments, above the lowest sea level stand (120 m), were reworked in the high energy environment present when relative sea-level was rising. The "LaHave Clay" is a postglacial loosely compacted silty clay to clayey silt. It was deposited at the same time as the Sable Island Sand and Gravel and its distribution is mainly confined to the basins and depressions of the shelf where it is ponded over underlying sediments. It is derived by a winnowing of the fine material from the sediments on the banks during relative sea level rise and from adjacent land areas.

The two experimental sites for the interface wave dispersion studies are marked in Fig. 1. They are located in northwestern Emerald Basin (EB) at 44°0.792' N, 63°1.308' W and seaward of the Eastern Shore (ES) area of Nova Scotia at 44°32.826' N, 63°17.400' W. At both sites, the surficial sediment type is LaHave Clay, underlain by Emerald Silt and then Scotian Shelf Drift. The EB site was chosen [Osler, 1994] because of the availability of a wide diameter geotechnical core and seismic reflection and refraction profiles using Huntec "boomer" [Moran *et al.*, 1991; Courtney, 1996, Personal Communication], airgun [Louden, 1994], and 3.5 kHz piezoelectric [Canadian Seabed Research, Ltd., 1996] sources. The OBS was deployed in 219 m of water, over 9 m of LaHave Clay, and 29 m of Emerald Silt. The geotechnical core, 87003-002 [Courtney and Mayer, 1993], has a 17 m penetration with measurements of compressional-wave speed, bulk density, water content, grain size, shear strength, impedance, magnetic susceptibility, and compressional-wave attenuation at 500 kHz. The median grain size in the core is 2 μm, porosities range from 80% at the seabed to 55% at the base of the core, and bulk densities are approximately 1500 kg/m$^3$ for LaHave Clay and 1600 kg/m$^3$ for Emerald Silt. The compressional-wave speed measured in the core is 1.45 to 1.49 km/s, consistent with field measurements of 1.46 to 1.49 km/s for LaHave Clay [Dodds, 1990]. Even though the clay is considered "rigid" (i.e. the shear modulus is non-zero), the compressional-wave speed of the surficial sediment is less than the typical speed of sound for bottom waters at this site, as the compressibility does not increase as rapidly as the bulk density in moving from the water into the sediment.

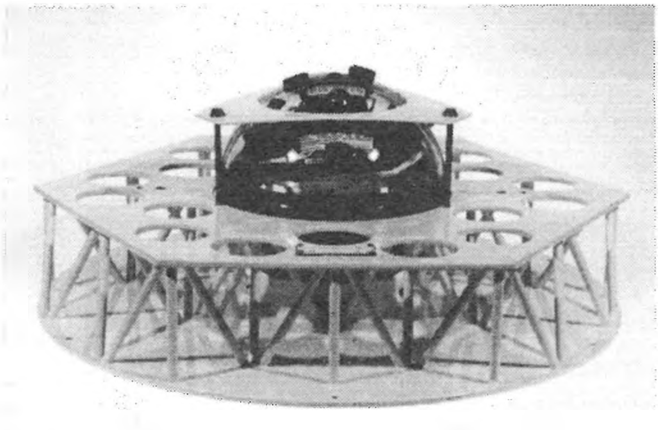

*Figure 3: The Acoustic Sensor Module of the DREA Ocean Bottom Seismometer. The sphere housing the geophones has a diameter of 0.25 m and is clamped to the 0.66 m diameter coupling disk.*

The ES site is situated in 156 m of water with a seabed comprised of 5.5 m of LaHave Clay overlying 20 m of Emerald Silt. The reflection profile (Fig. 2) is similar to that at the EB, however the boundary between the rhythmically banded Emerald Silt and the underlying Scotian Shelf Drift is more readily discerned. While there is limited geotechnical information at the ES site (surficial grabs and cores with 1 m penetration), the similarity in the reflection profiles and identification of the LaHave Clay and Emerald Silt formations suggests that the geo-acoustic environment is similar to that at EB. An exception may be the possibility of trapped gas within the surficial sediments [Moran *et al.*, 1991; Fader, 1991] at the EB site. Sidescan sonar images at the EB site [Canadian Seabed Research, Ltd., 1996] reveal that gas escape craters "pockmarks" are abundant while no evidence for pockmarks was seen in sidescan sonar images at the ES site.

## 3. OBS DESIGN AND INTERACTION WITH THE SEABED

The Acoustic Sensor Module of the DREA OBS (Fig. 3) houses the geophone sensors. It was built under contract according to DREA specifications [Dodds, 1994; Dodds *et al.*, 1994]. It consists of an orthogonal triad of 4.5 Hz geophones mounted on a block which is leveled and clamped to the base of the 0.25 m diameter spherical glass pressure vessel once the OBS has been deployed on the seabed. The pressure vessel is clamped to an aluminum coupling disk, formed by two concentric 0.66 m diameter horizontal plates connected by a framework of rods. This design provides a coupling disk which is rigid below 50 Hz, while keeping its mass minimal. The ASM is connected to a deployment frame by ropes which slacken when the OBS is on the seabed to decouple the ASM from the frame. The frame houses the deployment and recovery gear, power supply and telemetry electronics, protects the ASM during deployment and recovery, and provides a terminus for the armoured cable that carries the signals to the surface float (Fig. 5).

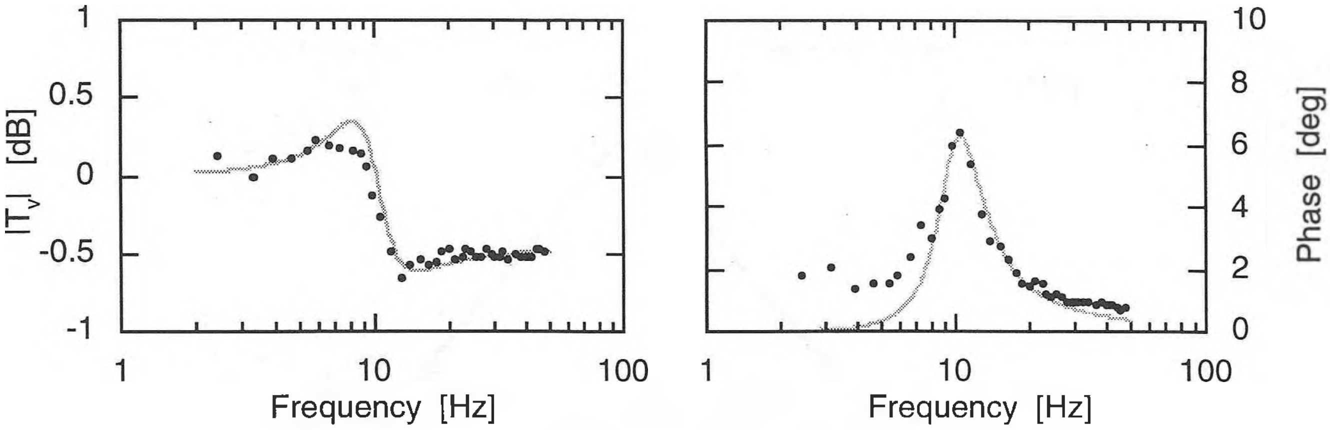

*Figure 4: The vertical motion seabed/OBS transfer function for a typical deployment on a clay seabed. The data points are values directly calculated from the measurement; the smooth curves are based on a mass-spring-dashpot model.*

The ASM is designed to minimize the interaction effects with the seabed [Dodds *et al.*, 1994] following the recommendations made by Sutton and Duennebier [1987]. Osler *et al.* [1994] derived transfer functions for the interaction of an OBS with the seabed and then applied this theory to experiments using the DREA OBS. By transfer function, we mean the ratio of the actual OBS velocity to the velocity of the seabed upon which the instrument rests, i.e. the actual quantity of interest. For faithful measurement, the transfer function should be as close to unity as possible. (Our analysis applies to any OBS for which rocking effects and interaction with nearby instrument packages can be ignored.) The transfer function for motion of the OBS in response to vertical seabed motion is

$$T_v = 1 - \frac{r}{r_\infty}\left(\frac{m - m_w}{m + m_{bot}}\right) \qquad (1)$$

where $r$ is the frequency-dependent "coupling ratio", $m_{bot}$ is the hydrodynamic added mass of the OBS when it is on the seabed, $m$ is the inertial mass of the OBS, $m_w$ is the mass of water it displaces, and

$$r_\infty = \frac{m + m_{sus}}{m + m_{bot}}, \qquad (2)$$

where $m_{sus}$ is the hydrodynamic added mass of the OBS when it is freely suspended in water. The coupling ratio is the ratio of the response of the ASM to forced motion when it is freely suspended in water and when it is on the seabed. The forcing at different frequencies in its 1–50 Hz operating band is effected by a miniature DC motor mounted inside the pressure vessel driving an eccentric mass of about one gram located about one-half centimetre off-axis. The excitation has both vertical and horizontal components and the phase of the forcing is tracked by a photo-optic sensor which detects the passage of the eccentric mass through a reference point.

When both amplitude and phase of the coupling ratio data are measured, the transfer function can be calculated directly by substituting the measured coupling ratio data into Eq. (1). The transfer function for a typical deployment on clay is shown in Fig. 4. The vertical transfer function is within 0.75 dB of unity at all frequencies, by virtue of the large hydrodynamic added mass, $m_{bot}$, which the coupling disk provides in the vertical (Fig. 3). We regard this correction to be insignificant for the purpose at hand, and we did not apply it to the data. The phase responses show some scatter, but only at very small phase values or when the magnitude response is very small. The measurement of seabed/OBS coupling indicates that the interface wave dispersion data (to be presented next) are accurate renderings of the true seabed motion.

## 4. EXPERIMENTAL PROCEDURE

Interface waves on the water-sediment boundary were generated by detonating small explosive charges at or near the seabed. The charges were formed with C4 plastic explosive molded around a blasting cap (non-electric No. 12) crimped to a fuse (M700) of sufficient length to burn for approximately 4 minutes. The charges were sealed in plastic, weighted to ensure they would descend to the seabed, and then deployed at different horizontal ranges as *C.F.A.V. Quest* proceeded away from the OBS at approximately 4 knots. Signals received on the DREA OBS geophones and hydrophone were digitized in the OBS, telemetered to *C.F.A.V. Quest* via the surface float, processed and displayed in real time to monitor data quality, and recorded for subsequent analysis (Fig. 5). Several measures were taken to mitigate the potential environmental impact of the explosions. Different charge weights from 100 to 500 g were tested during an initial experiment. The 250 g charges were the smallest with sufficient low frequency energy to generate interface waves on the soft clay seabed. As they were only effective at ranges less than approximately 300 m and had less energy in the higher order

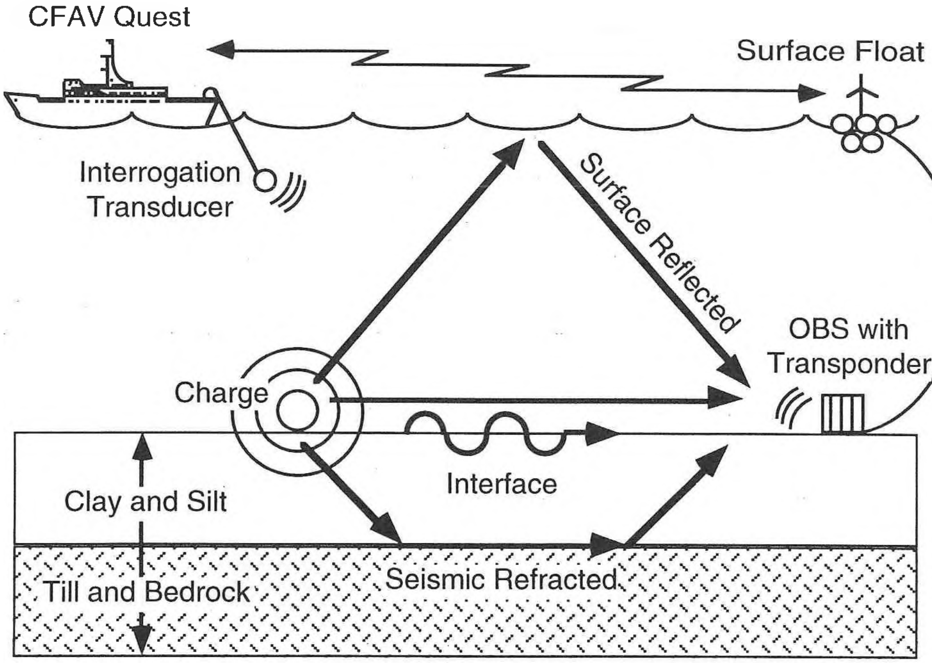

*Figure 5: Source to receiver arrival paths and schematic of experimental setup.*

modes (crucial in constraining models of shear speed structure), the 500 g charges were favoured. During the experiments, sonobuoys were deployed to listen for marine mammal vocalizations, the ships echo sounder was monitored for reflections from schools of fish, and the bridge maintained a visual watch for mammals on the surface.

Precise navigation was essential for the safe and successful conduct of this experiment. The ship itself uses Global Positioning System (GPS) navigation, whose inaccuracies may introduce errors of up to 100 m in absolute position. The OBS deployment frame was fitted with an acoustic transponder to measure the slant range to an interrogating transducer towed astern of *C.F.A.V. Quest* (Fig. 5). Prior to deploying explosives, the absolute position of the instrument was found [FITDS software, D.J. Dodds, GeoAcoustics Inc.] by minimizing the summed squared deviation between "observed" and "calculated" travel times using the Levenberg-Marquardt method [Dennis and Schnabel, 1983; Moré, 1977]. The observed travel time is that measured by the transponder system. The calculated travel time is that between the known interrogator position and an estimated position for the transponder—specified for the initial calculation and then revised to minimize the summed squared deviation. Typically 200 to 400 range measurements were used for each position determination. The calculated travel times are made assuming a reasonable

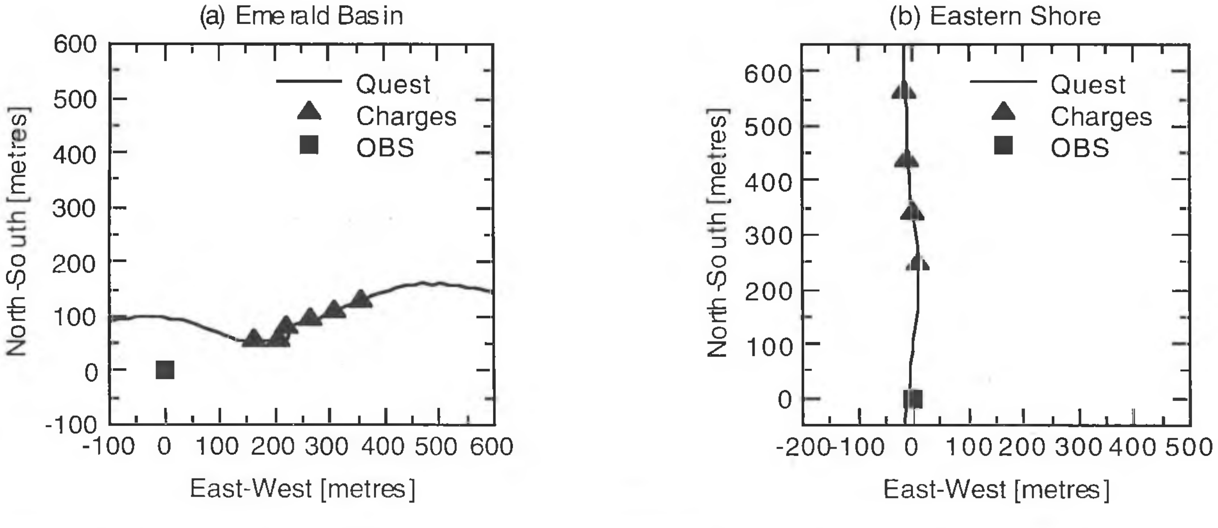

*Figure 6: Geometry of interface wave dispersion experiments at (a) the EB and (b) the ES site. Charge drop positions are GPS-derived positions and may not agree with acoustic ranges derived using Eq. 3.*

speed of sound, but it can also be a variable in the minimization. During an experiment, the slant and horizontal range of *C.F.A.V. Quest* relative to the OBS was monitored and once the OBS had been safely transited, charges were dropped at specified time or range intervals. The accuracy of relative range measurements is estimated at 5 m, limited by uncertainty in the position of the interrogating tow fish. Using this method, the scatter due to GPS error can be reduced, although there may still remain a bias in the resulting absolute position.

Plan views of the geometry of the experiments at the Emerald Basin and Eastern Shore sites are displayed in Fig. 6. The track of *C.F.A.V. Quest* and the drop positions of the charges are plotted relative to the absolute position of the OBS. Because the charges may drift laterally while descending to the seabed, accurate source to receiver ranges, $l$, were calculated using

$$l = \frac{c^2 \Delta t^2 - 4d^2}{2c\,\Delta t}, \qquad (3)$$

where $\Delta t$ is the difference in travel time between the direct and surface reflected arrival paths, $c$ is the speed of sound in water and $d$ is the water depth.

Sound speed profiles were measured with expendable sound velocimeters (XSVs), but precise details of the sound speed have little effect on the analysis, and a representative value of 1490 m/s has been used throughout. In particular, the transponder-positioning algorithm gives good results even if the assumed sound speed is not accurate, and the group speed of the interface wave modes (to be discussed below) is insensitive to the sound speed profile.

## 5. RESULTS

At each site, the interface wave generated at the shortest range—100 m for EB and 224 m for ES —has been selected for the dispersion analysis. The time series of vertical seabed motion as sensed by the geophones are plotted in the right panel of Figs. 7a and 7b, for EB and ES respectively. To reduce the dynamic range of the display, the amplitude of the time series has been compressed by a square root scaling factor. (This somewhat unconventional compression portrays the energy distribution in the waveform without distorting signals as much as a logarithmic compression.) The direct arrival is not shown because of the large disparity between the level of the interface wave and the direct arrival. The slowly propagating interface wave arrives at the OBS from 2 to 11 seconds after the direct water borne arrival at EB and from 5 to 15 seconds at ES.

The left panels in Figs. 7a and 7b are time-frequency-intensity decompositions of their respective interface waves displayed in the right panel. As with the time series, the amplitude of the power spectral density has been reduced by a square root compression before contouring to enhance the energy in lower amplitude arrivals (*e.g.* the higher order modes). The image of power spectral density was calculated using the *S* transform [Stockwell *et al.*, 1996] which is a joint time-frequency representation analysis technique with a frequency-dependent resolution. It is an extension of the Gabor [1946] and Wavelet [Goupillaud *et al.*, 1984] transforms designed to extend the principles of Fourier analysis to non-stationary time series. For a gaussian window width proportional to the period of the sinusoid being localized, as used to prepare Fig. 7, the *S* transform is

$$S(f,\tau) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} h(t)\left|f\right| e^{-(\tau-t)^2 f^2/2} e^{i2\pi f t} dt, \qquad (4)$$

where $\tau$ is the translation parameter with the same dimension as time, $h(t)$ is the time series, and $f$ is frequency.

The vertical axes for the images in Fig. 7 represent group speed, calculated using the time of flight since detonation of the charge and the source-receiver ranges calculated as previously specified. At each site, two interface wave modes are localized by the transform: a fundamental mode spanning 1 to 3 Hz having a group speed ranging from 10 to 40 m/s at EB and 15 to 50 m/s at ES; and a second mode

**Table 1: Geo-acoustic Parameters for Interface Wave Dispersion Modelling**

| | water | clay | silt | till |
|---|---|---|---|---|
| **density (normalized)** | 1 | 1.5 | 1.6 | 2.0 |
| **compressional-wave speed [m/s]** | 1490 | 1450 | 1550 | 1800 |
| **shear-wave speed [m/s]** | - | (see Fig. 9) | (see Fig. 9) | 180 |
| **compressional-wave attenuation [dB/λ]** | - | 0.2 | 0.5 | 0.5 |
| **shear-wave attenuation [dB/λ]** | - | 1.0 | 1.5 | 1.0 |
| **layer thickness at EB [m]** | ∞ | 9 | 29 | ∞ |
| **layer thickness at ES [m]** | ∞ | 5.5 | 20 | ∞ |

spanning 2.5 to 4 Hz having a group speed ranging from 15 to 30 m/s at EB and 25 to 35 m/s at ES. The group speed of an interface wave is related to the shear speed in the seabed to a depth of 1 or 2 wavelengths [Stoll *et al.*, 1991]. Interface waves have a dispersive nature—the lower frequency components penetrate deeper into the seabed where higher speed material is encountered. Consequently, they propagate at a higher group speed and arrive earlier at the OBS than the higher frequency components. (Note that the vertical axis for theses figures is actually linear in time, allowing grey-scale features to be identified with time-series features; however, the corresponding group speed has been indicated as an additional non-linear scale on the gry-scale plot.)

