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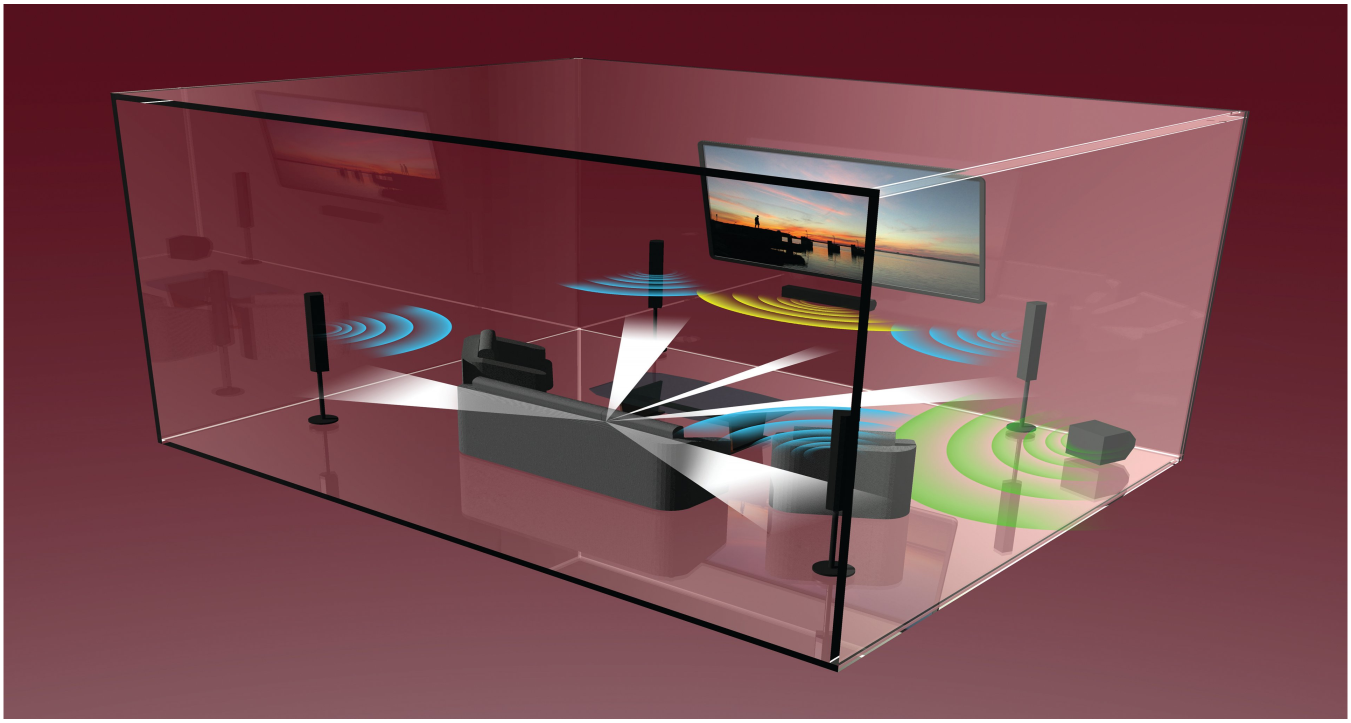

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Acoustique canadienne est publié quantre fois par an, en mars, juin, septembre et décembre. Cette revue trimestrielle est envoyée gratuitement aux membres individuels de l'Association canadienne d'acoustique (ACA) et aux abonnés institutionnels. L'Acoustique canadienne publie des articles arbitrés et des rubriques sur tous les aspects de l'acoustique et des vibrations. Ceci comprend la recherche, les recensions des travaux, les nouvelles, les offres d'emploi, les nouveaux produits, les activités, etc. Les articles concernant les résultats inédits ou les applications de l'acoustique ainsi que les articles de synthèse, les tutoriels et les exposées techniques, en français ou en anglais, sont les bienvenus.L'Association canadienne d'acoustique a sélectionné Paypal comme solution pratique pour le paiement en ligne de vos frais d'abonnement. Paypal prend en charge un large éventail de méthodes de paiement (Visa, Mastercard, Amex, compte bancaire, etc) et ne nécessite pas que vous ayez déjà un compte avec eux. Si vous désirez procéder à un paiement par chèque de votre abonnement, on vous invite à compléter le formulaire d'adhésion et l'envoyer avec votre chèque ou mandat au secrétaire de l'association (voir adresse ci-dessus). - Canadian Acoustical Association/Association Canadienne d'Acoustique P.B. 74068 Ottawa, Ontario K1M 2H9 Canada - (613) 562-5248 - (613) 562-5800 p. 3066 - secretary@caa-aca.ca - Prof. Chantal Laroche