We modelled the dispersion of the interface wave modes using the pulse version of the SAFARI fast-field seismo-acoustic propagation model [Schmidt, 1988] which has an option to calculate curves of phase and group speed vs. frequency for a specified environment. Dosso and Brooke [1995] used this technique for their data and found that the results were extremely sensitive to the profile of shear speed vs. depth in the seabed, and much less sensitive to the other seismo-acoustic parameters, such as compressional wave speed, layer densities, attenuations, etc. Our model consists of a water half-space above, a clay layer, a silt layer, and a till half space below; the numerical values for the geo-acoustic inputs are shown in Table 1, except for the shear speed profile. The layer thicknesses were derived from vertical-incidence seismic reflection profiles at the sites (*e.g.* Fig. 2) gathered during a contracted survey [Canadian Seabed Research, Ltd., 1996].

SAFARI treats the seabed as a sequence of parallel layers of elastic solid, each layer having constant properties. If a quantity is thought to have a continuous gradient with depth—as in the case of the shear speed for soft sediments—then it is necessary to divide a material layer into several sub-layers, approximating the continuous profile with a staircase-like piecewise constant sequence.

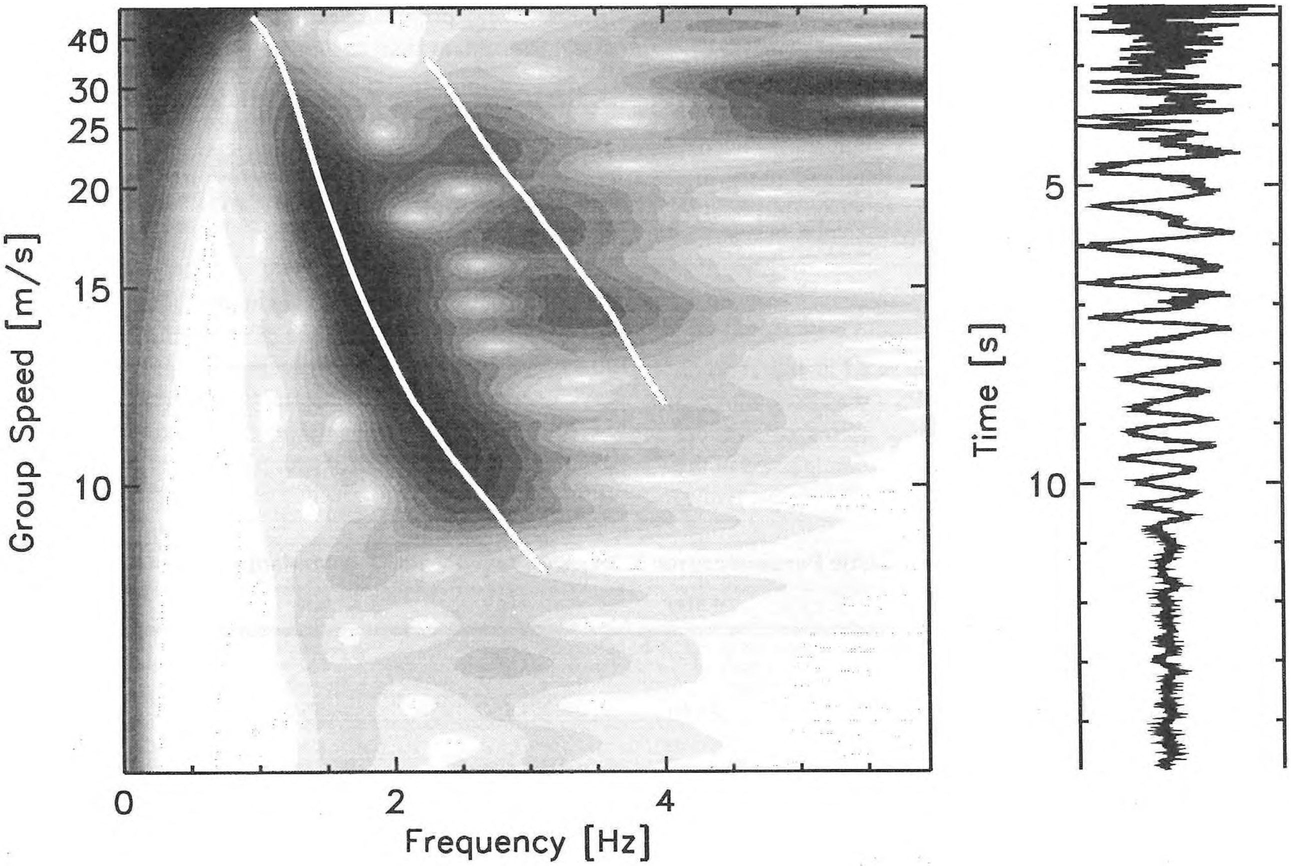

*Figure 7(a)* *S transform of an interface wave at the EB site (right hand panel). Solid line is the dispersion curve calculated using SAFARI and the shear-wave speed profile (Fig. 9). Square-root dynamic compression has been applied to both time series and grey scale to emphasize low-level signals.*

The observed dispersion data suggest that lower-frequency waves travel faster, implying that the longer wavelengths penetrate deeper and sample higher-speed material. (Dispersion could also result from the waterborne portion of the interface wave sensing the upper boundary of the ocean [Ewing *et al.*, 1957], but this effect occurs at frequencies much lower than our measurements, due to the very low wave speeds involved.) Following the suggestion of Stoll *et al.* [1991], we generated shear-speed staircases from an assumed continuous power-law profile of the form

$$c_s(z) = c_0 z^{\nu}, \tag{5}$$

in which $c_s$ is the shear speed at depth $z$ and $c_0$ and $\nu$ are parameters that control the shape of the profile. Because the shear speed (and hence the wavelength) increases with depth, we made each successive sub-layer progressively thicker to approximately maintain the same thickness-to-wavelength ratio for all the sub-layers. We used 11 clay and silt layers at EB and 9 layers at ES, where the soft sediments were not as thick. The resulting clay and silt sub-layer boundary depth sequence (in metres) is $z_n$={0, 0.25, 0.5, 1.5, 3.0, 5.5, 9.0, 13.5, 19.5, 25.5, 32, 38}. Then we calculated the sub-layer shear speeds from the formula

$$c_n = (1-\nu)c_0(z_{n+1} - z_n)/(z_{n+1}^{1-\nu} - z_n^{1-\nu}) \ , \tag{6}$$

which is derived from the principle that the travel time through a homogeneous sub-layer should be the same as the travel time through the same depth interval calculated using the continuous gradient of Eq. (5).

The inversion of the interface wave dispersion data to obtain the shear speed structures is accomplished through forward iterative modelling. Using reasonable guesses for the parameters $c_0$ and $\nu$, we calculate starting values for the shear speed staircase from Eq. (6) and include them with the parameters in Table 1 to prepare a SAFARI input file. After running the model, we compare the calculated group speed curves with the measured dispersion data. To simplify the comparison, we pick the maximum energy points from the time-frequency-intensity plots in Fig. 7 and plot them as speed-frequency plots along with the modelled group speed curves, as shown in Fig. 8. (The uncertainty in the

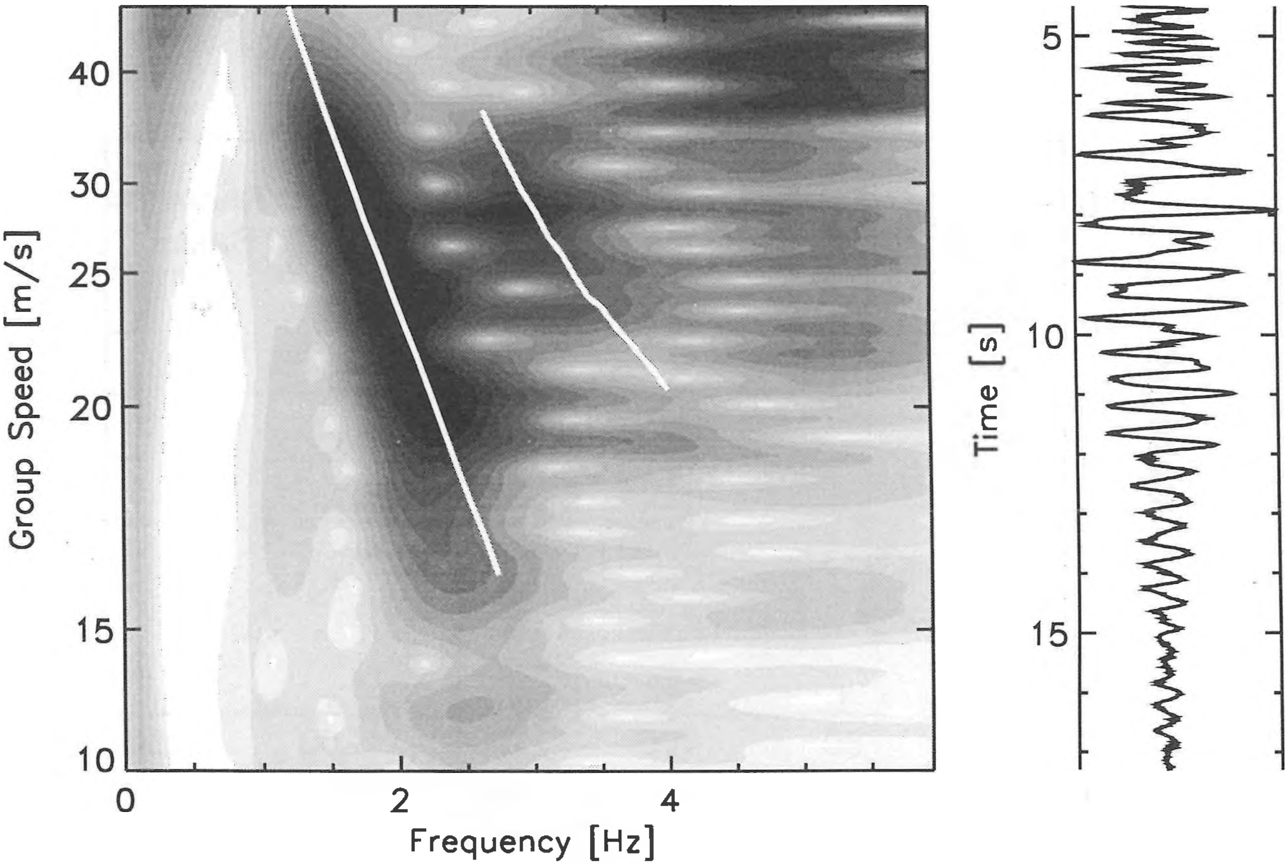

*Figure 7(b): S transform of an interface wave at the ES site (right hand panel). Solid line is the dispersion curve calculated using SAFARI and the shear-wave speed profile (Fig. 9). Square-root dynamic compression has been applied to both time series and grey scale to emphasize low-level signals.*

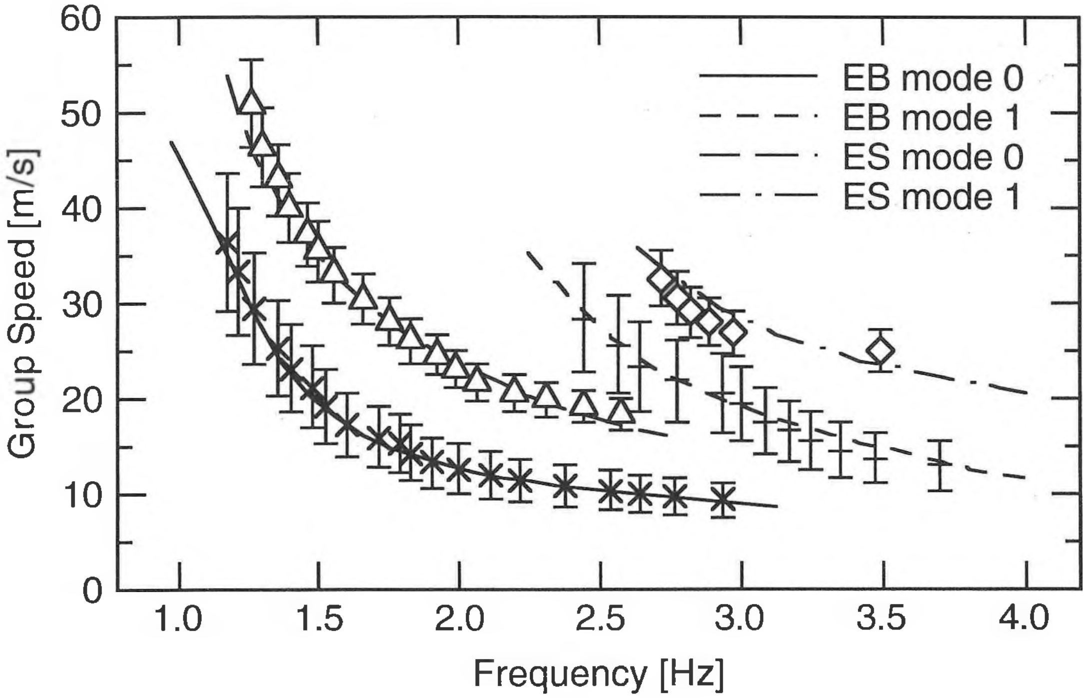

*Figure 8:* *Picks of maximum energy for the fundamental and higher order modes at the EB and ES sites are fit by theoretical dispersion curves calculated using SAFARI and the shear-wave speed profile in Fig. 9.*

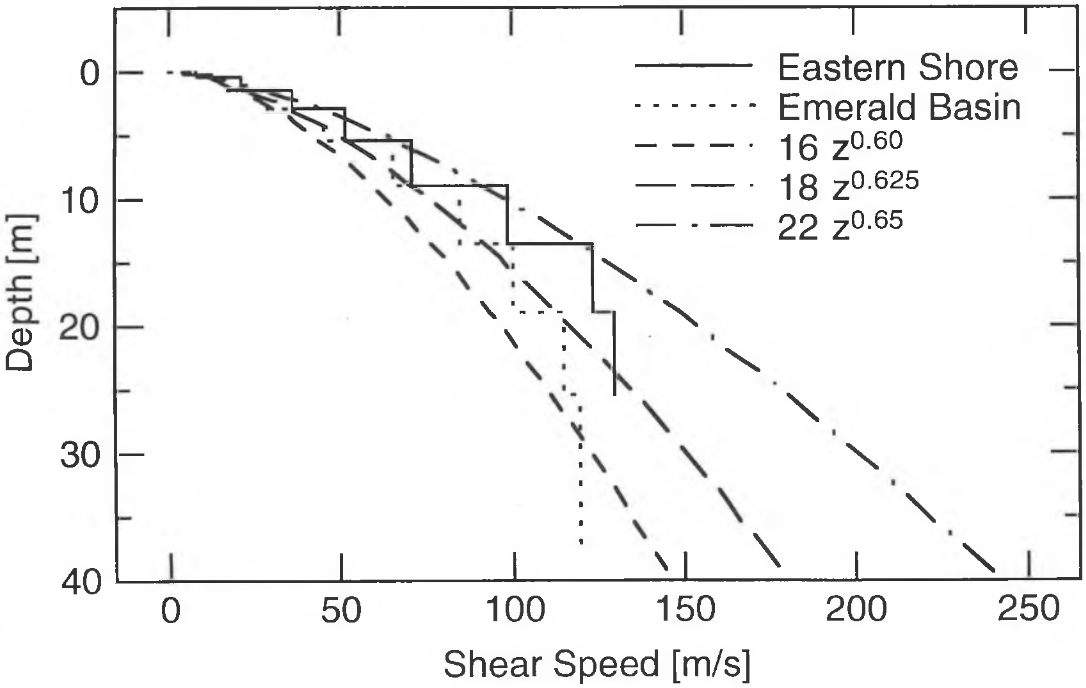

*Figure 9:* *Shear-wave speed from the inversion of interface wave dispersion data at the EB and ES sites on the Scotian Shelf.*

measured speeds derives from an uncertainty of ± 20 m in the calculated source-receiver ranges.) We vary the parameters $c_0$ and $\nu$ systematically and run SAFARI several times to achieve a reasonable fit overall, then we abandon Eq. (6) and adjust sub-layer shear speed values individually to obtain the final fit such as in Fig. 8. (We expect that actual sediment deposition processes would result in some variation of shear speed away from a smooth profile.) The resulting shear speed profiles for the EB and ES sites are shown in Fig. 9, along with some power-law profiles for comparison. The best-fit staircases are approximated by power law profiles with parameters $\nu = 0.63 \pm 0.03$ and $c_0 = 18.5 \pm 0.5$ m/s re 1 m for the EB site, and $\nu = 0.60 \pm 0.02$ and $c_0 = 21.5 \pm 0.5$ m/s re 1 m for the ES Site. The modelled dispersion curves are also superimposed on the grey-scale representations of the interface waves (Figs. 7a and 7b respectively).

Although the resulting profiles in Fig. 8 are plausible, there is some doubt regarding their uniqueness, as other workers have pointed out that the influence of the deeper layers becomes progressively less due to the concentration of energy in the interface wave modes towards the upper boundary. In this regard, at a given frequency, the higher-order modes seem to sample deeper sub-layers than the fundamental mode. Finding shear speed profiles to fit the dispersion of the fundamental mode is relatively easy, but inclusion of the higher mode in the fit restricts the range of allowed profiles. To refine the fit, more data would be required, perhaps from sources at different ranges or having more energy to excite higher modes in deeper layers. In summary, more confidence should be placed in the upper layers of these fits than in the lower.

## 6. DISCUSSION

Using an ocean bottom seismometer designed and partially constructed by DREA—the construction of the sensor portion having been contracted out—we have successfully recorded and interpreted explosively-generated interface waves on the seabed at two sites whose uppermost sediments are classified as clay and silt. Inversion of the measured dispersion data (*i.e.* group speed vs. frequency) using repetitive forward modelling with the SAFARI code has produced plausible profiles of shear speed vs. depth that are consistent with approximate power-law shear profiles of the form $c_s(z) = c_0 z^{\nu}$, with $\nu$ in the range 0.60–0.65 and $c_0$ in the range 16-22 m/s re 1 m. These measurements appear to be the first of their kind on the eastern Canadian continental shelf and the shear speeds fitted for the uppermost sub-layers are among the lowest determined anywhere using this method.

The fitted exponent $\nu$ seems higher than those for other sediments, which are of the order 0.3 [Stoll *et al.*, 1991]. (The uncertainty in source-receiver range translates into a proportional uncertainty in the $c_0$ parameter, but has little effect on the fit for the exponent $\nu$.) This deserves further investigation, particularly concerning the role of porosity in determining the shear speed. The Stoll *et al.* study assumes porosity is constant with increasing depth, so a porosity gradient might explain the higher exponent for the shear speed profile in clay. It is interesting to note that despite the high porosities and small grain sizes which lead the LaHave Clay to be classified as a suspension (*i.e.* the pore-fluid is stress-bearing rather than the grains [Courtney and Mayer, 1993; Nur *et al.* 1991]), the ability to generate interface waves in the material reveals that it does have some rigidity. Our observations concerning the nature of this material may also be of some use to geotechnical projects, such as the burial of submarine cables.

This paper does not consider the effect of the observed shear speed profiles on acoustic conditions for sonar operation, but the information provides a basis for such a study to be performed. These measurements provide ground truth for ocean acoustic experiments planned for the same sites.

## ACKNOWLEDGMENTS

John Osler was a Canadian Government Laboratory Visiting Fellow (a program administered by NSERC) and he thanks the Canadian Acoustical Association for support in the form of The Edgar and Millicent Shaw Postdoctoral Prize in Acoustics for the years 1994 and 1995.