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Éditorial
Editor's note

« Hello World!»

Ces deux mots, habituellement utilisés par tout programmeur informatique lors de ses premiers essais, résument bien l'état d'esprit qui est le mien à la rédaction de mon premier éditorial pour la revue *Acoustique canadienne*. Je suis très reconnaissant vis-à-vis des membres du comité de direction de l'Association canadienne acoustique et en particulier de mon prédécesseur, le professeur Ramani Ramakrishnan, de d'avoir confié la responsabilité de rédacteur-en-chef. J'en profite aussi pour remercier le professeur Frank Russo d'avoir assuré l'intérim et s'être vaillamment occupé des numéros de notre revue durant les derniers 16 mois.

Le numéro combiné que vous avez en main est d'une forme particulière. Il contient essentiellement les articles prévus pour le numéro de Décembre 2013, tout en revêtant la nouvelle mise en page prévue pour le numéro de Mars 2014. En effet, vous n'êtes pas sans savoir que depuis presque 18 mois, la revue Acoustique canadienne est publiée en ligne sur le site http://jcaa.caa-aca.ca, grâce au très complet « Open Journal Systems ». Or ce même système permet également la gestion éditoriale complète d'une revue scientifique depuis la gestion des soumissions électroniques, jusqu'à la préparation du contenu en ligne, en passant par l'indispensable processus de revue par les pairs. Il ne restait donc

Hello World!

These words, used by computer programmers in their early stages, fittingly describe my state of mind as I embark on writting my first editor's note for *Canadian Acoustics*. To begin, allow me to express my gratitude to the executive board of the Canadian Acoustics Association and in particular, to my predecessor, Professor Ramani Ramakrishnan, for conferring me the task of Editor. I would also like to thank Professor Frank Russo for his time as interim Editor and for carefully overseeing the journal issues during the last 16 months.

This combined issue is somewhat different in format. It contains mostly articles selected for December 2013, while donning the new page layout intended for March 2014. As you may be aware, for almost 18 months now the Canadian Acoustics journal has been accessible online at http://jcaa.caa-aca.ca, using the comprehensive “Open Journal Systems”. This software provides for all editing aspects of a scientific journal, from managing electronic submissions to formatting online material, not to mention the crucial process of peer-review. The software only lacked functionality to print a “paper” version and needed converter software. Eugen Popovici -the man behind the success of our migration online- along with Cécile Le Cocq -our new copyeditor- have met this challenge successfully and nearly on a voluntary basis, given the hours they dedicated plus qu'à greffer à ce système un convertisseur capable de produire la version "papier" de la revue. Eugen Popovici -l'homme derrière la réussite de notre migration en ligne- et Cécile Le Cocq -notre nouvelle relectrice-réviseur- ont relevé ce défi avec brio et de façon quasi bénévole, compte tenu du temps consacré et de notre maigre budget. Je tiens en effet à les remercier, au nom de l'Acoustique canadienne pour leur remarquable contribution qui assure ainsi la pérennité technologique de notre journal basé maintenant uniquement sur des logiciels libres et gratuits. Ce système permettra également à notre comité éditorial et nos éditeurs associés, dont vous trouverez les noms à la page 43, de mieux gérer les courriels et les documents électroniques. Vous constaterez aussi, à cette page, que le poste d'éditeur associé pour la section « Contrôle du bruit/ Ingénierie acoustique » est vacant; n'hésitez pas à me contacter si le défi vous intéresse!