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*Canadian Acoustics / Acoustique Canadienne 24(4) 23-28* **Technical Article / Article technique**

# RAY-TRACING MODELLING OF NOISE IN A FOOD-PACKING HALL

**Murray Hodgson**

Occupational Hygiene Programme and Department of Mechanical Engineering
University of British Columbia, 2206 East Mall, Vancouver, BC Canada V6T 1Z3

**David N. Lewis**

Environmental Engineering Section, Unilever Research, Port Sunlight Laboratory
Quarry Road East, Bebington, Wirral, Merseyside, UK L63 3JW

## ABSTRACT

By modelling workroom sound fields, the influence of building geometry, surface absorption, machine layout, sound power and directivity on noise at operator positions can be evaluated. This can be invaluable at the design stage of new projects or when assessing the most cost-effective approach to control noise in an existing installation. The approach adopted here is to predict the octave-band sound-propagation curves for a single noise source in the particular workroom using ray tracing. Curves are predicted for propagation in different directions within the building and for different acoustical treatments. They are approximated by one or two straight-line segments whose slope(s) are determined. A separate program is then used to compute the combined effect of all machine-noise sources in the workroom at positions on a 1-m grid, using the slope(s) and the applicable environmental correction factor. These techniques have been successfully applied to a number of major projects. Here, a case study is presented which illustrates a design-stage application to a new packing hall, which was modelled to evaluate the effects of increasing the ceiling absorption over all or part of the ceiling. The workroom is described and the predictions done are detailed. Also discussed are lessons learned with respect to workroom modelling.

## SOMMAIRE

En modelisant le champ sonore d'un local de travail, il est possible d'évaluer l'importance de facteurs tels la géométrie du bâtiment, l'absorption de surface, la disposition des machines et la puissance et directivité du son sur les niveaux de bruit aux positions des opérateurs de machines. Ce procédé peut être inestimable au stage de la conception de nouveaux projets, ou pour évaluer l'approche la plus économique pour contrôler le bruit dans un bâtiment déja construit. L'approche adoptée ici est une prédiction des courbes de propagation du son (bande d'octaves) pour une source de bruit unique dans un environnement de travail particulier, en utilisant le traçage de rayons. Les courbes sont évaluées pour la propagation dans des directions différentes à l'intérieur du bâtiment, et pour des traitements acoustiques différents. Elles sont déterminées approximativement par un ou deux segments droits dont là ou les pentes sont évaluées. Un logiciel séparé est utilisé pour calculer l'effet combiné de toutes les sources de bruit-machine dans le bâtiment à des points de grille séparés de 1 metre, en utilisant les pentes et un facteur de correction environnemental. Ces techniques ont été appliquées avec succès sur un certain nombre de projets importants. Un cas pratique, qui illustre une application au niveau de la conception d'un atelier d'emballage, a été modelisé pour évaluer l'effet d'une augmentation de l'absorption du plafond sur une partie ou sur la surface totale. Le local est décrit, et les prédictions sont présentées en détail. Nous discutons aussi les leçons apprises en rapport au modelisation d'un local.

## 1. INTRODUCTION

Concern for worker health and safety - not to mention occupational noise regulations - require the noise exposure of employed persons to be assessed, and for measures to limit noise exposure to acceptable levels to be defined. In the case of regulations, there is usually a requirement to reduce noise exposure to the lowest reasonably practicable level by engineering and/or administrative means. Regulations usually only discuss noise levels; however, it is well known that excessive reverberation is another important factor that must also be considered.

By predicting workroom sound fields the influence of building geometry, surface absorption, and machine layout, sound power and directivity on reverberation times and noise levels at worker positions can be evaluated. This is invaluable when assessing the most cost-effective approach to controlling noise in existing installations or at the design stage of new projects.

The approach adopted in the case histories reported here was to predict the reverberation time ($T_{60}$ in seconds) and/or the sound-propagation curves (the variation with distance, $r$, of the sound propagation, $SP(r)$, defined as the sound-pressure level, $L_p(r)$, minus the sound-power level, $L_W$, in dB) in octave bands for a single omnidirectional sound source in the workroom using ray-tracing techniques. Curves were predicted for propagation in different directions within the building and for different acoustical treatments. The curves were approximated by one or two straight-line segments. These segments are described by their slopes and absolute levels. The slopes were determined by regression, the absolute levels from applicable environmental correction factors. A separate program was then used to compute the combined effect of all noise sources in the building using the slopes and absolute levels of the sound-propoagation curves. This approach was considered more cost-effective than using ray tracing to calculate the total sound-pressure levels from the contributions of all of the sources; when many sources have to be considered run times can be prohibitive.

These techniques have been successfully applied to a number of major projects. A case study is presented here which illustrates their application at the design stage for a new food-packing hall which was modelled in order to evaluate the effects of increasing the acoustical absorption of all or part of the ceiling.

The aim of this paper is to illustrate the application of ray-tracing modelling techniques at a practical level. The case presented was a real-life study - contrained financially, technically and in time - done as part of the acoustical design of a facility. Time and cost constraints inevitably limit the effort that can be devoted to modelling. However, experience has shown that it can be a valuable tool to aid decision making in major projects. A further aim is to discuss what has been learned from the modelling exercise.

## 2. PREDICTION PROCEDURES

### 2.1 Sound-Propagation and Reverberation-Time Prediction by Ray Tracing.

Predictions of reverberation time and sound-propagation were made using ray-tracing techniques. The Ondet and Barbry model [1] for predicting sound-pressure levels in industrial workrooms with omnidirectional sound sources - extended to predict reverberation time - was used. More detailed descriptions of the model and its application are published elsewhere [1, 2].

Prediction involves modelling the workroom from a knowledge of the values of the following parameters at each prediction frequency: room geometry; surface absorption coefficients; fitting spatial distribution, densities and absorption coefficients; source sound-power level; source and receiver locations; air absorption exponent. Fitting density is quantified by frequency-invariant fitting scattering cross-section volume densities (in $m^{-1}$), typically assigned on the basis of experience as follows: nominally empty region, 0.03 [3]; low fitting density, 0.05-0.07; moderate fitting density, 0.08-0.17; substantial fitting density, 0.18-0.27; high fitting density, >0.27. The fitting absorption coefficient was 0.05 in all cases. Both fitting density and fitting absorption coefficient were assumed to be frequency invariant since this can give good results [2] and since the frequency variations are not known. The air-absorption-exponent values used in all predictions were those corresponding to a temperature of 20 °C and a relative humidity of 50 %.

The average slopes of the sound-propagation curves were determined from the slopes of least-square best-fit logarithmic regression lines through the predicted data, after approximating the curves by one or two straight-line segments - which ever gave the best results. Usually a single slope is accurate in smaller workrooms; a double slope may be more accurate in larger workrooms.

In all cases, once the room model was finalized, studies were done of the values of the ray-tracing parameters (the number of rays emitted by the source and the number of trajectories for which rays are traced) required to ensure accurate prediction in that case.

## 2.2 Sound-Pressure Level Prediction Using the Lewis Model

The combined effect of multiple noise sources within a workroom was modelled using a program ('the Lewis model') which computes the total A-weighted sound-pressure level at points on an imaginary 1-m grid over the workroom floor. Calculations can either be made in octave bands and the total A-weighted level computed. Alternatively, A-weighted levels can be derived from mid-frequency data; typically, industrial sound sources, such as packaging machines, have their highest sound powers in the 500-2000 Hz range. The program takes as input the horizontal coordinates of the machinery noise sources, their sound-power levels and information regarding their directivities (in two dimensions, defined as adjustments to the source sound-power level in six angular segments around the source). Constant-level background sources of noise (eg ventilation systems) are accounted for by logarithmically adding a constant background-noise level to the levels computed at all positions within the building.

The sound-propagation curves are assumed to comprise either one or two straight-line (on a logarithmic distance scale) segments. Each segment is described by its slope in dB/dd (dd means distance doubling) and its absolute level. The sound-propagation characteristics of the workroom can be input based on either a single-slope or a double-slope (eg 3 dB/dd up to 10 m and 4.2 dB/dd thereafter) curve shape. In addition, different propagation characteristics can be defined for different zones of the room. The values used for the slope(s) can be derived either from measured data, from empirical equations (for example, the Friberg [4] or Hodgson [5] models) or from predictions by more comprehensive approaches such as ray tracing. Absolute levels are estimated from applicable environmental correction factors [6].

The output from the program is a matrix of numbers representing the total A-weighted sound-pressure levels at positions 1 m apart over the floor of the building.

## 3. CASE HISTORY

### 3.1 Background

A new production / packaging facility was to be constructed inside an existing building. A design criterion of 85 dBA $L_{Aeq}$ was set for maximum noise levels within it. Advice was requested on measures that could be taken to ensure that this target was met. The area of particular concern was secondary packaging, in which five production lines were to be installed. The proposed ceiling height in this area was 4 m. The floor dimensions were approximately 37 m by 35 m. Two bounding walls were of painted brick, the others of half-glazed plastic-faced steel-laminate partitions. The ceiling was intended to be of 'walk-on' construction, made of 50 mm plastic-faced steel-laminate panels. The floor was of concrete with a sealed epoxy finish. The fittings consisted of packaging and other machines and conveyors. A plan and elevation of the room showing the schematic machine layout are presented in Figure 1.

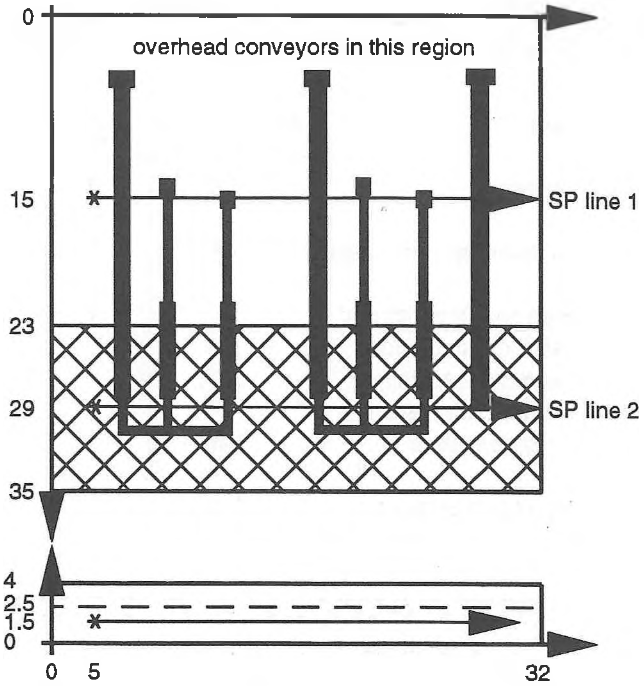


Figure 1. Plan and elevation of the food-packing hall as modelled, showing coordinated (in metres), sound propagation (SP) lines, extent of the partial ceiling treatment (cross-hatched) and the equipment layout (in black).

### 3.2 Ray-Tracing Prediction

Ray tracing was used to predict the mid-frequency reverberation times and octave-band sound-propagation curves, from which the average slopes were determined. Four cases were considered: a) without treatment (absorption coefficient, a= 0.07); b) moderately absorptive (a = 0.4) treatment of all of the ceiling; c) partial highly absorptive (a = 0.8) ceiling treatment - only one end of the ceiling was treated as shown in Figure 1; d) highly absorptive treatment of all of the ceiling.

The workroom was modelled from rough plan-and-section sketches showing the approximate machine layouts and heights, and from a knowledge of the internal untreated surface finishes. The room geometry was modelled - as shown in Figure 1 - and absorption coefficients for surfaces other than the ceiling were assigned as follows: floor, 0.02; vertical walls, 0.07. The room was divided into lower and

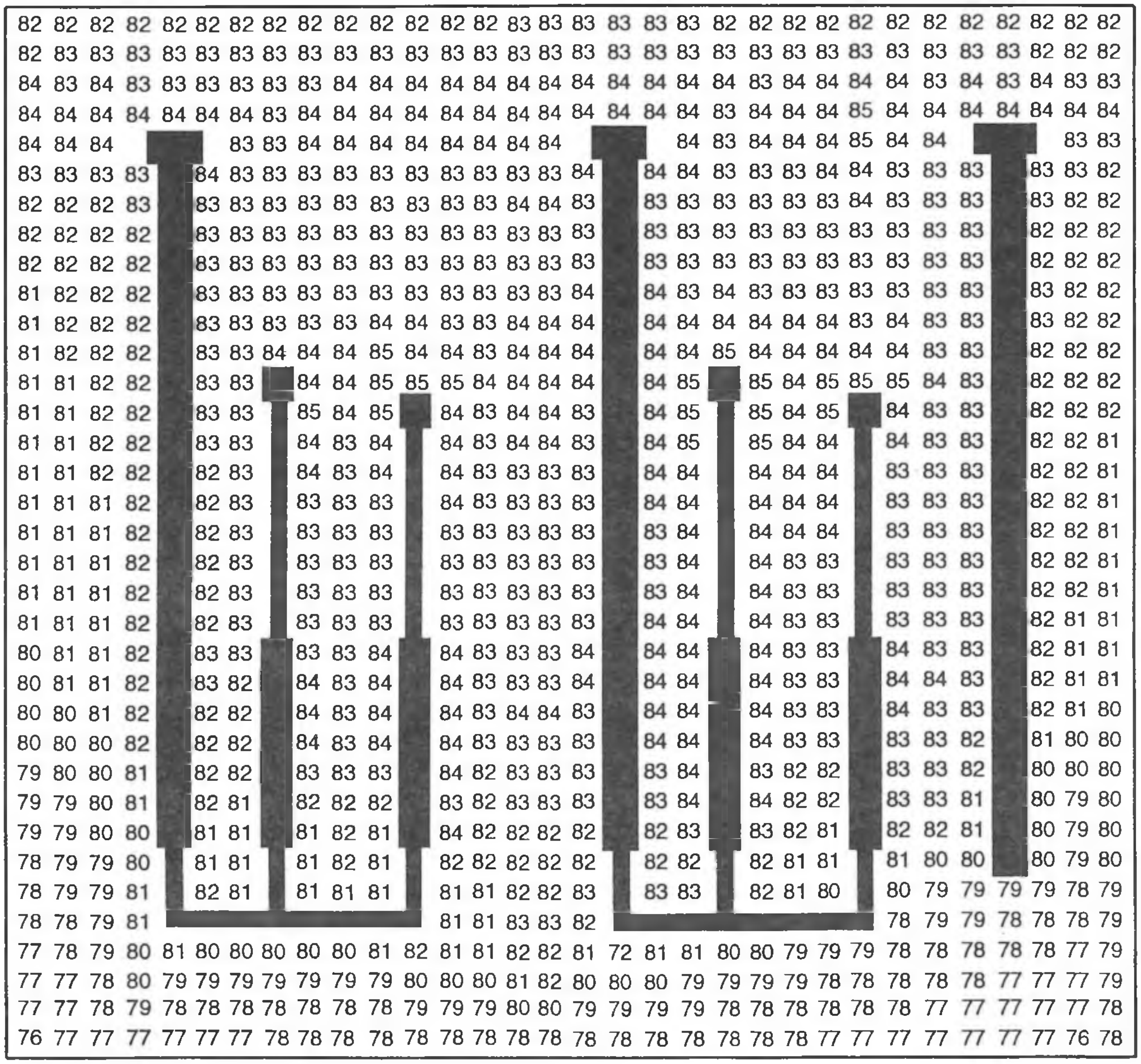
Table 1. Sound-propagation slopes and reverberation times ($T_{60}$) in the food-packing hall predicted by ray tracing

| Case | Slope (dB/dd) | $T_{60}$ (s) |
|---|---|---|
| A. Untreated | 2.4 | 2.9 |
| B. Moderate full treatment | 3.8 | 1.6 |
| C. High partial treatment: |  | 1.9 |
| - SP measured under untreated ceiling | 2.7 |  |
| - SP measured under treated ceiling | 4.6 |  |
| D. High full treatment | 5.1 | 0.6 |

upper fitting zones delimited at a height of 2.0 m, the estimated average machine height. These zones were assigned fitting scattering cross-section volume densities as follows: lower zone, 0.15 $m^{-1}$; upper zone, 0.03 $m^{-1}$. The sound-propagation curve was predicted for a convenient source position and in a direction which crossed the production lines in a part of the room under the untreated portion of the ceiling in the partially treated ceiling case (SP line 1 in Figure 1). The number of rays emitted from the source was 25000; each was traced for 80 trajectories. The predicted slopes and reverberation times are shown in Table 1.

### 3.3 Sound-Pressure Level Prediction

At the initial phase of the project accurate sound-power levels for the machinery noise sources were not available.



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| 76 | 77 | 77 | 77 | 77 | 77 | 77 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 76 | 78 |

Figure 2. Predicted A-weighted sound-pressure levels in the food-packing hall with partial ceiling treatment.

Preliminary predictions were therefore based on estimates of sound-power level obtained from measurements on similar equipment or on those specified to the suppliers - as well as, of course, on the predicted sound propagation data. Each machine was represented as an array of point sources, with one point source per cubic metre of volume; in all, 41 sources were used to model the production lines illustrated in Figure 1. The expected A-weighted sound-pressure levels were computed for this array of noise sources for each of the ceiling-treatment cases described above. For example, in the untreated case levels varied from 83-85 dBA at operator positions near the production lines; in the partially treated case, levels varied from 80-83 dBA.

Due to the uncertainties in the input sound-power data it was decided that, in order to ensure that the design criteria would be met, some acoustical treatment of the building should be included. Following detailed discussions with factory engineers and architects, the noise-control option chosen was to replace the walk-on ceiling above the main packing machines (the cross-hatched area in Figure 1 - this was the noisiest area with the most operators) with an Ecophon Hygiene N acoustical ceiling with measured mid-frequency diffuse-field absorption coefficient near 1. The workroom was built with this treatment option implemented.

Although specifications had been given for the maximum permissible noise levels from the machines, tests during commissioning of the new workroom indicated that these had largely been ignored by the machine suppliers. Detailed noise studies were therefore conducted on the dominant sources, their power levels were determined, and a programme of control measures was implemented. In addition, the option of not enclosing four overhead conveyors which were to have run above the walk-on ceiling at one side of the room was considered.

At this time the opportunity was also taken to measure the sound-propagation curves and reverberation times in the new workroom. Using the slopes of the measured sound-propagation curves and the measured source sound-power levels the expected noise levels were recomputed in order to assess whether or not the design criterion would be met if the noise-control measures on the dominant machines were implemented, and if the conveyors were not enclosed. The results of the predictions are shown in Figure 2; for comparison, the noise levels measured under full production conditions are shown in Figure 3. The agreement was good - typically within 1 dB.

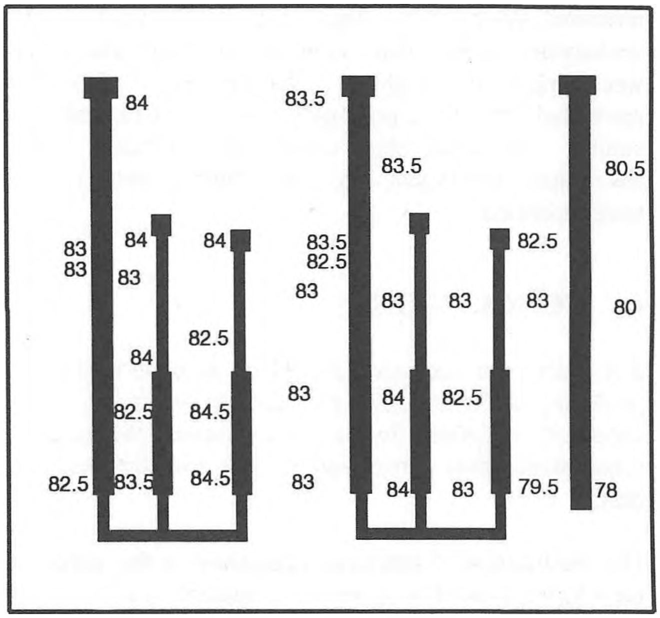

Figure 3. Measured A-weighted sound-pressure levels in the food-packing hall with partial ceiling treatment.

## 3.4 Final Remarks

The final treatment implemented was similar to prediction treatment case C. Thus it is instructive to compare predictions for this case with the results of measurement in the new workroom in order to evaluate the accuracy of the predictions done. The measured 125-8000 Hz octave-band reverberation times (in seconds) were as follows: 2.1 / 2.0 / 2.1 / 2.0 / 2.1 / 1.8 / 1.2. The predicted mid-frequency reverberation time was 1.9 s - only slightly lower than the measured values.