Ce numéro comporte en plus des trois articles scientifiques, un hommage à Floyd E. Toole aux travaux duquel notre illustration couverture fait référence.

Enfin, vous trouverez à la page 62 l'annuaire des membres 2013 de l'Association canadienne d'acoustique. Cet annuaire est bien pratique pour savoir qui fait quoi dans le domaine au Canada et il est traditionnellement envoyé dans le numéro de décembre. Il ne l'a pas été en 2013, car nous étions alors en pleine migration de nos bases de données. Ainsi, il serait bien important que vous preniez le temps de vérifier l'exactitude de vos coordonnées et de les corrigiez directement, le cas échéant, en vous connectant sur le site de la revue http://jcaa.caa-aca.ca

Sur ce, je vous souhaite une bonne lecture de ce numéro combiné et je vous salue tous d'un cordial : « Hello world ! »

Jérémie Voix
Rédacteur-en-chef

and our limited budget. On behalf of Canadian Acoustics, I would like to thank them for their remarkable contribution, as it will allow our journal to continue using technology based solely on free and open software. This system will also enable our editing committee and associate editors, whose names appear on page 43, to manage emails and electronic documents more efficiently. Also, that page, you will find that the position for associate editor for “Engineering Acoustics/Noise Control” is vacant; feel free to contact me if you are interested!

This issue features, on top of three scientific articles, a tribute to Floyd E. Toole whose research work is referenced by our cover art.

In closing, please note that the 2013 member directory for the Canadian Acoustics Association appears on page 62 of this issue. This directory lists who does what in the field in Canada and usually appears in the December issue. However, it did not in 2013 given that we were in the midst of moving our database online. Thus, please take a moment to verify your contact information and make any necessary corrections directly by means of the journal website http://jcaa.caa-aca.ca

With this, I hope you will enjoy reading this combined issue and I greet you all with a cordial: “Hello world!”

Jérémie Voix
Editor

ACOUSTIC EVALUATION OF A BAROQUE CHURCH- THROUGH MEASUREMENTS, SIMULATION, AND STATISTICAL ANALYSIS

David Queiroz de Sant'Ana and *Paulo Henrique Trombetta Zannin
Laboratory of Environmental and Industrial Acoustics and Acoustic Comfort
Federal University of Paraná, Brazil
[paulo.zannin@gmail.com; zannin@ufpr.br]
*Corresponding author

ABSTRACT

This paper describes the acoustic evaluation of historical baroque church in Brazil - *Igreja Nossa Senhora do Rosário de São Benedito* (Church of Our Lady of the Rosary of St. Benedict), built in the 18th century. The evaluation was performed in three stages: 1) *in situ* measurements of reverberation time (RT), early decay time (EDT), definition (D_{50}) and clarity (C_{80}); 2) reproduction of field conditions in a computational simulation using ODEON room acoustics prediction software, and 3) statistical analysis of the data. The integrated impulse response method was used here, as recommended by the ISO/3382-1:2009 standard. Results were subjected to an analysis of variance (ANOVA) to test the accuracy of the model. The model can be considered accurate, especially as far as reverberation times are concerned.

RÉSUMÉ

Cet article détaille l'évaluation acoustique d'une église baroque construite au 18e siècle et faisant partie du patrimoine du Brésil - *Igreja Nossa Senhora do Rosário de São Benedito* (église Notre-Dame du Rosaire de St-Benoit). L'évaluation a été réalisée en trois étapes : 1) Mesure sur site (*in situ*) du temps de réverbération (RT), le temps de décroissance initiale (EDT), de la définition (D50) et de la clarté (C80); 2) Simulation numérique à l'aide d'ODEON, un logiciel d'analyse acoustique, à partir des conditions observées sur site, et 3) Analyse statistique des données. Tel que suggérée par la norme ISO/3382-1:2009, la réponse impulsionnelle intégrée a été utilisé pour les fins de la présente étude. Les résultats obtenus ont ensuite été soumis à une analyse de la variance (ANOVA) pour vérifier la précision du modèle. En ce qui concerne les temps de réverbération, le modèle élaborée peut être considéré valide.