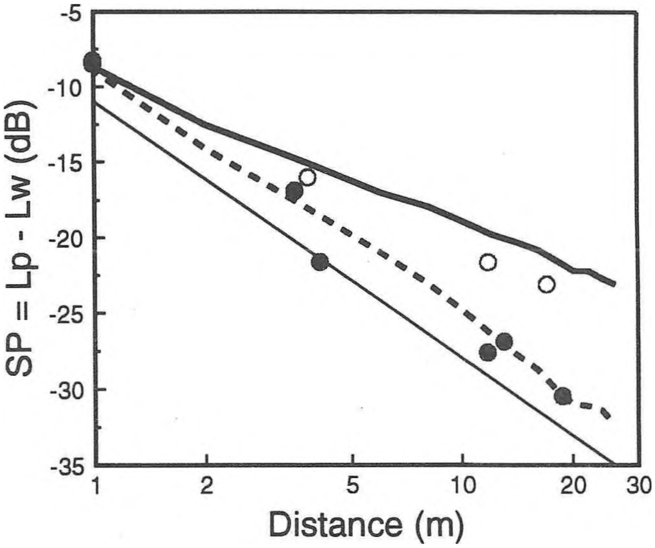

Figure 4. 1000-Hz sound propagation curves in the food-packing hall with partial ceiling treatment: under untreated ceiling - (○) measured, (▬▬) predicted; under treated ceiling - (●) measured, ( ▪ ▪ ▪ ) predicted. (———) free-field curve.

Figure 4 compares the predicted 1000-Hz sound-propagation curves for the partial-treatment case with those measured along the two lines shown in Figure 1. In the workroom as modelled, sound-propagation-curve slopes were apparently slightly underestimated. This was particularly true for a propagation line under the untreated ceiling, suggesting that either the untreated ceiling absorption coefficient or the fitting density was underestimated.

## 4. CONCLUSIONS

Ray tracing has been shown to be an accurate method for predicting workroom noise provided the workroom can be accurately modelled. In the cases presented the modelled sound-propagation curves agreed well with the measured data.

The combination of approaches presented in this paper has been found to work well and give valuable information to help decisions in major capital projects. In the applications to which this type of modelling has been applied the accuracy of the model has been found to be typically within 2 dBA provided the source data was valid.

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# Ocean Acoustic Tomography

## by Walter Munk, Peter Worcester and Carl Wunsch

The world's oceans are extremely vast - a 1000-km x 1000-km square represents about 1% of an ocean basin. Even in such a relatively small region, measurement of any of the fluid properties or behaviours using traditional techniques represents a significant investment in money and resources, requiring the use of a large number of deep-sea equipment moorings and several ships and/or aircraft. Acoustic tomography provides an opportunity to reduce the cost of such measurements and to improve the data quality. Since its introduction by Walter Munk and Carl Wunsch in 1979, acoustic tomography has been shown to be a useful tool for understanding ocean processes that affect many things in our day-to-day lives. The world's oceans are important in climate regulation, weather, food production, prospecting, and Defence: tomography has application in all of these fields.

In the past seventeen years there have been dozens, if not hundreds, of journal papers related to the theory and practice of tomographic techniques in the oceans. This book brings together, in one place, nearly all aspects of the field and in doing so fills what was a growing void. The book does not contain a lot of original material, but rather summarizes the history, theory, hardware, analyses, and practice of ocean tomography. Each topic is treated at an advanced level of understanding and readers will clearly benefit from past experience in underwater acoustics and oceanography. Perhaps the most valuable asset a new practitioner of ocean tomography will obtain by reading this book is an overall picture of the current state of the field with an immediate guide to areas where new work is required in this still evolving specialty.

The book itself is sturdily bound and is formatted to have a pleasant size and weight. The paper and print quality are both good, and the book contains many figures highlighting results from journal articles or illuminating topics of discussion. Figures are predominantly reproduced in black and white, although six colour plates highlight some selected results. The material in the book is presented in a formal manner making considerable use of footnotes and lengthy figure captions. It is notable that the preface contains the statement, "The reader will find a multitude of errors." This statement turns out to be true! Fortunately, almost all the errors appear to be located in one chapter (Chapter 2) and most are of a relatively trivial nature. The vast majority of the errors are incorrect references to equations or sections. Surprisingly, all the references to equations in Chapter 2 in succeeding paragraphs appear to be correct.

Turning now to the contents of the book, Chapter 1 is a motivational introduction to ocean acoustic tomography. This introduction does a good job describing the background, problems, and approaches to tomography. Chapter 2 discusses the range-independent forward problem. This is a lengthy chapter containing most of the mathematics and theory in the book. Topics are illustrated with examples employing an idealized adiabatic polar profile and the 'canonical' temperate profile. The material begins with simple ray and mode theory and proceeds to modal perturbation theory. Chapter 3 discusses the effect of a moving fluid in the ocean. Topics covered include currents, circulation, vorticity, divergence, and non-reciprocity. The impact of these features is illustrated by a discussion of the results from reciprocal-transmission experiments. Chapter 4 returns to the forward problem again, but this time for range-dependent scenarios. The topics include the adiabatic approximation, 'loop' resonance, internal waves, ray chaos, mode-coupling, horizontal refraction, and bathymetric effects.

Chapter 5 presents a change-of-face by leaving theory and propagation aspects behind and turning to the details of experiment design, observation, and measurement techniques. Topics include the sonar equation and related issues, signal processing (pulse compression), noise and scattering, vertical arrival angles, Doppler, time-keeping, and positioning. Chapter 6 addresses the inverse problem - given the measurements, how is the structure or the unknown quantities determined? Essentially, the answer is obtained by solving a highly under-determined set of equations with due regard to the likely error bounds on the unknowns and observed quantities. Methods discussed include least-squares, singular-value decomposition, and Gauss-Markov estimation. Variations of the techniques with both linear and non-linear equations are presented. The techniques are illustrated by application to actual experiments. Chapter 7 continues with model based inversions. In this chapter the issues of constraining model solutions with a priori information or measured data are presented. Formal treatment ends in Chapter 8 entitled, 'The Basin Scale.' In this chapter, major experiments are described and include the Perth-Bermuda antipodal transmissions, the Heard Island Feasibility Test, and the Acoustic Thermometry of Ocean Climate project.

The book closes with a short chapter that reminds the reader of the scientific capabilities that have been demonstrated with tomography and the resulting insights into the physics of the ocean. Following this final chapter are two appendices and an extensive list of references (approx. 400). Appendix A is a personal history (apparently narrated by Walter Munk) of the authors' involvement with ocean acoustic tomography and is entertaining reading. Appendix B, 'Ocean Acoustic Propagation Atlas,' is a useful compilation of the acoustic action, sound-speed profile, selected mode functions, and arrival patterns for 500-km long transmissions at 70 Hz for sites around the world.

In summary, despite a moderate number of mostly trivial errors and a formal style throughout most of the volume, I can recommend 'Ocean Acoustic Tomography' as a valuable book for anyone working in underwater acoustics or physical oceanography. For those considering acoustic probing of the ocean or sea-floor, this book is a 'must-read.' The best tribute that I can pay, is that by reading this book I have learned a great deal on a variety of topics that I shall apply to my own work in underwater acoustics.

**Reviewed by: Garry J. Heard, Defense Research Establishment Atlantic**

*[This book - ISBN 0-521-47095-1 - is available from Cambridge University Press, New York, at a price of US$59.95]*

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## EMPLOYMENT WANTED

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## Prix de l'ACA à la mémoire de Raymond Hétu

L'assemblée des directeurs de l'Association canadienne d'Acoustique et le comité du Prix Raymond Hétu ont décidé d'établir un nouveau prix, à la mémoire de Raymond Hétu, qui serait financé en tout ou en partie par des dons des membres de l'ACA. A leur demande, j'invite donc les membres à faire parvenir leurs dons pour ce prix. Des fonds substantiels ont déja été promis. S. v. p. me faire parvenir vos chèques libellés au nom de l'Association canadienne d'Acoustique et y inscrire, Re: Prix Raymond Hétu. Un reçu d'impôt sera émis.

## CAA Prize in Memory of Raymond Hétu

The Board of Directors of the Canadian Acoustical Association, and the Raymond Hétu Prize Committee, have decided to establish a new prize in memory of Raymond Hétu which would be financed all or in part by donations from the members of the CAA. At their request, I invite you to make donations towards this prize. Substantial funds have already been promised. Please send cheques made out to the Canadian Acoustical Association and marked, Re: Raymond Hétu Prize to me. A tax receipt will be issued.

**Murray Hodgson** - *Président, Comité du Prix Raymond Hétu / Chair, Raymond Hétu Prize Committee*

Canadian Acoustical Association
Association Canadienne d'Acoustique

# 1996 PRIZE WINNERS / RÉCIPIENDAIRES 1996

## EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS
## PRIZ POST-DOCTORAL EDGAR AND MILLICENT SHAW EN ACOUSTIQUE

**Vijay Parsa, University of Western Ontario**

*"Objective measurement of quality and intelligibility of hearing-aid processed speech"*

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## ALEXANDER GRAHAM BELL PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS
## PRIZ ALEXANDER GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

**Mark Pell, McGill University**

*"An acoustic investigation of speech prosody in adults with and without unilateral brain damage"*

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## FESSENDEN STUDENT PRIZE IN UNDERWATER ACOUSTICS
## PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

**Dean Addison, University of Victoria**

*"Extraction of reflectors from acoustic images"*

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## ECKEL PRIZE IN NOISE CONTROL
## PRIZ ECKEL EN CONTROLE DU BRUIT

**Nelson Heerema, University of British Columbia**

*"A simplified model for predicting noise levels and reverberation times in industrial workrooms"*

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## DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Professional ≥30 years / Professionel ≥30 ans: **Maurice Amram, École Polytechnique**

*"A new vacuum activated damping device to reduce noise and vibration during riveting"*

Professional <30 years / Professionel <30 ans: **Jean-Luc Wojtowicki, Université de Sherbrooke**

*"Noise reduction in a factory workplace using ray tracing method: a complete study from prediction to experimental validation"*

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## STUDENT AWARDS / PRIX ÉTUDIANT

**Nelson Heerema, University of British Columbia**

*"Empirical models for predicting noise levels and reverberation times in industrial workrooms"*

**Raphael Slawinski, University of Calgary**

*"A finite difference scheme for wave propagation through absorbing media"*

**Waqar-Un-Nissa Valiani, University of British Columbia**

*"Auralization of speech-communication cues"*

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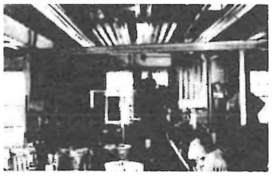

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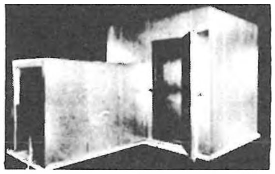

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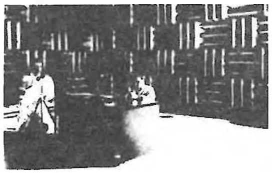

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# Minutes of the Board of Directors Meeting

## Calgary, October 8, 1996

| | | | | |
|---|---|---|---|---|
| *Present*: | J. Hemingway<br>A. Cohen<br>J. Bradley | E. Slawinski<br>M. Hodgson<br>C. Sherry | B. Gosselin<br>D. Chapman<br>S. Abel | |
| *Regrets*: | L. Cheng | S. Dosso | D. Quirt | D. Jamieson |

*Meeting called to order at 19:30.*

Minutes of May 1996 BOD meeting as published in the June 1996 issue of *Canadian Acoustics* were accepted. (Moved by: S.Abel, seconded C. Sherry, passed).

### President's Report

No new business other than items on agenda.

### Secretary's Report

Membership is decreasing in all categories. Total membership in October 1995 was 408 and in October 1996 was 376, a decrease of 8%.

A motion was made to require meeting organizers to sign up all non-member attendees as members to prevent our membership from shrinking. (Moved by J. Bradley, seconded by E. Slawinski, passed).

Secretary reported a small surplus in funds in the secretarial account and requested a float of $1500 for the new financial year. A motion was made that the secretarial float for the 1996/1997 financial year be $1500. (Moved by S. Abel, seconded by B. Gosselin, passed).

### Treasurer's Report

The treasurer reported problems with continued funding of our various prizes because of currently low interest rates. Unfortunately, available operating funds may not in the future be able to compensate for the lack of interest income. As a solution to the current year's problem of ensuring that all prizes can be funded, it was moved that this year, if necessary, the treasurer be permitted to use operating funds to supplement our interest income and ensure that all prizes that are awarded can be paid. (Moved by S. Abel, seconded by M. Hodgson, passed).

The treasurer also reported that our new auditor will try to recover GST payments and that, if successful, our operating budget should stay in the black.

It was moved that, as a means of generating increased revenue, the treasurer should make a motion at the annual general meeting to raise regular membership fees from $35 to $40. (Moved by C. Sherry, seconded by R. Ramakrishnan, passed).

A. Cohen suggested that the treasurer look into the possibility of using tax-exempt gifts by BOD members to CAA to minimize costs of subsidizing travel costs to the Spring BOD meeting. S. Abel will check with our auditor if this is possible.

The treasurer submitted a financial status forecast that for the period Sept 1, 1995 to August 31, 1996 income was approximately $1,000 greater than expenditures. The amended projected budget showed expected revenue for 1996/1997 to be $21,150. and expected expenses to be $20,650. A motion to accept the treasurer's report was moved forward. (Moved M. Hodgson, seconded by A. Cohen, passed).

### Awards Coordinator's Report

D. Chapman will revise the awards booklet and get it printed in time for mailing with the December issue of *Canadian Acoustics*. He announced that he would like to resign this position; the BOD will appoint a replacement at the Spring BOD meeting.

### National Youth Science Fair Prize

The national science-fair organization requested $1,000 of which half would go towards a prize to a student. After some negotiation, A. Cohen was able to have this reduced to $800 plus a subscription to *Canadian Acoustics*. There was considerable discussion as to whether or not CAA could now afford this. It was moved that due to our current fiscal restraints this matter should be brought to the membership for approval at the annual general meeting. (Moved by, S. Abel, seconded by C. Sherry, passed).

### Student Awards

At this CAA meeting (Oct. 1996) R. Ramakrishnan reported that approximately 10 of the 15 student papers have been submitted for these prizes.

### Raymond Hétu Prize

M. Hodgson reported receiving two cheques totaling $1,300 as a result of an announcement in *Canadian Acoustics*. The committee will continue to seek donations and to develop guidelines for this award. One suggestion was a book prize. J. Bradley offered to include a request for donations in the January 1997 mailing for membership fees.

### Shaw Prize

M. Hodgson suggested that the rules for the Shaw Prize should be reviewed and, in particular, an appeal process should be considered. It was moved that a committee be set up with E. Slawinski as chair to review the rules and the possibility of an appeal process for all CAA awards and that they should report to the BOD at the next Spring board meeting. (Moved by, S. Abel, seconded by R. Ramakrishnan, passed).

### Directors' Awards

B. Gosselin reported that two papers published in *Canadian Acoustics* have been selected: for the professional under 30 (J.L. Wojtowicki), and for the professional over 30 (M. Amram).

### Editor's Report

M. Hodgson reported problems due to the bankruptcy of our previous printer. Problems with the new printing company are being resolved. Reducing the conference papers from 2 to 1 page summaries saved CAA approximately $3000. Although there was discussion of the merits of printing longer versions of conference papers and separate conference proceedings, it was agreed that the benefits of the standard format and archival nature of the *Canadian Acoustics* conference issue was the much preferred approach. *Canadian Acoustics* will again publish 1-page summaries of all conference papers next year.

Some changes to the editorial board are planned. The current advertising editor, C. Hugh, would like to resign and a replacement is required. The editor will limit all expenses for the journal during the 1996/1997 financial year to no more than $14,000.

### Past / Future Meetings

*1995 Québec*

B. Gosselin submitted a report detailing the success of this meeting. A total of 72 people registered and 64 presentations were scheduled. A profit of $2,137.11 was made, of which $510 was in the form of new CAA memberships.

*1996 Calgary*

Organizers are optimistic for a very successful and profitable meeting.

*1997 Windsor*

The meeting is planned for Wednesday, Thursday, Friday, October 8, 9, 10, 1997. R. Gaspar and R. Ramakrishnan are co-chairs of the meeting. The Cleary International Centre has been booked for the meeting and the proposed budget would lead to an approximate $3,000 profit.

### Nominations Committee

It was proposed that all members of the executive be nominated again for the next year. Two new directors were proposed: J. Nicolas and D. Giusti.

### New Business

C. Sherry reported that CSA has agreed to continue support of the Z107 committee.

The past president, D. Chapman, would like to resign and feels that it is unfair that he is the only member of the executive that apparently cannot do so.

*Meeting adjourned at 23:33.*

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The Canadian Acoustical Association
l'Association Canadienne d'Acoustique

## Minutes of the Annual General Meeting
### Calgary, October 9, 1996

*J. Hemingway called the meeting to order at 17:30.*

The minutes of the Annual General Meeting of October 24, 1995 were accepted as published in the December 1995 issue of *Canadian Acoustics*. (Moved by S. Abel, seconded by R. Ramakrishnan, passed).

### President's Report

No new business.

### Secretary's Report

The secretary reported that membership was down in all categories from a total of 408 in October 11, 1995 to 376 on October 1, 1996, a decrease of 8%.

Processing of new memberships and renewals is proceeding smoothly. A small balance in the secretarial funds was reported and a reduced float of $1,500.00 was requested for the next financial year.

The secretary's report was accepted. (Moved by S. Abel, seconded by B. Dunn, passed).

### Treasurer's Report

The treasurer reported revenues of approximately $1,000 greater than expenses during the past financial year and that decreasing interest rates were making it increasingly difficult to fund the various CAA awards from interest income. This status has been confirmed by the CAA's auditor. A projected budget with expected expenses of $20,650 and expected revenues of $21,150 was presented.

To help to stabilize CAA finances, a motion was made to increase annual membership fees from $35 to $40. (Moved by S. Abel, seconded by D. Addison). This was then amended to include an increase of a further $10 (B. Dunn). The amendment was carried by 19 votes for and 10 against, and the original motion was carried with 20 votes for and 8 against. Membership fees for the new financial year will be $50.

A motion to accept the treasurer's report was carried. (Moved by S. Abel, seconded by B. Dunn, passed).

### Awards Coordinator's Report

D. Chapman announced that various awards would be announced at the meeting banquet and that the amounts for each award were unchanged. He also announced that E. Slawinski would chair a committee to review the various rules associated with the CAA awards and would make recommendations to the BOD at their Spring meeting.

There was some discussion concerning the use of operating funds to support CAA awards. There was a motion that on a long-term basis the BOD be directed to award prizes only from income from capital funds. (Moved by T. Kelsall, seconded by D. Havelock, defeated).

A subsequent motion to reaffirm the BOD's prerogative to review the CAA financial status and to revise the setting of prizes was carried. (Moved by B. Dunn, seconded by D. Addison, passed).

### Raymond Hétu Award

M. Hodgson reported receipt of $1,300 as a result of an appeal published in *Canadian Acoustics*. Further donations will be invited and the sub-committee will produce recommendations for the type and amount of this prize. A motion to keep these new funds separate from other CAA investments was defeated. (Moved by S. Abel, seconded by B. Dunn, defeated). To confirm the support of the membership a motion to set up a new prize to honour Raymond Hétu was carried. (moved by S. Abel, seconded by H. Forester, passed).

### National Youth Science Fair

Continued support of this award received lengthy debate with some participants stressing the merits of making National Science Fair participants aware of acoustics and others suggesting that CAA could not afford this particular award. Some suggested that this issue should have been decided by the BOD. A motion to discontinue support of the CAA prize at the National Science Fair and to encourage members to support youth interest in acoustics at the local level was defeated. (Moved by S. Abel, seconded by D. Addison, defeated). A motion to table the first motion until the next annual general meeting was also defeated. (Moved I. Gliener, seconded by B. Dunn, defeated).

### Editor's Report

The editor reported that the recent bankruptcy of Love printing caused several problems and delayed the arrival of the conference issue. Francine Desharnais is the new News Editor and a new Advertising Editor is being sought. The change from two- to one-page conference paper summaries saved CAA approximately $3,000 and will be continued one more year. Each copy of the journal costs approximately $7.50 and each page of each issue costs approximately $45 to $50 to produce.

There was a recommendation that the editor consider some form of page charge, though others argued that this would counter efforts to increase the number of published papers. There was a vote of thanks for the editor's continuing efforts.

### Membership

No mailings have been sent out during the past 18 months because funds were not available. The membership chairman requested that each member help to attract new members. CAA now has an internet home page at www.uwo.ca/hhcru/caa.

### Past/Future Meetings

*1995 Québec*

A surplus of $2,137 was reported. There was a vote of thanks for a very successful meeting under particularly difficult conditions.

*1996 Calgary*

Initial reports suggest there are approximately 102 participants and 86 presentations with expectations of a financial success.

*1997 Windsor*

Ramakrishnan and Gaspar are co-chairs and have booked facilities in the Cleary Centre. The meeting is to be October 8, 9, and 10, 1997 with a theme of Sound Quality.

### Nominations Committee

Proposed:

| | |
|---|---|
| President | J. Hemingway |
| Past President | D. Chapman |
| Secretary | J. Bradley |
| Treasurer | S. Abel |
| Recruitment | D. Jamieson |
| Editor | M. Hodgson |
| Proposed new directors | J. Nicolas<br>D. Giusti |

Accepted by acclamation.

*Meeting adjourned 19:32.*


NOISE BADGE
705

# NEWS / INFORMATIONS

## CONFERENCES

*The following list of conferences was mainly provided by the Acoustical Society of America.*

1996

2-6 December: Third Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, HI. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; E-mail: asa@aip.org, WWW: http://asa.aip.org

8-13 December: 14th World Conference on Non-Destructive Testing, New Delhi. Contact: B. Jaj, Metallurgy and Materials Group, Indira Gandhi Centre for Atomic Research, Kalpakkam 603102, India; E-mail: dmg@igcar.iitm.emet.in

11-13 December: 28th Annual Scientific Meeting British Medical Ultrasound Society, Edinburgh, Scotland. Contact: General Secretary BMUS, 36 Portland Place, London W1N 3DG, UK; FAX: +44 171 323 2175.

16-18 December: Numerical/Analytical Methods for Fluid-Structure Interaction Problems, Nottingham, UK. Contact: Institute of Acoustics, Agriculture House, 5 Holywell Hill, St Albans, Herts AL1 1EU, UK; FAX: +44 1727 850 533; E-mail: acoustics@clus1.ulcc.ac.uk

1997

20-22 January: EAA Symposium: Psychoacoustics in Industry and Universities, Eindhoven, The Netherlands. Contact: Ms. P. Stoop, Institute of Perception Research, P.O. Box 513, 5600 MB Eindhoven, The Netherlands; FAX: +31 40 277 3874; E-mail: stoop@natlab.research.philips.com

27-28 February: Penn State Ultrasonic Transducer Engineering Workshop, Newport Beach, CA. Contact: Donna Rode, SPIE, P.O. Box 10, Bellingham, WA 98227-0010, Tel.: 360-676-3290; E-mail: donnar@mom.spie.org or K. Kirk Shung, 231 Hallowell Bldg., Penn State Univ., University Park, PA 16802, Tel.: 814-865-1407; E-mail: kksbio@engr.psu.edu

17-19 March: Spring Meeting ASJ, Kyoto, Japan. Contact: ASJ Ikeda Building, 2-7-7 Yoyogi, Shibuya-ku, Tokyo, 151 Japan; FAX: +81 3 3379 1456.

2-4 April: International Symposium on Simulation, Visualization, and Auzalization for Acoustic Research and Education, Tokyo, Japan. Contact: M. Morimoto, Faculty of Engineering, Kobe University, Rokko, Nada, Kobe 657, Japan; Fax: +81 78 881 2508.

13-16 April: 23rd International Symposium on Acoustical Imaging, Boston, MA. Contact: Sidney Lees, Bioengineering Dept., Forsyth Dental Ctr., 140 Fenway, Boston, MA 02115; FAX: 617-262-4021; E-mail: slees@forsyth.org

14-18 April: Fourth French Congress on Acoustics, Marseille, France. Contact: Secretariat CFA4, 31 chemin J. Aiguier, 13402, Marseille, cedex 20, France; Fax: +33 91228248; E-mail: cfa-4@lma.cnrs-mrs.fr

21-24 April: International Conference on Acoustics, Speech, and Signal Processing ICASSP 97, Munich, Germany. Contact: H. Fastl, Lehrstuhl fur Mensch-Maschine-Kommunikation, Technische Universitat Munchen, 80290 Mnchen, Germany; Fax: +49 89 2105 8535; E-mail: fas@mmk.e-tchnik.tu.muenchen.de

## CONFÉRENCES

*La liste de conférences ci-jointe a été offerte en majeure partie par l'Acoustical Society of America.*

1996

2-6 décembre: 3e rencontre conjointe de l'Acoustical Society of America et de l'Acoustical Society of Japan, Honolulu, HI. Renseignements: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; E-mail: asa@aip.org; WWW: http://asa.aip.org

8-13 décembre: 14e conférence mondiale sur les tests non-destructifs, New Delhi, Inde. Renseignements: B. Jaj, Metallurgy and Materials Group, Indira Gandhi Centre for Atomic Research, Kalpakkam 603102, India; E-mail: dmg@igcar.iitm.emet.in

11-13 décembre: 28e rencontre scientifique annuelle de la British Medical Ultrasound Society, Edinburgh, Écosse. Renseignements: General Secretary BMUS, 36 Portland Place, London W1N 3DG, UK; FAX: +44 171 323 2175.

16-18 décembre: Méthodes numériques/analytiques pour problèmes d'intéraction fluide-structure, Nottingham, Royaume-Uni. Renseignements: Institute of Acoustics, Agriculture House, 5 Holywell Hill, St Albans, Herts AL1 1EU, UK; FAX: +44 1727 850 533; E-mail: acoustics @clus1.ulcc.ac.uk

1997

20-22 janvier: Symposium EAA: La psycho-acoustique en industrie et dans les universités, Eindhoven, Pays-Bas. Renseignements: Ms. P. Stoop, Institute of Perception Research, P.O. Box 513, 5600 MB Eindhoven, The Netherlands; FAX: +31 40 277 3874; E-mail: stoop@natlab.research.philips.com

27-28 février: Séminaire d'ingénierie de Penn State sur les transducteurs ultrasoniques, Newport Beach, CA. Renseignements: Donna Rode, SPIE, P.O. BOx 10, Bellingham, WA 98227-0010, Tel.: 360-676-3290; E-mail: donnar@mom.spie.org or K. Kirk Shung, 231 Hallowell Bldg., Penn State Univ., University Park, PA 16802, Tel.: 814-865-1407; E-mail: kksbio@engr.psu.edu

17-19 mars: Rencontre du printemps ASJ, Kyoto, Japon. Renseignements: ASJ Ikeda Building, 2-7-7 Yoyogi, Shibuya-ku, Tokyo, 151 Japan; FAX: +81 3 3379 1456.

2-4 avril: Symposium international sur la simulation, visualisation et l'auzalisation pour la recherche et l'éducation en acoustique, Tokyo, Japon. Renseignements: M. Morimoto, Faculty of Engineering, Kobe University, Rokko, Nada, Kobe 657, Japan; Fax: +81 78 881 2508.

13-16 avril: 23e symposium international sur l'imagerie, Boston, MA. Renseignements: Sidney Lees, Bioengineering Dept., Forsyth Dental Ctr., 140 Fenway, Boston, MA 02115; FAX: 617-262-4021; E-mail: slees@forsyth.org

14-18 avril: 4e congrès français sur l'acoustique, Marseille, France. Renseignements: Secrétariat CFA4, 31 Chemin J. Aiguier, 13402, Marseille, cedex 20, France; Fax: +33 91228248; E-mail: cfa-4@lma.cnrs-mrs.fr

21-24 avril: Conférence internationale sur l'acoustique, la parole et le traitement de signal ICASSP 97, Munich, Allemagne. Renseignements: H. Fastl, Lehrstuhl fur Mensch-Maschine-Kommunikation, Technische Universitat Munchen, 80290 Mnchen, Germany; Fax: +49 89 2105 8535; E-mail: fas@mmk.e-tchnik.tu.muenchen.de

21-25 April: International Conference on Shallow-Water Acoustics, Beijing, China. Contact: Renhe Zhang, Institute of Acoustics, Academia Sinica, Beijing 100080, China. FAX: +86 10 6256 9079; E-mail: zrh@canna.ioa.ac.cn

12-16 May: FASE Symposium on Hydroacoustics, Jurata/Gdansk, Poland. Contact: Institute of Experimental Physics, Gdansk University, Wita Stwosza 57, 80-952 Gdansk, Poland: Fax: +489 58 413175; E-mail: fizas@halina.univ.gda.pl

20-22 May: SAE Noise and Vibration Conference, Traverse City, MI, USA. Contact: SAE/MJA, 3001 W. Big Beaver Road, Suite 320, Troy, MI 48084, USA; FAX: +1 810 649 0425.

21-23 May: 25th Annual Meeting Italian Acoustical Association, Perugia, Italy. Contact: F. Astrubali, Istituto di Energetica, Via G. Duranti 1-A/4, 06125 Perugia, Italy; FAX: +39 75 582 5596; E-mail: rossi@apollo.isten.ing.unipg.it

5-7 June: Conference on ICP and Inner Ear Pressure, Bath, UK. Contact: British Society of Audiology, 80 Brighton Rd., Reading RG6 1PS, UK; Fax: +44 1734 351915.

15-17 June: NOISE-CON 97, State College, PA. Contact: Institute of Noise Control Engineering, P.O. Box 320, Arlington Branch, Poughkeepsie, NY 12603, Tel.: 914-891-1407; FAX: 914-463-0201.

15-20 June: Eighth International Symposium on Nondestructive Characterization of Materials, Boulder, CO. Contact: Debbie Harris, The Johns Hopkins University, Ctr. for Nondestructive Evaluation, 102 Maryland Hall, 3400 N. Charles St., Baltimore, MD 21218, Tel.: 410-516-5397; FAX: 410-516-7249, E-mail: cnde@jhuvms.hcf.jhu.edu

16-20 June: 133rd Meeting of the Acoustical Society of America, State College, PA. Contact: Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; WWW: http//asa.aip.org

18-21 June: 3rd European Conference on Audiology, Prague, Czech Republic. Contact: Paediatric Otolaryngologic Clinic, Faculty Hospital Motol, V Uvalu 84, 15018 Prague 5, Czech Republic; FAX: +42 2 2443 2620.

25-27 June: 5th International Congress of the International Society of Applied Psycholinguistics, Porto, Portugal. Contact: Maria da Graça Pinto, Universidade do Porto, Faculdad de Letras, Via Panorâmica, s/n, PT-4150 Porto, Portugal; FAX: +351 2 610 1990.

25-27 June: 12th Echocardiology Symposium and 9th Meeting of the International Cardiac Doppler Society, Rotterdam, The Netherlands. Contact: LMC Congress Service, P.O. Box 593, 3700 AN Zeist, The Netherlands, FAX: +31 343 533 357.

2-4 July: Ultrasonics International '97, Delft, The Netherlands. Contact: W. Sachse, Dept. of Theoretical and Applied Mechanics, Cornell Univ., Ithaca, NY 14853; Fax: 607 255 9179; E-mail: sachs@msc.cornell.edu

9-13 July: International Clarinet Association, Texas Tech Univ., Lubbock, TX. Contact: Keith Koons, Music Department, Univ. of Central Florida, P.O. Box 161354, Orlando, FL 23816-1354, Tel; 407-823-5116; E-mail: kkoons@pegasus.cc.ucf.edu

21-25 avril: Conférence internationale sur l'acoustique en eau peu profonde, Beijing, Chine. Renseignements: Renhe Zhang, Institute of Acoustics, Academia Sinica, Beijing 100080, China. FAX: +86 10 6256 9079; E-mail: zrh@canna.ioa.ac.cn

12-16 mai: Symposium FASE sur l'hydroacoustique, Jurata/Gdansk, Pologne. Renseignements: Institute of Experimental Physics, Gdansk University, Wita Stwosza 57, 80-952 Gdansk, Poland: Fax: +489 58 413175; E-mail: fizas@halina.univ.gda.pl

20-22 mai: Conférence SAE sur le bruit et les vibrations, Traverse City, MI, E-U. Renseignements: SAE/MJA, 3001 W. Big Beaver Road, Suite 320, Troy, MI 48084, USA; FAX: +1 810 649 0425.

21-23 mai: 25e rencontre annuelle de l'Association d'acoustique italienne, Perugia, Italie. Renseignements: F. Astrubali, Istituto di Energetica, Via G. Duranti 1-A/4, 06125 Perugia, Italy; FAX: +39 75 582 5596; E-mail: rossi@apollo.isten.ing.unipg.it

5-7 juin: Conférence sur l'ICP et la pression de l'oreille interne, Bath, Royaume Uni. Renseignements: British Society of Audiology, 80 Brighton Rd., Reading RG6 1PS, UK; Fax: +44 1734 351915.

15-17 juin: NOISE-CON 97, State College, PA. Renseignements: Institute of Noise Control Engineering, P.O. Box 320, Arlington Branch, Poughkeepsie, NY 12603, Tel.: 914-891-1407; FAX: 914-463-0201.

15-20 juin: Huitième symposium international sur la caractérisation non-destructive des matériaux, Boulder, CO. Renseignements: Debbie Harris, The Johns Hopkins University, Ctr. for Nondestructive Evaluation, 102 Maryland Hall, 3400 N. Charles St., Baltimore, MD 21218, Tel.: 410-516-5397; FAX: 410-516-7249, E-mail: cnde@jhuvms.hcf.jhu.edu

16-20 juin: 133e rencontre de l'Acoustical Society of America, State College, Pennsylvanie. Renseignements: Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; WWW: http//asa.aip.org

18-21 juin: 3e conférence européenne en audiologie, Prague, Czech Republic. Renseignements: Paediatric Otolaryngologic Clinic, Faculty Hospital Motol, V Uvalu 84, 15018 Prague 5, Czech Republic; FAX: +42 2 2443 2620.

25-27 juin: 5e congrès international de la Société internationale de psycho-linguistique appliquée, Porto, Portugal. Renseignements: Maria da Graça Pinto, Universidade do Porto, Faculdad de Letras, Via Panorâmica, s/n, PT-4150 Porto, Portugal; FAX: +351 2 610 1990.

25-27 juin: 12e symposium d'échocardiologie et 9e rencontre de la Société internationale du doppler cardiaque, Rotterdam, Pays Bas. Renseignements: LMC Congress Service, P.O. Box 593, 3700 AN Zeist, The Netherlands, FAX: +31 343 533 357.

2-4 juillet: Ultrasonics International '97, Delft, Pays-Bas. Renseignements: W. Sachse, Dept. of Theoretical and Applied Mechanics, Cornell Univ., Ithaca, NY 14853; Fax: 607 255 9179; E-mail: sachs@msc.cornell.edu

9-13 juillet: Association internationale de la clarinette, Texas Tech Univ., Lubbock, TX. Renseignements: Keith Koons, Music Department, Univ. of Central Florida, P.O. Box 161354, Orlando, FL 23816-1354, Tel: 407-823-5116; E-mail: kkoons@pegasus.cc.ucf.edu

14-17 July: 6th International Conference on Recent Advances in Structural Dynamics, Southampton, UK. Contact: N. Ferguson, ISVR, University of Southampton, Southampton SO17 IBJ, UK; FAX: +44 1703 593033; E-mail: mzs@isvr.soton.ac.uk

14-17 August: 1997 World Congress on Ultrasonics, Yokohama, Japan. Contact: S. Ueha, Precision and Intelligence Lab., Tokyo Inst. of Technology 4259 Nagatsuta, Midori-ku, Yokohama 226, Japan; Fax: +81 45 921 0898; E-mail: ucu97@pi.titech.ac.jp

21-23 August: ACTIVE 97 Inter-Noise Satellite Symposium, Budapest, Hungary. Contact: ACTIVE 97 Secretariat, POAKFI, Fou 68, 1028 Budapest, Hungary; FAX: +36 1 202 0452.

25-27 August: Internoise 97, Budapest, Hungary. Contact: OPAKFI, Fo. u. 68, 1027 Budapest, Hungary; Fax: +36 1 202 0452.

1-4 September: Modal Analysis Conference - IMAC-XV Japan, Tokyo, Japan. Contact: N. Okubo, Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Yokyo 112, Japan; FAX: +81 3 3817-1820; E-mail: jmac@okubo.mech.chuo-u.ac.jp

7-11 September: American Academy of Otolaryngology--Head and Neck Surgery, San Francisco, CA. Contact: American Academy of Otolaryngology--Head and Neck Surgery, One Prince St., Alexandria, VA 22314. Tel.: 703-836-4444; FAX: 703-683-5100.

9-12 September: 31st International Acoustical Conference "Acoustics - High Tatra 97", High Tetra, Slovakia. Contact: E. Rajcan, Technical University Zvolen, 96053 Zvolen, Slovakia; FAX: +42 855 321 811; E-mail: 31iac@tuzvo.sk

10-12 September: Biomechanics of Hearing, Stuttgart, Germany. Contact: EUROMECH Colloquium 368, W. Schiehlen, Institute B of Mechanics, University of Stuttgart, 70550 Stuttgart, Germany; E-mail: wos@mechb.uni-stuttgart.de

10-12 September: New Zealand Acoustical Society Biennial Conference, Christchurch, New Zealand. Contact: NZ Acoustical Society, P.O. Box 1181, Auckland, New Zealand.

22-24 September: Second Biennial Hearing Aid Research and Development Conference, Bethesda, MD. Contact: National Institute of Deafness and Other Communication Disorders, 301-970-3844; FAX: 301-907-9666; E-mail: hearingaid@tascon.com

22-25 September: 5th European Conference on Speech Communication and Technology, Patras, Greece. Contact: G. Kokkinakis, Department of Electrical and Computer Engineering, University of Patras, 26110 Rion-Patras, Greece; Fax: +30 61 991 855, E-mail: gkokkin @wcl.ee.upatras.gr

23-26 September: Fluid-Structure Interaction in Acoustics, Delft, The Netherlands. Contact: EUROMECH Colloquium 369, A.H.P. van der Burgh, Faculty of Technical Mathematics and Informatics, University of Technology, P.O. Box 5031, 2600 GA Delft, The Netherlands; E-mail: burgh @dv.twi.tudelft.nl

7-10 October: 1997 IEEE Ultrasonics Symposium, Toronto, Canada. Contact: S. Foster, Department of Medical Biophysics, Sunnybrook Health Science Ctr., 2075 Bayview Avenue, Toronto, Ontario M4N 3M5, Canada; E-mail: stuart@owl.sunnybrook.utoronto.ca

14-17 juillet: 6e conférence internationale sur les progrès récents en dynamique structurale, Southampton, Royaume-Uni. Renseignements: N. Ferguson, ISVR, University of Southampton, Southampton SO17 IBJ, UK; FAX: +44 1703 593033; E-mail: mzs@isvr.soton.ac.uk

14-17 août: 1997 congrès mondial sur les ultrasons, Yokohama, Japon. Renseignements: S. Ueha, Precision and Intelligence Lab., Tokyo Inst. of Technology 4259 Nagatsuta, Midori-ku, Yokohama 226, Japan; Fax: +81 45 921 0898; E-mail: ucu97@pi.titech.ac.jp

21-23 août: ACTIVE 97 Symposium satellite d'Inter-Noise, Budapest, Hongrie. Renseignements: ACTIVE 97 Secretariat, POAKFI, Fou 68, 1028 Budapest, Hungary; FAX: +36 1 202 0452.

25-27 août: Internoise 97, Budapest, Hongrie. Renseignements: OPAKFI, Fo. u. 68, 1027 Budapest, Hungary; Fax: +36 1 202 0452.

1-4 septembre: Conférence sur l'analyse par modes - IMAC-XV Japon, Tokyo, Japon. Renseignements: N. Okubo, Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Yokyo 112, Japan; FAX: +81 3 3817-1820; E-mail: jmac@okubo.mech.chuo-u.ac.jp

7-11 septembre: Académie américaine d'otolaryngologie - Chirurgie de la tête et du cou, San Francisco, CA. Renseignements: American Academy of Otolaryngology--Head and Neck Surgery, One Prince St., Alexandria, VA 22314; Tel.: 703-836-4444; FAX: 703-683-5100.