1. INTRODUCTION

The development of room acoustic prediction techniques is quite recent. The first efforts in this area emerged in the early 20th century with the works of Wallace Clement Sabine. Until that time, the acoustic quality of a room was determined by trial and error and a little luck, or through the reproduction of successful cases [1, 2].

In the following decades, several investigation techniques to find analysis solutions for room acoustics were developed, including the use of physical scale models. These models were widely employed for testing concert hall designs. Despite their efficiency, however, scale models have gradually been abandoned as modern computer processing capabilities improve.

Digital models often save time and costs for evaluation, and also offer the flexibility to easily change various acoustical parameters such as building materials, room occupancy, etc [3, 4, 5]. However, computer models must still be treated with some care. According to Long [2]: "*The simplifications necessary to be able to carry out* *the calculations in a reasonable time still leave us with an imperfect picture, but as technical sophistication and computing ability increase, the models are improving*".

Computational predictions have become the object of periodic assessments by the international scientific community. Vorländer [6] and Bork [7, 8, 9] conducted international round robin calculations to evaluate the performance of room acoustics simulation software. These authors found that the weaknesses of all the software they evaluated involved the calculations of low frequencies and the treatment of the effects of edge diffraction, especially in seating areas. Other difficulties encountered in these models involved the correct characterization of surfaces in terms of their sound absorption and diffusion properties [10, 11, 12, 13, 14].

A comparison of calculated values and data obtained by measurements is fundamental in checking the quality of the model. According to Bradley and Wang [15]: "*…reverberation time has been the parameter most widely used by academics and industry to calibrate models*". The reasons for this are that this parameter is easy to measure, its sensitivity in relation to positions is low, thus increasing the repeatability of sampling, and the fact that these programs calculate reverberation time consistently, which simplifies its statistical treatment [15].

In addition, predictions should be compared with optimal reference values in order to assess the acoustic quality of the digital prediction model. The ISO/3382-1:2009 [16] standard shows optimum values for several metrics, as well as the perception threshold for mean frequency values in a single position in concert halls and multipurpose auditoriums with volumes exceeding 25,000 m^3 (Table 1).

In Brazil, room acoustics is being standardized and the criteria for acoustic treatments of enclosed spaces are recommended by the Brazilian standard NBR 12179:1992 [17, 18, 19, 20]. This standard considers only reverberation time for acoustic conditioning [18]. It recommends the use of the classical equations of Sabine or Eyring [5, 21, 22].

Subjective impression of the sound field	Objective descriptor	Single number frequency averaging* [Hz]	Perceptible difference	Typical interval **
Reverberation	Early Decay Time	500 to 1000	Rel. 5%	1.0 s to 3.0 s
Perceived sound quality	Clarity, C_{80}, in dB	500 to 1000	1 dB	-5 dB to +5 dB
	Definition, D_{50}	500 to 1000	0.05	0.3 to 0.7
	Center time, Ts, in ms	500 to 1000	10 ms	60 ms to 260 ms

*The single number frequency averaging denotes the arithmetical average for the octave bands.

**The typical interval is for mean values over the frequency in a single position in concert halls and multipurpose auditoriums with volumes above 25,000 m^3 (ISO3382-1 [16])

Table 1. Values of some acoustic descriptors suggested by ISO 3382-1:2009 (Adapted from ISO3382-1 [16])

2. MATERIALS AND METHODS

The objective of this paper is to present the calibration of a computational model for predicting the acoustic parameters of a baroque church in the city of Curitiba, Brazil. The calibration will be performed based on a statistical comparison of the reverberation time of values measured *in situ* and values obtained by computer simulation. This work was divided into three stages: 1) Characterization of the room and *in situ* measurements of reverberation time (RT), early decay time (EDT), definition (D_{50}) and clarity (C_{80}), 2) Reproduction of field conditions in a computational simulation with ODEON version 9.0 room acoustic prediction software and 3) Statistical analysis of the data.

2.1 Characterization of the room and *in situ* measurements

The *Igreja Nossa Senhora do Rosário de São Benedito* (Church of Our Lady of the Rosary of St. Benedict) is an 18th century building of baroque architecture. This church was constructed on the site of a former colonial-style chapel built for slaves, which was called *Igreja Rosário dos Pretos de São Benedito* (Church of the Rosary of the Blacks of St. Benedict). The original church was inaugurated in 1737 and served as the headquarters of the Catholic Church in Curitiba (Brazil) from 1875 to 1893, during the construction of the Metropolitan Cathedral (Figure 1).

The building is made of stone masonry and its interior walls are plastered and painted with water based paint. Stained glass windows illuminate the interior of the church.

The floor is made of parquet laid on concrete and the wooden ceiling is painted with oil-based paint, with no decorations of any kind. The bare wooden benches are unpadded. The benches in the aisles seat approximately 310 people. In the choir above the entrance is a tube organ. Table 2 describes the main dimensions of this enclosed space.

Figure 1. Inside view of the Church - *Nossa Senhora do Rosário de São Benedito*

Architectural characteristics	Dimensions
Maximum width – including side chapels	13.5 m.
Maximum length– measured in front of the altar	28 m.
Maximum height– measured from floor to ceiling at the highest point of the arch, vault or flat ceiling	8.6 m.
Height of the altar – measured from the floor of the altar to the highest point of the ceiling	8.5 m.
Total volume	2488.6 m^3
Total floor area	305.4 m^2

Table 2. Interior dimensions of *Nossa Senhora do Rosário de São Benedito* Church

2.2 *In situ* measurements

The following equipment was used for the measurements of the interior of the church: 1) A omnidirectional sound source connected to a power amplifier; 2) A omnidirectional microphone connected to a sound level meter; 3) DIRAC 3.1 signal generating and decay curve recording software installed in a microcomputer; 4) RME *Fireface* 800 - firewire audio interface circuit board used for connecting the equipment to the microcomputer.

The loudspeakers were positioned at two points in the presbytery (Figure 2 - Source position S1, S2), one on the axis of symmetry of the main chapel and the other on the lectern facing the congregation. The receiver points were distributed around the naves in a regular 5x5 meter grid, making a total of six points in the principal nave and two points in the lateral nave (Figure 2). The microphone (Figure 2 – Microphone position - MP - 1 to 8) was sequentially positioned in the seating between the benches, at a height of 1.2 m from the floor, which reproduces the condition of the seated audience [16]. At each position impulse response was measured using exponential sweep signal to excite the air volume inside the room and then the various acoustical parameters were calculated by DIRAC 3.1 [23]. Triplicate measurements were also taken in for each combined loudspeaker and microphone pair, which yielded the average for the analysis.

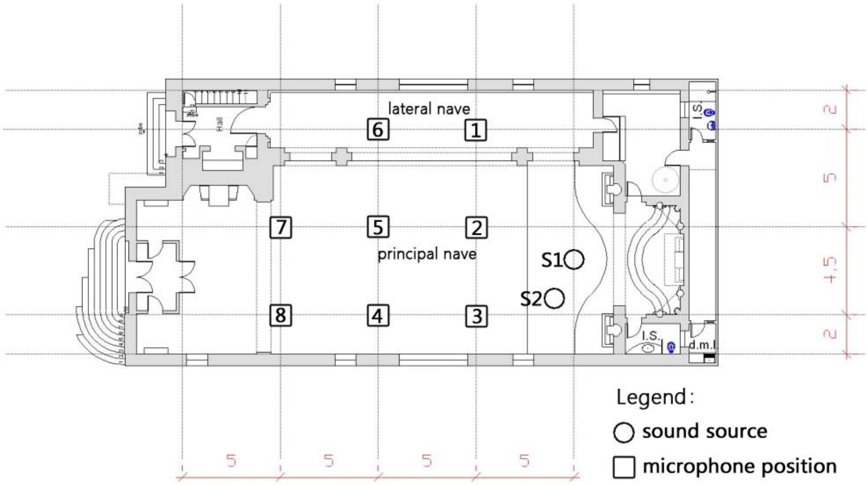

Figure 2. *Nossa Senhora do Rosário* Church – floor plan of the nave and presbytery