9-12 septembre: 31e conférence internationale d'acoustique "Acoustics - High Tatra 97", High Tetra, Slovakia. Renseignements: E. Rajcan, Technical University Zvolen, 96053 Zvolen, Slovakia; FAX: +42 855 321 811; E-mail: 31iac@tuzvo.sk

10-12 septembre: Biomécanique de l'audition, Stuttgart, Allemagne. Renseignements: EUROMECH Colloquium 368, W. Schiehlen, Institute B of Mechanics, University of Stuttgart, 70550 Stuttgart, Germany; E-mail: wos@mechb.uni-stuttgart.de

10-12 septembre: Conférence biennale de la Société d'acoustique de la Nouvelle-Zélande, Christchurch, Nouvelle-Zélande. Renseignements: NZ Acoustical Society, P.O. Box 1181, Auckland, New Zealand.

22-24 septembre: 2e conférence biennale sur la recherche et le développement des prothèses auditives, Bethesda, MD. Renseignements: National Institute of Deafness and Other Communication Disorders, 301-970-3844; FAX: 301-907-9666; E-mail: hearingaid@tascon.com

22-25 septembre: 5e conférence européenne de la communication et la technologie de la parole, Patras, Grèce. Renseignements: G. Kokkinakis, Department of Electrical and Computer Engineering, University of Patras, 26110 Rion-Patras, Greece; Fax: +30 61 991 855, E-mail: gkokkin @wcl.ee.upatras.gr

23-26 septembre: Intéractions fluide-structure en acoustique, Delft, Pays-Bas. Renseignements: EUROMECH Colloquium 369, A.H.P. van der Burgh, Faculty of Technical Mathematics and Informatics, University of Technology, P.O. Box 5031, 2600 GA Delft, The Netherlands; E-mail: burgh@dv.twi.tudelft.nl

7-10 octobre: Symposium de 1997 de l'IEEE sur les ultrasons, Toronto, Canada Renseignements: S. Foster, Department of Medical Biophysics, Sunnybrook Health Science Ctr., 2075 Bayview Avenue, Toronto, Ontario M4N 3M5, Canada; E-mail: stuart@owl.sunnybrook.utoronto.ca

8-10 October: 1997 Acoustics Week in Canada, Windsor, Canada. Contact: Dr. R. Ramakrishnan, Vibron Ltd, 1720 Meyerside Drive, Mississauga, Ontario, L5T 1A3. Tel.: (905) 670-4922; FAX: (905) 670-1698.

19-21 November: WESTPRAC VI 97, Hong Kong. Contact: S.K. Tang, WESTPRAC Secretary, Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hum, Hong Kong; FAX: +852 27746146; E-mail: besktang@polyu.edu.hk

1-5 December: 134th Meeting of the Acoustical Society of America, San Diego, CA. Contact: Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; WWW: http//asa.aip.org

15-18 December: 5th International Congress on Sound and Vibration, Adelaide, Australia. Contact: ICSV5 Secretariat, Department of Mechanical Engineering, University of Adelaide, South Australia 5005, Australia; FAX: +61 8 8303 4367; E-mail: icsv5@mecheng.adelaide.edu.au

1998

23-27 March: DAGA 98 - German Acoustical Society Meeting, Zürich, Switzerland. Contact: DEGA, Physics/Acoustics Department, Universität Oldenburg, 26111 Oldenburg, Germany; FAX: +49 441 798 3698; E-mail: dega@aku.physik.uni-oldenburg.de

8-10 June: EAA/EEAA Symposium "Transport Noise and Vibrations", Tallinn, Estonia. Contact: East-European Acoustical Association, Moskovskoe Shosse 44, 196158 St.-Petersburg, Russia; FAX: +7 812 127 9323; E-mail: krylspb@sovam.com

22-26 June: 135th meeting of the Acoustical Society of America/16th International Congress on Acoustics, Seattle, WA. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; E-mail: asa@aip.org, WWW: http://asa.aip.org

13-17 September: American Academy of Otolaryngology--Head and Neck Surgery, San Francisco, CA. Contact: American Academy of Otolaryngology--Head and Neck Surgery, One Prince St., Alexandria, VA 22314. Tel.: 703-836-4444; FAX: 703-683-5100.

12-16 October: 136th meeting of the Acoustical Society of America, Norfolk, VA. Contact: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; E-mail: asa@aip.org; WWW: http://asa.aip.org

16-18 November: Inter-Noise 98, Christchurch, New Zealand. Contact: New Zealand Acoustical Society, P.O. Box 1181, Auckland, New Zealand.

## MORE NEWS...

The Western Pacific Regional Acoustics Conference (WESTPRAC) is to be held for the second time in Hong Kong from 19-21 November 1997, as listed above. The 3-day technical acoustics conference involves all of the Asian acoustical societies: Hong Kong, China, Korea, Japan, Singapore, Australia etc. The Call for papers brochure can be found at http://www.polyu.edu.hk/~westprac. Proposals for papers in all areas of acoustics are welcome.

**CAA on the Web!** Members of the Canadian Acoustical Association are reminded to visit their new WWW home page located at "http://www.uwo.ca/hhcru/caa/". Suggestions for the development of the page are welcomed, particularly for links to the web sites of Canadian laboratories involved in acoustics research and to key sources of acoustics information throughout the world.

8-10 octobre: Semaine canadienne d'acoustique 1997, Windsor, Canada. Renseignements: Dr. R. Ramakrishnan, Vibron Ltd, 1720 Meyerside Drive, Mississauga, Ontario, L5T 1A3. Tel.: (905) 670-4922; Fax: (905) 670-1698.

19-21 novembre: WESTPRAC VI 97, Hong Kong. Renseignements: S.K. Tang, WESTPRAC Secretary, Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hum, Hong Kong; FAX: +852 27746146; E-mail: besktang@polyu.edu.hk

1-5 décembre: 134e rencontre de l'Acoustical Society of America, San Diego, Californie. Renseignements: Acoustical Society of America, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; Fax: 516-576-2377; E-mail: asa@aip.org; WWW: http//asa.aip.org

15-18 décembre: 5e congrès international sur les sons et vibrations, Adelaide, Australie. Renseignements: ICSV5 Secretariat, Department of Mechanical Engineering, University of Adelaide, South Australia 5005, Australia; FAX: +61 8 8303 4367; E-mail: icsv5@mecheng .adelaide.edu.au

1998

23-27 mars: DAGA 98 - Rencontre de la Société allemande d'acoustique, Zürich, Suisse. Renseignements: DEGA, Physics/Acoustics Department, Universität Oldenburg, 26111 Oldenburg, Germany; FAX: +49 441 798 3698; E-mail: dega@aku.physik.uni-oldenburg.de

8-10 juin: Symposium EAA/EEAA "Bruit et vibrations des transports", Tallinn, Estonia. Renseignements: East-European Acoustical Association, Moskovskoe Shosse 44, 196158 St.-Petersburg, Russia; FAX: +7 812 127 9323; E-mail: krylspb@sovam.com

22-26 juin: 135e rencontre de l' Acoustical Society of America/16e congrès international d'acoustique, Seattle, WA. Renseignements: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; E-mail: asa@aip.org; WWW: http://asa.aip.org

13-17 septembre: Académie américaine d'otolaryngologie - Chirurgie de la tête et du cou, San Francisco, CA. Renseignements: American Academy of Otolaryngology--Head and Neck Surgery, One Prince St., Alexandria, VA 22314. Tel.: 703-836-4444; FAX: 703-683-5100.

12-16 octobre: 136e rencontre de l'Acoustical Society of America, Norfolk, VA. Renseignements: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, Tel.: 516-576-2360; FAX: 516-576-2377; E-mail: asa@aip.org; WWW: http:// asa.aip.org

16-18 novembre: Inter-Noise 98, Christchurch, Nouvelle-Zélande. Renseignements: New Zealand Acoustical Society, P.O. Box 1181, Auckland, New Zealand.

## AUTRES NOUVELLES...

La conférence WESTPRAC (Western Pacific Regional Acoustics Conference) aura lieu pour la seconde fois à Hong Kong, du 19 au 21 novembre 1997, tel qu'indiqué ci-dessus. Toutes les sociétés d'acoustique asiatiques (Hong Kong, Chine, Corée, Japon, Singapour, Australie etc.) participeront à cette conférence technique de 3 jours. La brochure d'appel de communications est disponible au http://www.polyu .edu.hk/~westprac. Les communications dans tous les domaines d'acoustique sont les bienvenues.

**L'ACA sur le Web!** Les membres de l'Association canadienne d'acoustique sont rappelés de visiter leur nouvelle page sur le World Wide Web située au "http://www.uwo.ca/hhcru/caa/". Les suggestions sur le développement de la page sont appréciées, particulièrement pour ce qui a trait aux liens avec d'autres centres canadiens impliqués dans la recherche acoustique et avec des sources d'information sur l'acoustique au travers du monde.

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| Musical Acoustics / Electroacoustics | 4 | Acoustique musicale / Electroacoustique |
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Adel A.M. Abdou
Concordia University
CBS, Rm BE-255
1455 de Maisonneuve W.
Montréal, QC H3G 1M8
(514) 848-7918 FAX: (514) 848-7965
aabdou@concordia.ca
Member 1,2,10

Dr. Sharon M. Abel
Mount Sinai Hospital
600 University Ave.
Suite 843
Toronto, ON M5G 1X5
(416) 586-8278 FAX: (416) 586-8588
abel@mshri.on.ca
Member 5,6,8

Acquisitions Section/Inspec.
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daddison@gsi.bc.ca
Student

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Barman & Associates
50 Ronson Drive, Suite 127
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Prudence Allen
University of Western Ontario
Dept. of Communicative Disorders
Elborn College
London, ON N7G 2A9
(519) 661-2001x8944
FAX: (519) 661-3866
pallen@uwovax.uwo.ca
Student 5,7,8

Dr. D.L. Allen
Vibron Limited
1720 Meyerside Dr.
Mississauga, ON L5T 1A3
(416) 670-4922 FAX: (416) 670-1698
Member 1,5,7

Mr. Maurice Amram
Ecole Polytech. de Montréal
Dép. de génie physique
CP 6079, Succursale A
Montréal, QC H3C 3A7
(514) 340-4572 FAX: (514) 340-3218
Member 1,5,7

Mr. Chris Andrew
DPW, Noise Control Office
Co-ordinator
433 Eastern Avenue
Toronto, ON M4M 1B7
(416) 392-0791 FAX: (416) 392-1058
Member 1,5

James R. Angerer
105 Florentia St.
Seattle, WA, USA 98109
(206) 237-6421 FAX: (206) 237-5247
jra9854@enif.boeing.com
Member 1,6,8

Mr. Horst Arndt
Unitron Industries Ltd.
20 Beasley Drive
P.O. Box 9017
Kitchener, ON N2G 4X1
(519) 895-0100 FAX: (519) 895-0108
Member 2,6,8

Marc Asselineau
Peutz & Associes
103 boul. Magenta
F-75010 Paris, France
+33 1 42858485 FAX: +33 1 42821057
Sustaining Subscriber 1,4,5

ASFETM
3565 rue Jarry Est
Bureau 202
Montréal, QC H1Z 4K6
(514) 729-6961 FAX: (514) 729-8628
Member

Noureddine Atalla
G.A.U.S.
Dept. of Mechanical Eng.
Université de Sherbrooke
Sherbrooke, QC J1K 2R1
(819) 821-7102
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Yiu Nam Au-Yeung
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(905) 764-8465 FAX: (905) 764-8465
Member 1,5,7

Jeffery S. Bamford
Apartment 807
165 Queen Street South
Hamilton, ON L8P 4R3
(905) 570-0139 FAX: (905) 570-1161
jeffb@audiolab.uwaterloo.ca
Member 2,10,11

Kenneth E. Barron
Consultant in Acoustics
1334 Chaster Rd
RR #4, S8 C28
Gibsons, BC V0N 1V0
(604) 886-2299 FAX: (604) 886-2299
kenneth _barron@sunshine.net.ca
Member 1,5,7

Bradley Basnett
157 King St.
Carleton Place, ON K7C 1G5
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John Beamish
University of Alberta
Physics Department
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(403) 492-5692 FAX: (403) 492-0714
beamish@phys.ualberta.ca
Member 3,4

Byron C. Becker
331 - 1340 University Dr. N.W.
Calgary, AB T2N 3Y7
bcbecker@acs.ucalgary.ca
Student 2,4,5

Mr. Alberto Behar
45 Meadowcliffe Dr.
Scarborough, ON M1M 2X8
(416) 265-1816 FAX: (416) 265-1816
albehar@orbonline.net
Member 1,5,8

Mr. S. Benner
Ministry of Environment & Energy
3rd Fl. -250 Davisville Ave.
Toronto, ON M4S 1H2
(416) 440-3549 FAX: (416) 440-6973
Member 1,5

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North Vancouver, BC V7G 1J6
(604) 929-6942
Member 1,5

Elliott H. Berger
Cabot Safety Corp.
7911 Zionsville Rd.
Indianapolis, IN
USA 46268
Member

Marc-André Bernier
Université de Sherbrooke
Dép. génie mécanique
2500 boul. Université
Sherbrooke, QC J1K 2R1
mbernier@kirk.gme.usherb.ca
Student 2,6,10

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(519) 623-100 FAX: (519) 623-7500
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(514) 938-9775 FAX: (514) 938-8595
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Mr. Christopher T. Blaney
Environmental Section, MOT
Atrium Tower, 5th Floor
1201 Wilson Ave.
Downsview, ON M3M 1J8
(416) 235-5268 FAX: (416) 235-4922
Member 5

Stephen Bly
Radiation Protection Bureau
Room 228A
775 Brookfield Rd.
Ottawa, ON K1A 1C1
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sbly@hpb.hwc.ca
Member 3,5

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G.A.U.S., Dép. de génie mécanique
Université de Sherbrooke
Sherbrooke, QC J1K 2R1
(819) 821-7157 FAX: (819) 821-7163
Student 5,7

Eugene H. Bolstad
5903 109B Ave.
Edmonton, AB T6A 1S7
(403) 468-1872 FAX: (403) 468-1872
Courtesy Subscription 1,5

Stephen Bourke
202 - 1875 West 7th Avenue
Vancouver, BC V6J 1S9
(604) 980-5850
Member 1,2,5

Mr. J.W. Boutilier
1143 Upper Paradise Road
Hamilton, ON L9B 2N3
Member 1,2,5

Mr. P.G. Bowman
Union Gas Ltd.
50 Keil Dr.
Chatham, ON N7M 5M1
(519) 352-3100 FAX: (519) 436 5210
Member 5

Marc Bracken
Aercoustics Engineering
Suite 127, 50 Ronson Dr.
Toronto, ON M9W 1B3
(416) 249-3361 FAX: (416) 249-3613
Member 1,2,4,6

Dr. James Bradford
Brock University
Dept. of Computer Science
St. Catharines, ON L2S 3A1
(905) 688-5550 FAX: (905) 688-3255
bradford@spartan.ac.brocku.ca
Member 6,8

J.S. Bradley
National Research Council Canada
Institute for Research in Construction
Acoustics Lab., Building M-27
Ottawa, ON K1A 0R6
(613) 993-9747 FAX: (613) 954-1495
john.bradley@nrc.ca
Member 1,2,4

Dr. A.J. Brammer
National Research Council Canada
Institute for Microstructural Science
Ottawa, ON K1A 0R6
(613) 993-6160 FAX: (613) 952-3670
Member 5,6,7

Mr. David W. Brown
Brown Strachan Assoc.
Two Yaletown Sq.
1290 Homer St.
Vancouver, BC V6B 2Y5
(604) 689-0514 FAX: (604) 689-2703
Member 1,5,7

Mr. David G. Browning
139 Old North Road
Kingston, RI, USA 2881
(401) 783-4362 FAX: (401) 783-4362
Member 3,9,10

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Mr. Claudio Bulfone
531 - 55A St.
Delta, BC V4M 3M2
(604) 943-8224 FAX: (604) 666-1175
70441.2765@compuserve.com
Member 1,5,7

C.J. Buma
10408 36 Ave.
Edmonton, AB T6J 2H4
(403) 435-9172 FAX: (403) 435-9172
Member 1,4,5

Todd A. Busch
University of British Columbia
Department of Mechanical Engineering
2324 Main Mall
Vancouver, BC V6T 1Z4
(604) 878-6284 FAX: (604) 822-2403
busch@mech.ubc.ca
Student

Mr. Richard Cabot
1980 Twin Points Dr.
Lake Oswego, OR, USA 97034
(503) 627-0832 FAX: (503) 641-8906
rcc@ap.com
Member 2,4,6

Mr. Angelo J. Campanella
Campanella Assoc.
3201 Ridgewood Drive
Columbus, OH, USA 43026-2453
(614) 876-5108 FAX: (614) 771-8740
acampane@magnus.acs.ohio-state.edu
Member 1,3,5

Daryl Caswell
3120 Breen Cr. NW
Calgary, AB T2L 1S7
(403) 282-7093
Student 1,4,6

William J. Cavanaugh
Cavanaugh Tocci Assoc Inc
3 Merifield Lane
Natick, MA, USA 01760
(508) 443-7871 FAX: (508) 443-7873
Member 1,5,6

Mr. Yvan Champoux
Université de Sherbrooke
Dép. de génie mécanique
Faculté des sciences appliquées
Sherbrooke, QC J1K 2R1
(819) 821-7146 FAX: (819) 821-7163
Member 1,2,5

P. Chan
Godfrey Aerospace
331 Alden Rd.
Markham, ON L3R 3L4
(905) 470-7033 FAX: (905) 470-7029
Member 5,7

Mr. David M.F. Chapman
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS B2Y 3Z7
(902) 426-3100 FAX: (902) 426-9654
dave.chapman@drea.dnd.ca
Member 9

N. Ross Chapman
University of Victoria
School of Earth & Ocean Sciences
P.O. Box 3055
Victoria, BC V8W 3P6
Member 9

Brian Chapnik
HGC Engineering
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON L5N 1P7
(905) 826-4044 FAX: (905) 826-4940
chapnik@me.me.utoronto.ca
Student 2,5,7

Mr. Marshall Chasin
34 Bankstock Dr.
North York, ON M2K 2H6
(416) 733-4342
Member 2,5,6

M. Cheesman
University of Western Ontario
Dept. of Communicative Disorders
Fac. Applied Health Sciences
Elborn College
London, ON N6G 1H1
(519) 279-2111, ext. 8283
FAX: (519) 661-3805
cheesman@uwovax.uwo.ca
Member 5,7,8

Honwai Honry Cheng
Engineering Development Department
7/F, Shamshuipo Centre
215 Fuk Wah Street
Shamshuipo, Kowloon, Hong Kong
(852) 432-8481 FAX: (852) 433-4515
Direct Subscriber 1,3,7

Mr. Li Cheng
Université Laval
Dept. de génie mécanique
Fac. des sciences et de génie
Québec, QC G1K 7P4
(418) 656-7920 FAX: (418) 656-7415
licheng@gmc.ulaval.ca
Member 5,7

Chief Editor
Acoustics Australia
Acoustics Australia Lib.
Australian Def. Force Academy
Canberra, ACT 2600, Australia
Courtesy Subscription

Mr. Q. Chieu Chau
700 University Avenue H14 C12
Toronto, ON M5G 1X6
(416) 592-6874 FAX: (416) 592-2530
chieu.chau@hydro.on.ca
Member 1,2,6

Dr. W.T. Chu
National Research Council Canada
Institute for Reserach in Construction
Acoustics Lab., Building M-27
Ottawa, ON K1A 0R6
(613) 993-9741 FAX: (613) 954-1495
wing.chu@nrc.ca
Member 1,5,7

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National Research Council Canada
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1060 West 8th Ave.
Vancouver, BC V6H 1C4
Indirect Subscriber

Leah Clyburn
R.R. #3 Westville
Pictou County (Sylvester), NS B0K 2A0
(519) 888-4567 ext 6018
ldclybur@healthy.uwaterloo.ca
Student 5,7

Lisa D. Clyburn
R.R. #3
Westville, NS   B0K 2A0
(403) 434-9484
ldclybur@gpu.srv.ualberta.ca
Student   10

Mr. John B. Codrington
Acres International Ltd.
5259 Dorchester Road
P.O. Box 1001
Niagara Falls, ON   L2E 6W1
(905) 374-5200  FAX:  (905) 374-1157
Member   5,7

Dr. Annabel J. Cohen
University of Prince Edward Island
Dept. of Psychology
Charlottetown, PE   C1A 4P3
(902) 628-4331  FAX:  (902) 566-0420
annabel@ernie.psyc.upei.ca
Member   4,6,8

Connie Colantonio
4505 Beauvoir
St-Leonard, QC   H1R 1V3
(514) 398-1210  FAX:  (514) 398-8123
Student   7,8,10