2.3 Computational Model

The acoustic simulation was performed using the Odeon 9.0 software [24] and consisted of the following steps: 1) Test of the geometry – identification of errors of the three-dimensional surfaces; 2) Positioning of the loudspeaker and receiver points according to the field survey; 3) Characterization of the surfaces as a function of the sound absorption and diffusion coefficients of the finishing materials found in the room. The digital three-dimensional model was created using VectorWorks 11.5 software [25] and, albeit simplified, it reproduces the main geometric characteristics of the enclosed space under study. Most of the sound absorption coefficients used here were available in the library of the software ODEON. The absorption coefficients used in the model are listed in Table 3 [26].

.

Materials	**Frequency in octave bands (Hz)**					
	125	**250**	**500**	**1000**	**2000**	**4000**
Wood sheathing, pine	0.10	0.11	0.10	0.08	0.08	0.11
Chairs, lightly upholstered concert hall chairs, average	0.35	0.45	0.57	0.61	0.59	0.55
Lime cement plaster	0.02	0.02	0.03	0.04	0.05	0.05
Single pane of glass, 3mm	0.08	0.04	0.03	0.03	0.02	0.02
Solid wooden door	0.14	0.10	0.06	0.08	0.10	0.10
Ceilings, plasterboard ceiling on battens with large air-space above	0.20	0.15	0.10	0.08	0.04	0.02
Floors, wood parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07
Windows, window glass	0.35	0.25	0.18	0.12	0.07	0.04

Table 3. Absorption coefficients of finishing materials used in churches [26]

Another important acoustic characteristic of surfaces is their property of diffusing reflected rays. Due to the scantiness of data on the diffusion coefficients of materials and because their applicability is based to a large extent on the experience of technicians and researchers [27, 28], the diffusion coefficients used in this model are the ones suggested by the manufacturer of the simulation program used here [29]. Table 4 describes the practical rules for its application.

Characteristics of surfaces	**Sound diffusion coefficient**
Large rigid or solid surfaces	0.1
Highly diffusive surfaces such as audiences in concert halls	0.7
Rooms with many small items, such as classrooms and offices, that are ignored in the modeling process	0.3

Table 4. Practical criteria for application of the sound diffusion coefficient – characterization of surfaces (Adapted from Christensen [29])

The ODEON software has three precision levels to calculate acoustical parameters [24]: 1) Survey, 2) Engineering, and 3) Precision. These three levels of precision have been associated to two methods of computing diffusion – total diffusion and Lambert´s cosine law (Lambert´s oblique) – and have been applied to two distinct situations: 1) all materials, or 2) soft material only. From these parameters, 12 different calculation combinations are possible, with each one producing a set of results - as can be seen in Table 5. In view of the innumerable/diverse possibilities of the software, the results should be compared to determine which level of precision and method of calculation is the most accurate.

2.4 Statistical treatment

Statistical treatments were applied as an auxiliary tool for the calibration of the models. Only data for the reverberation time (RT) were analyzed. Statistical analysis of the reverberation time by octave band facilitates the application of analysis of variance tests, because values vary very little with the position and its distribution throughout the room tends to normality [30, 31, 32, 33].

As mentioned in Section 2.3, 12 groups were obtained through computational predictions, and one group from measurements taken in the *Nossa Senhora do Rosário* church. For purposes of comparison, this is the control group against which all the other groups were compared. The prediction groups were numbered 2 to 13. The groups were created from the combinations provided by the software Odeon (Table 5), and were subjected to Kolmogorov-Smirnov, ANOVA, Tamhane and LSD tests [30, 31, 32, 33].

Data have been subjected to the ANOVA (Analysis of Variance). According to Vieira [32]: "*One ANOVA should only be applied to a set of observations if the conditions of Independence, equality of variances and normality of the samples are met. In practical terms, however, these 3 assumptions are hardly all met.*"

One of the most widespread test for verification of sample normality is that of Kolmogorov-Smirnov [32]. This test assesses the correlation between the observed distribution of the sample and a particular theoretical distribution. If the hypothesis of normality of data is confirmed, the analysis of variance (ANOVA) can be performed.

The ANOVA is employed in order to compare the means of more than two groups at the same time. It is an extension of the Student´s t-test [32]. According to Bisquerra et.al [33]: "*The null hypothesis can be so named: there are no diferences between the observed means, that* *is, the observed differences are a result of random phenomena. Thus, one can consider that the different samples belong to a single population. With the ANOVA, one can conclude whether the hypothesis of difference between a pair of groups can or cannot be accepted*".

With ANOVA, one comes to the conclusion, to accept or reject the hypothesis of difference between the means of the groups, as a result of a certain source of variation. But in order to localize the differences between the groups, multiple comparison tests are then performed (*post hoc* tests). In this work we used Tamhane and LSD tests [30, 31, 32, 33]. Tamhane's test is applied to not homoscedastic samples, i.e., those having non-homogeneous variance. With the same purpose, samples with homogeneous or homoscedastic variance were treated with LSD test [30, 31, 32, 33].

The 12 groups of prediction are presented in Table 5.

3. RESULTS AND ANALYSIS

First, the *in situ* measurements were analyzed and compiled. Then, the predicted reverberation time for each Group were compared against the measured ones to determine which prediction Group agrees more with the on-site results. Afterwards, the predicted and measured values for the other acoustical parameters were compared.

3.1. Reverberation time inside *Nossa Senhora do Rosário Church*

From the analysis of the measured impulse response, the following reverberation times were obtained for each source and microphone position.

Group description	Group no.
Measured values	**1**
Survey + Lambert + soft materials only	2
Survey + Lambert + all materials	3
Survey + full diffusion + soft materials only	4
Survey + full diffusion + all materials	5
Engineering + Lambert + soft materials only	6
Engineering + Lambert + all materials	7
Engineering + full diffusion + soft materials only	8
Engineering + full diffusion + all materials	9
Precision + Lambert + soft materials only	10
Precision + Lambert + all materials	11
Precision + full diffusion + soft materials only	12
Precision + full diffusion + all materials	13

Table 5. Statistically tested acoustic prediction group

Combination Source/Microphone Position (S-MP)	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1-MP1	3.05	2.99	3.29	3.18	2.94	2.44
S1-MP2	2.83	3.05	3.32	3.16	2.89	2.40

S1-MP3	3.00	3.17	3.35	3.12	2.91	2.32
S1-MP4	2.86	3.05	3.37	3.21	2.96	2.48
S1-MP5	2.92	3.15	3.32	3.17	2.96	2.46
S1-MP6	3.04	2.98	3.27	3.23	2.96	2.43
S1-MP7	2.97	3.15	3.28	3.20	3.01	2.48
S1-MP8	2.93	3.03	3.36	3.26	3.03	2.39

Table 6. Measured Reverberation Time T_{30} for sound source in position S1

Combination Source/Microphone Position (S-MP)	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S2-MP1	3.06	3.02	3.23	3.21	2.94	2.38
S2-MP2	3.17	3.04	3.23	3.14	3.00	2.43
S2-MP3	2.94	2.93	3.31	3.21	2.96	2.48
S2-MP4	3.03	3.05	3.28	3.21	3.02	2.50
S2-MP5	2.64	3.01	3.31	3.32	3.00	2.45
S2-MP6	2.98	2.99	3.34	3.14	2.97	2.41
S2-MP7	2.84	3.11	3.39	3.21	2.98	2.42
S2-MP8	2.87	3.07	3.31	3.20	2.97	2.48

Table 7. Measured Reverberation Time T_{30} for sound source in position S2

3.2. Statistical analysis between predicted and measured results

The 12 prediction groups along with the measured group were statistically analyzed, based on T_{30}, as follow. The normality test (Kolmogorov-Smirnov applied respectively to each group) showed a p-value higher than 0.05 for all the groups analyzed in the *Nossa Senhora do Rosário* church. This shows that within each groups the reverberation times are distributed normally in all the loudspeaker frequencies and positions.