Arthur J. Collier
c/o DREA
P.O. Box 1012
Dartmouth, NS   B2Y 3Z7
(902) 426-3100  FAX:  (902) 426-9652
collier@drea.dnd.ca
Member   7,9

Mr. Joseph L. Corcoran
Matrix Projects Limited
4622 Caulfield Dr.
West Vancouver, BC   V7W 1E8
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Member   1,5,7

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Suite 507
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Audra Crowe
148 Marwood Circle NE
Calgary, AB   T2A 2S2
Student   7,8

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Indirect Subscriber

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F 38401 St. Martin d'Heres, France
Indirect Subscriber

Dr. Lola Cuddy
Queen's University
Dept. of Psychology
Kingston, ON   K7L 3N6
(613) 545-6013  FAX:  (613) 545-2499
cuddyl@qucdn.queensu.ca
Member   4,6,8

Robert Cyr
Nova Scotia Power
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Scotia Sq., Barr Tower
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Member

Dr. Gilles Daigle
National Research Council Canada
Inst. for Microstructural Science
Ottawa, ON   K1A 0R6
(613) 993-6188  FAX:  (613) 952-3670
Member   3,5

Dalimar Instruments Inc.
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Dr. Huw G. Davies
University of New Brunswick
Dept. of Mechanical Engineering
Box 4400
Fredricton, NB   E3B 5A3
(506) 453-4513  FAX:  (506) 453-5025
davies@unb.ca
Member

Jack L. Davis
Nova Gas Transmision Ltd.
P.O. Box 2535, Station M
Calgary, AB   T2P 2N6
(403) 290-7365  FAX:  (403) 290-7227
Member   2,7

Dr. Lloyd A. Dawe
University of Western Ontario
Dept. of Psychology
Social Science Centre
London, ON   N6A 5C2
(519) 679-2111  FAX:  (519) 661-3961
dawe@vaxr.ccsi.ca
Member   3,5,7

David DeGagne
Environment Protection
ERCB
640  - 5th Ave. SW
Calgary, AB   T2P 3G4
(403) 297-3200  FAX:  (403) 297-3520
Member   10

Professeur J. Dendal
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Paula Fournier
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25 Goulbourn Avenue
Ottawa, ON K1N 8C7
(613) 565-4122 FAX: (613) 564-9919
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Ronald Fox
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Dalhousie University
Dept. of Psychology
Halifax, NS B3H 4J1
(902) 494-8888
franklan@ac.dal.ca
Student 4,6,8

Ron Freiheit
Wenger Corp.
555 Park Dr.
Owatonna, MN, USA 55060
(507) 455-4100 FAX: (507) 455-4258
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University of British Columbia
Audiology & Speech Sciences
5804 Fairview Ave.
Vancouver, BC V6T 1Z3
(604) 822-4716 FAX: (604) 822-6569
kathy-fuller@audiospeech.ubc.ca
Member 6,8

W.Rober J. Funnell
McGill University
Faculty of Medicine
3775 rue University
Montréal, QC H3A 2B4
(514) 398-6739 FAX: (514) 398-7461
funnell@medcor.mcgill.ca
Member

Ken Fyfe
University of Alberta
4-9 Mechanical Engineering
Edmonton, AB T6G 2G8
(403) 492-7031 FAX: (403) 492-2200
ken.fyfe@ualberta.ca
Member 1,2,3,6,10

D.A. Galama
University of Alberta
Dept. of Linguistics
4-32 Assiniboia hall
Edmonton, AB T6G 2E7
(403) 492-3434 FAX: (403) 492-0806
galama@cepstra.ling.ualberta.ca
Student 5,7,8

Line Gamache
Apt. 302
3439 William Tremblay St
Montréal, QC H1X 3J4
Member 3,5,6

Mr. V. Gambino
3329 Beau Rivage Cresc., Lot 40
Mississauga, ON L5L 5H2
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Dr. Robert Gaspar
822 Lounsborough Street
Windsor, ON N9G 1G3
(519) 972-0677 FAX: (519) 972-0677
gasparr@engn.uwindsor.ca
Member 1,5,7

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Dept. of Psychology
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Josée Gauthier
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Sherbrooke, QC J1K 2R1
(819) 821-7812 FAX: (819) 821-7163
jgenot@sofia.gme.usherb.ca
Student 2.6.10

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van der Houvenstraat 33
2596 PL Den Haag,
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Concord, ON L4K 4H1
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blaise@envir.hydro.qc.ca
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Kristina Greenwood
1279 Hammond Street
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(905) 632-6639
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Montréal, QC H3G 1M8
(514) 848-3191 FAX: (514) 848-7965
guy@cbs.engr.concordia.ca
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McMaster Univ, 3H50 HSC
Occupational Health Program
Hamilton, ON L8N 3Z5
(416) 525-9140
Member

Souheil Hakim
Royal Victoria Hospital
Women's Pavilion F-531
687 Pine Ave. W.
Montréal, QC H3A 1A1
(514) 842-1231x4454
souheil@rvhob2.lan.mcgill.ca
Student 3

Seyed Mohammad Hashemi
2200 Chapdelaine, #207
Ste-Foy, QC G1V 4G8
(418) 656-2131 (4862)
hashemiAgmc.ulaval.ca
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University of British Columbia
Occupational Hygiene Programme
2206 East Mall, 3rd Fl.
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(604) 822-3073 FAX: (604) 822-9588
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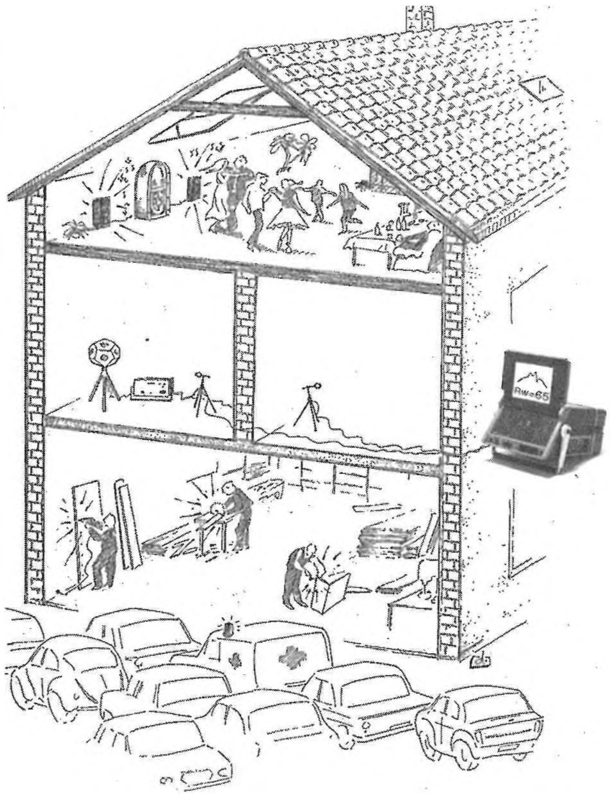

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P.O. Box 3055, MS 8895
Victoria, BC V8W 3P6
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Mr. John W. Kopec
Riverbank Acoustical Labs
IIT Research Institute
1512 S Batavia Avenue
Geneva, IL, USA 60134
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Ontario Hydro Technologies
800 Kipling Avenue, KB 214
Toronto, ON M8Z 5S4
(416) 207-6178 FAX: (416) 231-5479
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T.U.V. Rheinland
344 Sheppard Ave. E., Suite 1
North York, ON M2N 3B4
(416) 733-3677 FAX: (416) 733-7781
Member 1,2,5

Mr. C.A. Krajewski
95 Southill Drive
Don Mills, ON M3C 2H9
(416) 441-1998 FAX: (416) 441-6973
Member 1,5,7

Dr. G. Krishnappa
National Research Council Canada
Institute for Machinery Research
Montreal Road, Bldg. M-16
Ottawa, ON K1A 0R6
(613) 993-2241 FAX: (613) 941-1157
krishnappa@imr.mcm.lan.nrc.ca
Member 2,5,7

Mr. K. Kruger
Alb Pub Wks, Supp & Serv
Tech Resources Div.
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Edmonton, AB T6G 5A6
(403) 422-0208 FAX: (403) 422-9673
Member 1,5,7

Mr. Verne Kucy
The Corporation of Delta
4500 Clarence Taylor Cr.
Delta, BC V4K 3E2
(604) 946-3281 FAX: (604) 946-7492
Member 1,5,6

Dr. Hans Kunov
University of Toronto
Institute of Biomedical Eng.
Rosebrugh Building
Toronto, ON M5S 1A4
(416) 978-6712 FAX: (416) 978-4317
hkunov@vm.utcc.utoronto.ca
Member 2,6,8

Laboratoire Central
Prefecture de Police
39 Bis, rue de Dantzig
75015 Paris, France
Indirect Subscriber

Patrick Labrecque
Université de Sherbrooke
Dép. génie mécanique
2500 boul. Université
Sherbrooke, QC J1K 2R1
(819) 821-7000 FAX: (819) 821-7163
patrick.labrecque@gme.usherb.ca
Student 4,6,10

Pat Lama
350 Rabro Dr.
Hauppauge, NY, USA 11788
(516) 348-0282 FAX: (516) 348-0279
Member 6

Denis Lamonde
Mecart Inc.
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110 rue de Rotterdam
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(418) 878-3584 FAX: (418) 878-4877
Direct Subscriber 1,4,5

Mike Lantz
Queen's University
Dept. of Psychology
Kingston, ON K7L 3N6
(613) 547-9683
lantzm@qucdn.queensu. ca
Student 4,6

Dr. Chantal Laroche
Universite d'Ottawa
Audiologie/Orthophonie
545 King Edward
Ottawa, ON K1N 7N5
(613) 562-5800ext3066
FAX: (613) 562-5256
claroche@aix1.uottawa.ca
Member 5,6,8

Bruce Larson
#2 - 1290 Homer Street
Vancouver, BC V6B 2Y5
(604) 689-0514 FAX: (604) 689-2703
Member 1,6

Dr. Charles A. Laszlo
University of British Columbia
Inst. for Hearing Accessibility Research
2356 Main Mall
Vancouver, BC V6T 1Z4
(604) 822-3956 FAX: (604) 822-5949
laszlo@ee.ubc.ca
Member 5,7

Vincent Y. Lau
Barron Kennedy Lyzun & Assoc.
145 W 17th St., Suite 250
North Vancouver, BC V7M 3G4
(604) 988-2508 FAX: (604) 988-7457
Member 1,2,5,7

Ann Laubstein
293 Clemow
Ottawa, ON K1S 2B7
(613) 234-8825
alaubste@ccs.carleton.ca
Member

André Leblond
Services Lignes Aeriennes, IREQ
1800, Montée Sainte-Julie
Varennes, QC J3X 1S1
(514) 652-8410 FAX: (514) 652-8309
Student 6

André Leblond
Université Laval
Département de génie mécanique
Ste-Foy, QC G1K 7P4
(418) 565-2131x4862
Student

Bruno Leclerc
Bombardier Inc.
Division Sea-Doo/Ski-Doo
1650, de l'Eglise
St-Antoine de Tilly, QC G0S 2C0
(418) 886-2451 FAX: (418) 886-2143
Member 1,2,4,6,10

Dr. Hie K. Lee
14 Beaufort Drive
Kanata, ON K2L 1Z4
(613) 957-8460 FAX: (613) 957-8563
Member 5,6,7

Dr. L.J. Leggat
Director General
Defence Research Establishment Ottawa
Dept. of National Defence
Ottawa, ON K1A 0Z4
(613) 998-2303 FAX: (613) 993-6095
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Université d'Ottawa
Audiologie/Orthophonie
545 King Edward
Ottawa, ON K1N 6N5
(613) 564-7537 FAX: (613) 564-9919
Member 5,6,8

Jean-Pierre Letourneau
Ministère environnement et faune
Suite 71, 2360 chemin Ste-Foy
Ste-Foy, QC G1V 4H2
(418) 644-3629
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Dr. Igor V. Levit
6948 Ash St.
Vancouver, BC V6P 3K4
(604) 321-8063 FAX: (604) 321-8063
Member 1,5,7

Jingfang Li
University of British Columbia
Dept. of Mechanical Engineering
2324 Main Mall
Vancouver, BC V6T 1Z4
Member 1,2,6

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spl@audiolab.uwaterloo.ca
Member 2,3,6

Alexander P. Lorimer
7 Bent Oak Circle
Mississauga, ON L5N 4J2
(905) 542-2796
Member 1,5,7

Mr. David Lubman
14301 Middletown Lane
Westminster, CA, USA 92683
(714) 898 9099 FAX: (714) 373-3050
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Daniel Lyzun
Barron Kennedy Lyzun & Assoc.
145 W 17th St., Suite 250
North Vancouver, BC V7M 3G4
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Prof. Roman Gr. Maev
University of Windsor
Dept .of Mechanical Engineering
Ultrasonic Microscopy Lab.
Windsor, ON N9B 3P4
(519) 253-4232 FAX: (519) 973-7062
Member 3,10

Anthony Mak
810 East 18th Avenue
Vancouver, BC V5V 1G8
mak@mech.ubc.ca
Student 1,2,4

Mr. G.C. Maling (Jr.), Editor
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University of Waterloo
Dept. of Mechanical Engineering
Waterloo, ON N2L 3G1
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Patrice Masson
12 D'Auteuil
St. Julie de Vercheres, QC J0L 2S0
(514) 649-1454
Student 7

Mr. Nigel Maybee
12 Woodmont Pl. SW
Calgary, AB T2W 4N3
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Georgetown University
Physics Department, JASA
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Headwaters Health Authority
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Okotoks, AB T0L 1T3
(403) 652-3297 FAX: (403) 652-2537
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Mark McDonald
Skyfold, Div. of Railtech Ltee
325 Lee Ave.
Baie d'Urfe, QC H9X 3S3
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Sherry McKay
25 St. Mary St., Suite 1004
Toronto, ON M4Y 1R2
Student 2,4,5

Dr. Wm. P.S. McKay
1162 South Park St.
Halifax, NS B3H 2W8
(902) 429-5617 FAX: (902) 496-3624
Member 6,7

Mr. Andrew C. McKee
Vibrason Instruments
430 Halford Road
Beaconsfield, QC H9W 3L6
(514) 426-1035
Member

Zita McRobbie
Simon Fraser University
Linguistics Dept.
Burnaby, BC V5A 1S6
(604) 291-5782 FAX: (604) 291-5659
zita_mcrobbie@sfu.ca
Member 7,8

Mr. T. Medwedyk
Group One Acoustics Inc.
1538 Sherway Dr.
Mississauga, ON L4X 1C4
(416) 896-0988 FAX: (416) 897-7794
Direct Subscriber 1,4,7

Bertrand Mercier
Université de Sherbrooke
Dép. de génie mécanique
2500 boul. Université
Sherbrooke, QC J1K 2R1
(819) 821-7000 FAX: (819) 821-7163
Student 2,6

H.M. Merklinger
P.O. Box 494
Dartmouth, NS B2Y 3Y8
(902) 461-3100 x 167
Member 2,8,9

Dr. J.G. Migneron
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Member 1,5

Jerd Miller
McGill University, c/o Royal Victoria
Hospital Ob/Gyn,
Women's Pavilion, Rm F5131
687 Pine Ave. West
Montréal, QC H3A 1A1
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Jrhai Missaoui
Université Laval
Département de génie mécanique
C.P. 36082
Ste-Foy, QC G1R 4W7
(418) 651-1361
Student

Dr. Thomas Moore
Queen's University
Dept. of Mechanical Engineering
Kingston, ON K7L 3N6
(613) 545 2582 FAX: (613) 545-6489
mooretn@qucdn.queensu.ca
Member 5,7

Philippe Moquin
Mitel Corp.
350 Legget Drive
P.O. Box 13089
Kanata, ON K2K 1X3
(613) 592-2122ext2102
FAX: (613) 592-4784
philippe-moquin@mitel.com
Member 1,2,5

M. Michel Morin
MJM Conseillers en Acoustique Inc.
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Health Canada
Medical Devices Bureau, Environ. Health
Directorate
Room 1605, Stats. Can. - Main Building
Tunney's Pasture, Ottawa, ON K1A 0L2
(613) 957-7285 FAX: (613) 957-7318
Member 3,5,10

Murray Munro
Simon Fraser University
Department of Linguistics
Burnaby, BC V5A 1S6
(604) 291-3654
mjmunro@sfu.ca
Member 4,7,8

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G.A.U.S., Université de Sherbrooke
Dép. de génie mécanique
Sherbrooke, J1K 2R1
(819) 821-7157 FAX: (819) 821-7163
Member 5,10

Dr. Trevor R.T. Nightingale
Manager, Acoustics Laboratories
Schuller International, Mountain Technical
Center
10100 West Ute Avenue, P.O. Box 625005
Littleton, CO, USA 80162-5005
(303) 978-5200 FAX: (303) 975-0474
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Barron Kennedy Lyzun & Assoc.
145 W 17th St., Suite 250
North Vancouver, BC V7M 3G4
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Member 6

Dr. John C. Osier
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS B2Y 3Z7
(902) 426-3100 FAX: (902) 426-9654
osler@maggie.drea.dnd.ca
Member 9

Dr. M.M. Osman
Ontario Hydro, H14
700 University Ave.
Toronto, ON M5G 1X6
(416) 592-6098 FAX: (416) 592-2530
Member 5,7

Mathieu Ouellet
1600 Montee Ste-Julie
Varennnes, QC J3X 1S4
(514) 652-1530 FAX: (514) 652-1533
Member 1,2,4

M. Pierre M. Ouimet
7925 Cote St Luc
Montréal, QC H4W 1R5
(514) 485 5423 FAX: (514) 485-5802
Member 1

Russell Ovans
Jason Sound Industries Ltd.
1709 Welch St.
North Vancouver, BC V7P 3G9
(604) 986-2367 FAX: (604) 988-1036
ovans@sfu.ca
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Mr. John M. Ozard
Esquimalt Defence Research Detachment
FMO
Victoria, BC V0S 1B0
(604) 363-2729 FAX: (604) 363-2856
ozard@orca.drep.ca
Member 9

Mr. Thomas Paige
Vibron Ltd.
1720 Meyerside Drive
Mississauga, ON L5T 1A3
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Member 1,2,5

George J. Pan
National Research Council Canada
Building M-36, Room 1017
Ottawa, ON K1A 0R6
(613) 993-6160 FAX: (613) 952-3670
pan@nrcphy1.phy.nrc.ca
Member 2,7,8,10

Raymond Panneton
Université de Sherbrooke
G.A.U.S.
Dép de génie mécanique
Sherbrooke, QC J1K 2R1
Student

Louise Paré
Audiologiste
966 Neufchatel
Repentigny, QC J5Y 2A5
(514) 759-9900 FAX: (514) 759-5149
Member 5,6

Vijay Parsa
Hearing Health Care Research Unit
University of Western Ontario
Elborn College
London, ON N6G 1H1
(519) 661-3901 FAX: (519) 661-3805
parsa@aydui,hhcru.uwo.ca
Member 7,8,10

Mr. Richard Patching
Patching Associates Acoustical
Engineering
6815 - 8th St. NE, Suite 105
Calgary, AB T2E 7H7
(403) 274-5882 FAX: (403) 295-0732
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Ms. V.M. Pate
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Member 1,5,7

Mr. Richard J. Peppin
5012 Macon Rd.
Rockville, MD, USA 20852
(301) 995-7738 FAX: (301) 995-7739
Member 1,5,7

David Pfingstgraef
10 Luton Cr.
St. Thomas, ON N5R 5K1
(519) 633-8501 FAX: (519) 631-1825
Student 2,4,6

Ms. P. Phillips
University of Georgia
Dept. of Psychology
Athens, GA, USA 30602
(706) 613-9596
cmspsy24@uga.cc.uga.edu
Student 4,6

Claire Piché
9663 Basile-Routhier
Montréal, QC H2C 2C1
(514) 388-7620
Student 1,2,4

Dr. J.E. Piercy
National Research Council Canada
Inst. For Microstructural Sciences
Bldg. M-36
Ottawa, ON K1A 0R6
(613) 749-8929
Member 3,5,6

Dr. John R. Platt
McMaster University
Dept. of Psychology
Hamilton, ON L8S 4K1
(905) 525-9140 FAX: (905) 529-6225
platt@mcmaster.ca
Member 4,6

Linda Polka
McGill University
Sch of Communication Science
1266 Pine Ave.
Montréal, QC H3G 1A8
(514) 398-7235 FAX: (514) 398-8123
cztg@musica.mcgill.ca
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Dr. S.E. Prasad
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amsales@blachford.ca
Member 1,2,6

Bruno Proulx
Université Laval
Pavilion Parent, #8748
Sainte-Foy, QC G1K 7P4
(514) 656-2131 FAX: (514) 656-4899
Student 2,6

Daniel P. Prusinowski
Angevine Acoustical Cons. Inc.
116 Hamlin Avenue
East Aurora, NY, USA 14052-0725
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Member 1,2,5

Dr. J.D. Quirt
National Research Council Canada
Institute for Research in Construction
Acoustics Laboratory, Bldg. M-27
Ottawa, ON K1A 0R6
(613) 993-9746 FAX: (613) 954-1495
david.quirt@nrc.ca
Member 1,2,5

Hung Tran Quoc
Groupe d'acoustique de UDM
C.P. 6128, Succ. Centre Ville
Montreal, QC H3C 3J7
(514) 343-7301 FAX: (514) 343-5740
Member 5,7

Bratislav Radovanovic
#508 - 246 Willow Road
Guelph, ON N1H 6R6
(519) 824-7470 FAX: (519) 824-5458
Student 2,6

Dr. Ramani Ramakrishnan
41 Watson Avenue
Toronto, ON M6S 4C9
(905) 762-6093 FAX: (905) 670-1698
Member 1,5,7

Dr. L.A. Read
Dean Arts & Science
Wilfrid Laurier University
75 University Ave. W
Waterloo, ON N2L 3C5
(519) 884-1970 ext 2220
Member 1,4

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P.O. Box 229
N 5701 Voss, Norway
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Member 1,5,6

Dr. R.J. Rogers
University of New Brunswick
Dept. of Mechanical Engineering
P.O. Box 4400
Fredericton, NB E3B 5A3
(506) 453-4513 FAX: (506) 453-5025
rjr@unb.ca
Member 5,7

Dr. M. Roland Mieszkowski
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(902) 429-9622 FAX: (902) 429-9622
mmieszko@ac.dal.ca
Member 2,6,8

Tom Rose
Rose Associates
117 Red Oak
Flower Mound, TX, USA 75028
(214) 539-7011
Member 1,5,7

Pedro Manrique Rubio
5758 Plantagenet
Montréal, QC H3S 2K3
(514) 739-9935 FAX: (514) 739-2021
Member 2,5,8

Mr. Wm. D. Ruth
Hearing Measurements Co Ltd.
27 Strathearn Ave., Unit 2
Bramalea, ON L6T 4V5
(905) 791-428 FAX: (905) 791-3055
Member 5

James G. Ryan
National Research Council Canada
Inst. for Microstructural Sciences
Building M-36
Ottawa, ON K1A 0R6
(613) 993-2300 FAX: (613) 952-3670
Member 4,7,11

Dr. M.P. Sacks
Tacet Engineering Ltd.
111 Ava Road
Toronto, ON M6C 1W2
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Alex Sakuta
Ontario Hydro
Mechanical Research Dept.
800 Kipling Ave., KR 277
Toronto, M8Z 5S4
(416) 207-6691 FAX: (416) 231-5479
sakutaa@ice3.kcps.rd.hydro.on.ca
Member 1,5,9

Michael Sanderson
Chalmers University of Technology
Dept. of Applied Acoustics
S-41296 Gothenburg, Sweden
+46 31 72-2203 FAX: +46 31 72-2212
mike@ta.chalmers.se
Student 1,5,7

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Montréal, QC H2M 2N9
(514) 383-1550 FAX: (514) 383-3234
csauvageau@mtl.criq.qc.ca
Member 2,6,10

Jacques Savard
SNC-Lavalin Environnement inc.
2271 boul. Fernand-Lafontaine
Longueuil, QC J4G 2R7
(514) 651-6710 FAX: (514) 651-0885
savaj@snc-lavalin.com
Member 2,6,11

Mr. Miron Savic
58 Hirshhorn Avenue
Elliot Lake, ON P5A 1N9
(705) 848-3263
Member 5,7,8

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Member 1,2,4

Bruce Schneider
University of Toronto
Dept. of Psychology, Erindale Campus
Mississauga, ON L5L 1C6
(905) 828-5414
schneil@psych.utoronto.ca
Member 5,7,8

Mr. Henry Scory
IRSST
505 Maisonneuve Ouest
Montréal, QC H3A 3C2
(514) 288-1551 FAX: (514) 288-9632
Member 3,5,7

Dr. Richard C. Seewald
University of Western Ontario
Elborn College
Communicative Disorders
London, ON N6G 1H1
(519) 661-3901 FAX: (519) 661-3805
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(213) 455-2702
Member 1,2,4

Dr. Edgar A.G. Shaw
Researcher Emeritus
National Research Council Canada
Inst. for Microstructural Sciences
Ottawa, ON K1A 0R6
(613) 993-6157 FAX: (613) 952-3670
Member 2,5,6

Cameron W. Sherry
Enviro Risque Inc.
78 Lucerne
Pointe Claire, QC H9R 2V2
(514) 426-8720 FAX: (514) 426-8719
Member 1,5

Davor Sikic
Jade Acoustics Inc.
Suite 203 - 545 North Rivermede Dr.
Concord, ON L4K 4H1
(905) 660-2444 FAX: (905) 660-4110
Member 1,2,6,10

Ms. Elzbieta B. Slawinski
University of Calgary
Dept. of Psychology
2500 University Drive NW
Calgary, AB T2N 1N4
(403) 220-5205 FAX: (403) 282-8249
eslawins@acs.ucalgary.ca
Member 6,8

Raphael Slawinski
University of Calgary
Dept. of Geology and Geophysics
2500 University Dr. N.W.
Calgary, AB T2N 1N4
(403) 220-3083 FAX: (403) 286-8151
raphael@geo.ucalgary.ca
Student

SNC/Lavalin Environment Inc.
2 Felix Martin Place
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gilbert@dgbt.doc.ca
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Windsor, ON N9G 1G3
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Sustaining Subscriber 1,5,7

Daniel St. Georges
1815 - 58th Avenue
Montréal, QC H1A 2P8
(514)642-5176 FAX: (514) 485-5802
stgeorge@srcing.login.qc.ca
Member 1,5,6

Dr. Philip R. Staal
Defence Research Establishment Atlantic
P.O. Box 1012
Dartmouth, NS B2Y 3Z7
(902) 426-3100 FAX: (902) 426-9654
staal@maggie.drea.dnd.ca
Member 3,5,9

David R. Stapells
University of British Columbia
School of Audiology & Speech Sciences
5804 Fairview Ave.
Vancouver, BC V6T 1Z3
(604) 822-5795 FAX: (604) 822-6569
Member 5,7,8

Robert D. Stevens
HGC Engineering Ltd.
Plaza One, Suite 203
2000 Argentia Rd.
Mississauga, ON L5N 1P7
(905) 826-4044 FAX: (905) 826-4940
Member 1,4,5

Mr. John Stevenson
WCB of BC, Prev Div
8100 Granville St.
Richmond, BC V6Y 3T6
(614) 276-3100 FAX: (604) 276-3247
Member 1,2,5

Dr. Michael R. Stinson
National Research Council Canada
Inst. for Microstructural Sciences
Building M-36
Ottawa, ON K1A 0R6
(613) 993-3729 FAX: (613) 952-3670
Member 3,5,6

Mr. Robert A. Strachan
Brown Strachan Assoc.
Two Yaletown Sq.
1290 Homer St.
Vancouver, BC V6B 2Y5
(604) 689-0514 FAX: (604) 689-2703
Member 1,5,7

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Dept. of Biology
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Member 6,8,9

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troccaz@mec.etsmtl.ca
Student 2,6,10

Prof. B. Truax
Simon Fraser University
Dept. of Communication
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(604) 291-3687 FAX: (604) 291-4024
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(604) 222-7897
awareing@unixg.ubc.ca
Student 2,6,10

Dr. A.C.C. Warnock
National Research Council Canada
Institute for Research in Construction
Acoustics Laboratory, Bldg. M-27
Ottawa, ON K1A 0R6
(613) 993-9370 FAX: (613) 954-1495
warnock@nrc.lan.ca
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Memorial University
Dept. of Physics
St. John's, NF A1B 3X7
(709) 737-2011 FAX: (709) 737-8739
dougw@weejordy.physics.mun.ca
Student 3,9

Mr. Keith Wilson
Owens-Corning Canada Inc.
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North York, ON M2N 6T9
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Vibra-Sonic Control
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Member 1,5,7

Dr. G.S.K. Wong
National Research Council Canada
Inst. for Nat. Meas. Stds.
Building M-36
Ottawa, ON K1A 0R6
(613) 993-6159 FAX: (613) 952-1394
Member 2,3,5

Roland Woodcock
Université du Québec, ETS
Dép. de génie mécanique
4750, ave. Henri-Julien
Montréal, QC H2T 2C8
(514) 289-8800 FAX: (514) 289-8755
woodcock@mec.etsmtl.ca
Member 1,2,3

Lixue Wu
National Research Council Canada
INMS, Bldg. M-36, Room 14
Ottawa, ON K1A 0R6
(613) 998-1282
Member

Karen Yu
11 Virginia Cr.
London, ON N5X 3G4
(519) 660-8812
Student 5,6,8

M. Manell E. Zakharia
Lab. d'Acoust et Signaux Sonar
ICPI
25 rue du Plat
69288 Lyon Cedex 02, France
(33) 72325074 FAX: (33) 783-78034
manell.zhakaria@sp1.g_net.fr
Member 3,9

Adam Zielinski
University of Victoria
Dept. of Elec. & Comp. Eng.
P.O. Box 3055
Victoria, BC V8W 3P6
(604) 721-8622 FAX: (604) 721-6052
adam.zielinski@ece.uvic.ca
Member 8,9,11

# The Canadian Acoustical Association
# l'Association Canadienne d'Acoustique

## PRIZE ANNOUNCEMENT

A number of prizes, whose general objectives are described below, are offered by the Canadian Acoustical Association. As to the first four prizes, applicants must submit an application form and supporting documentation to the prize coordinator before the end of February of the year the award is to be made. Applications are reviewed by subcommittees named by the President and Board of Directors of the Association. Decisions are final and cannot be appealed. The Association reserves the right not to make the awards in any given year. Applicants must be members of the Canadian Acoustical Association. Preference will be given to citizens and permanent residents of Canada. Potential applicants can obtain full details, eligibility conditions and application forms from the appropriate prize coordinator.

### EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS

This prize is made to a highly qualified candidate holding a Ph.D. degree or the equivalent, who has completed all formal academic and research training and who wishes to acquire up to two years supervised research training in an established setting. The proposed research must be related to some area of acoustics, psychoacoustics, speech communication or noise. The research must be carried out in a setting other than the one in which the Ph.D. degree was earned. The prize is for $3000 for full-time research for twelve months, and may be renewed for a second year. Coordinator: Sharon Abel, Mount Sinai Hospital, 600 University Avenue, Toronto, ON M5G 1X6. Past recipients are:

| | | | | | |
|---|---|---|---|---|---|
| *1990* | *Li Cheng* | *Université de Sherbrooke* | *1995* | *Jing-Fang Li* | *University of British Columbia* |
| *1993* | *Roland Woodcock* | *University of British Columbia* | *1996* | *Vijay Parsa* | *University of Western Ontario* |
| *1994* | *John Osler* | *Defense Research Estab. Atlantic* | | | |

### ALEXANDER GRAHAM BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND BEHAVIOURAL ACOUSTICS

The prize is made to a graduate student enrolled at a Canadian academic institution and conducting research in the field of speech communication or behavioural acoustics. It consists of an $800 cash prize to be awarded annually. Coordinator: Don Jamieson, Department of Communicative Disorders, University of Western Ontario, London, ON N6G 1H1. Past recipients are:

| | | | | | |
|---|---|---|---|---|---|
| *1990* | *Bradley Frankland* | *Dalhousie University* | *1993* | *Aloknath De* | *McGill University* |
| *1991* | *Steven D. Turnbull* | *University of New Brunswick* | *1994* | *Michael Lantz* | *Queen's University* |
| | *Fangxin Chen* | *University of Alberta* | *1995* | *Kristina Greenwood* | *University of Western Ontario* |
| | *Leonard E. Cornelisse* | *University of Western Ontario* | *1996* | *Mark Pell* | *McGill University* |

### FESSENDEN STUDENT PRIZE IN UNDERWATER ACOUSTICS

The prize is made to a graduate student enrolled at a Canadian university and conducting research in underwater acoustics or in a branch of science closely connected to underwater acoustics. It consists of $500 cash prize to be awarded annually. Coordinator: David Chapman, DREA, PO Box 1012, Dartmouth, NS B2Y 3Z7.

| | | | | | |
|---|---|---|---|---|---|
| *1992* | *Daniela Dilorio* | *University of Victoria* | *1994* | *Craig L. McNeil* | *University of Victoria* |
| *1993* | *Douglas J. Wilson* | *Memorial University* | *1996* | *Dean Addison* | *University of Victoria* |

### ECKEL STUDENT PRIZE IN NOISE CONTROL

The prize is made to a graduate student enrolled at a Canadian academic institution pursuing studies in any discipline of acoustics and conducting research related to the advancement of the practice of noise control. It consists of a $500 cash prize to be awarded annually. The prize was inaugurated in 1991. Coordinator: Murray Hodgson, Occupational Hygiene Programme, University of British Columbia, 2206 East Mall, Vancouver, BC V6T 1Z3.

| | | | | | |
|---|---|---|---|---|---|
| *1994* | *Todd Busch* | *University of British Columbia* | *1996* | *Nelson Heerema* | *University of British Columbia* |
| *1995* | *Raymond Panneton* | *Université de Sherbrooke* | | | |

### DIRECTORS' AWARDS

Three awards are made annually to the authors of the best papers published in *Canadian Acoustics.* All papers reporting new results as well as review and tutorial papers are eligible; technical notes are not. The first award, for $500, is made to a graduate student author. The second and third awards, each for $250, are made to professional authors under 30 years of age and 30 years of age or older, respectively. Coordinator: Blaise Gosselin, Hydro Québec, 16$^{e}$ étage, 75 boul. René Lévesque ouest, Montréal, QC H2Z 1A4.

### STUDENT PRESENTATION AWARDS

Three awards of $500 each are made annually to the undergraduate or graduate students making the best presentations during the technical sessions of Acoustics Week in Canada. Application must be made at the time of submission of the abstract. Coordinator: Alberto Behar, 45 Meadowcliffe Drive, Scarborough, ON M1M 2X8.

# The Canadian Acoustical Association
# l'Association Canadienne d'Acoustique

## ANNONCE DE PRIX

Plusieurs prix, dont les objectifs généraux sont décrits ci-dessous, sont décernés par l'Association Canadienne d'Acoustique. Pour les quatre premiers prix, les candidats doivent soumettre un formulaire de demande ainsi que la documentation associée au coordonnateur de prix avant le dernier jour de février de l'année durant laquelle le prix sera décerné. Toutes les demandes seront analysées par des sous-comités nommés par le président et la chambre des directeurs de l'Association. Les décisions seront finales et sans appel. L'Association se réserve le droit de ne pas décerner les prix une année donnée. Les candidats doivent être membres de l'Association. La préférence sera donnée aux citoyens et aux résidents permanents du Canada. Les candidats potentiels peuvent se procurer de plus amples détails sur les prix, leurs conditions d'éligibilité, ainsi que des formulaires de demande auprès du coordonnateur de prix.

### PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE

Ce prix est attribué à un(e) candidat(e) hautement qualifié(e) et détenteur(rice) d'un doctorat ou l'équivalent, qui a complèté(e) ses études et sa formation de chercheur, et qui désire acquérir jusqu'à deux années de formation supervisée de recherche dans un établissement reconnu. Le thème de recherche proposée doit être relié à un domaine de l'acoustique, de la psycho-acoustique, de la communication verbale ou du bruit. La recherche doit être menée dans un autre milieu que celui où le candidat a obtenu son doctorat. Le prix est de $3000 pour une recherche plein temps de 12 mois avec possibilité de renouvellement pour une deuxième année. Coordonnatrice: Sharon Abel, Mount Sinai Hospital, 600 University Avenue, Toronto, ON M5G 1X6. Les récipiendaires antérieur(e)s sont:

| | | | | | |
|---|---|---|---|---|---|
| *1990* | *Li Cheng* | *Université de Sherbrooke* | *1995* | *Jing-Fang Li* | *University of British Columbia* |
| *1993* | *Roland Woodcock* | *University of British Columbia* | *1996* | *Vijay Parsa* | *University of Western Ontario* |
| *1994* | *John Osler* | *Defense Research Estab. Atlantic* | | | |

### PRIX ÉTUDIANT ALEXANDER GRAHAM BELL EN COMMUNICATION VERBALE ET ACOUSTIQUE COMPORTEMENTALE

Ce prix sera décerné à un(e) étudiant(e) inscrit(e) dans une institution académique canadienne et menant un projet de recherche en communication verbale ou acoustique comportementale. Il consiste en un montant en argent de $800 qui sera décerné annuellement. Coordonnateur: Don Jamieson, Department of Communicative Disorders, University of Western Ontario, London, ON N6G 1H1. Les récipiendaires antérieur(e)s sont:

| | | | | | |
|---|---|---|---|---|---|
| *1990* | *Bradley Frankland* | *Dalhousie University* | *1993* | *Aloknath De* | *McGill University* |
| *1991* | *Steven D. Turnbull* | *University of New Brunswick* | *1994* | *Michael Lantz* | *Queen's University* |
| | *Fangxin Chen* | *University of Alberta* | *1995* | *Kristina Greenwood* | *University of Western Ontario* |
| | *Leonard E. Cornelisse* | *University of Western Ontario* | *1996* | *Mark Pell* | *McGill University* |

### PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

Ce prix sera décerné à un(e) étudiant(e) inscrit(e) dans une institution académique canadienne et menant un projet de recherche en acoustique sous-marine ou dans une discipline scientifique reliée à l'acoustique sous-marine. Il consiste en un montant en argent de $500 qui sera décerné annuellement. Coordonnateur: David Chapman, DREA, PO Box 1012, Dartmouth, NS B2Y 3Z7.

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### PRIX ÉTUDIANT ECKEL EN CONTROLE DU BRUIT

Ce prix sera décerné à un(e) étudiant(e) inscrit(e) dans une institution académique canadienne dans n'importe quelle discipline de l'acoustique et menant un projet de recherche relié à l'avancement de la pratique en contrôle du bruit. Il consiste en un montant en argent de $500 qui sera décerné annuellement. Ce prix a été inauguré en 1991. Coordonnateur: Murray Hodgson, Occupational Hygiene Programme, University of British Columbia, 2206 East Mall, Vancouver, BC V6T 1Z3.

| | | | | | |
|---|---|---|---|---|---|
| *1994* | *Todd Busch* | *University of British Columbia* | *1996* | *Nelson Heerema* | *University of British Columbia* |
| *1995* | *Raymond Panneton* | *Université de Sherbrooke* | | | |

### PRIX DES DIRECTEURS

Trois prix sont décernés, à tous les ans, aux auteurs des trois meilleurs articles publiés dans l'*Acoustique Canadienne*. Tout manuscrit rapportant des résultats originaux ou faisant le point sur l'état des connaissances dans un domaine particulier sont éligibles; les notes techniques ne le sont pas. Le premier prix, de $500, est décerné à un(e) étudiant(e) gradué(e). Le deuxième et le troisième prix, de $250 chacun, sont décernés à des auteurs professionnels âgés de moins de 30 ans et de 30 ans et plus, respectivement. Coordonnateur: Blaise Gosselin, Hydro Québec, 16e étage, 75 boul. René Lévesque ouest, Montréal, QC H2Z 1A4.

### PRIX DE PRESENTATION ÉTUDIANT

Trois prix, de $500 chacun, sont décernés annuellement aux étudiant(e)s sous-gradué(e)s ou gradué(e)s présentant les meilleures communications lors de la Semaine de l'Acoustique Canadienne. La demande doit se faire lors de la soumission du résumé. Coordonnateur: Alberto Behar, 45 Meadowcliffe Drive, Scarborough, ON M1M 2X8.

# INSTRUCTIONS TO AUTHORS FOR THE PREPARATION OF MANUSCRIPTS

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**The Canadian Acoustical Association**

**l'Association Canadienne d'Acoustique**

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