From the homogeneity of Variance test apply to the reverberation time of all predicted groups (Table 8), it appears that the span of the results from group to group is dependant of the source position. With p-value higher than 0.05 except at 125 Hz, the predictions with the loudspeaker in position S1 provided samples with homogeneous variance, meaning small differences from group to group results. In contrast, for all the prediction groups and at all the frequencies, the variances in position S2 of the loudspeaker were inhomogeneous (Table 8); the difference between the results of each prediction group is then significant for this source position.

In addition to being inhomogeneous, the null hypothesis for significant differences among the groups was not accepted for any of the samples subjected to analysis of variance (Table 9) – p-value is lower than 0.05. There are then quite possibly large differences between the means of the reverberation time predicted by Odeon while varying the calculation parameters (12 different calculation combination, see table 5).

The multiple comparison tests detected significant differences between all the prediction groups and the measured values. These differences were concentrated mostly at the frequencies of 250 Hz and 4000 Hz, and were distributed more uniformly among the others. In a comparison of the different positions of the loudspeaker, the simulations for the speaker in position S2 showed a significantly better performance (Table 10).

As one can see in the table 10, Group 7 showed the best reproduction of the measured values (p-value > 0.05) in the largest number of octave bands, and therefore has been used for the following steps of the study.

Loudspeaker position	**p-value per Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1	0.007	0.087	0.116	0.123	0.212	0.363
S2	0.019	0.006	0.000	0.000	0.003	0.003

Table 8. Homogeneity of Variance Test

Loudspeaker position	**p-value per Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1	0.000	0.000	0.000	0.000	0.000	0.000
S2	0.000	0.000	0.001	0.000	0.000	0.000

Table 9. ANOVA Test

Group description	**Group no.**	**Frequency in octave bands (Hz)**					
		125	250	500	1000	2000	4000
Survey + Lambert + soft materials only	2	▪	∇	●	▪	▪	∇
Survey + Lambert + all materials	3	●	∇	●	●	▪	∇
Survey + full diffusion + soft materials only	4	▪	∇	▪	∇	●	∇
Survey + full diffusion + all materials	5	●	∇	▪	▪	▪	●
Engineering + Lambert + soft materials only	6	▪	∇	●	▪	●	∇
Engineering + Lambert + all materials	7	▪	∇	▪	▪	▪	∇
Engineering + full diffusion + soft materials only	8	▪	∇	▪	∇	∇	∇
Engineering + full diffusion + all materials	9	●	∇	●	▪	▪	∇
Precision + Lambert + soft materials only	10	●	∇	▪	▪	●	∇
Precision + Lambert + all materials	11	▪	∇	●	▪	▪	∇
Precision + full diffusion + soft materials only	12	▪	∇	▪	∇	∇	∇
Precision + full diffusion + all materials	13	●	∇	▪	▪	▪	∇

Legend:

p-value < 0.05 for S1 and S2	∇
p-value < 0.05 for S1	●
p-value < 0.05 for S2	□
p-value > 0.05	▪

Table 10. Multiple Comparison Test between all the Prediction Groups and the Measured T_{30} Values

3.3. Comparison between measured and predicted reverberation time

Figures 3 and 4 indicate the measured and calculated/predicted (Group 7 – reverberation times). The best statistical performance for the prediction of Speaker S2 is shown in Figure 4. In this case the calculated best mach the measured data. The standard ISO/3382-1 [16] recommends that the results for (RT) are presented as a “single number frequency averaging”, according to Table 1: *“The single number frequency averaging denotes the arithmetical average for the octave bands, 500 to 1000 Hz*”.

It was found that the simulated results of Group 7 for this enclosed space presented differences of less than 0.16 seconds, i.e., differences of less than 5% from the T_{30} measured from point to point in the room. This performance meets the value proposed by ISO/3382-1:2009 [16] which recommends a tolerable difference of 5%. In view of this finding, the modeling of Group 7 was taken as representative of the existing room. Moreover, since the remaining calculated parameters originated from the room’s reverberant field, the results of the other three metrics (EDT, C_{80} and D_{50}) will be presented and compared with their respective measured values.

Tables 11 and 12 show the results for the predicted reverberation time (RT).

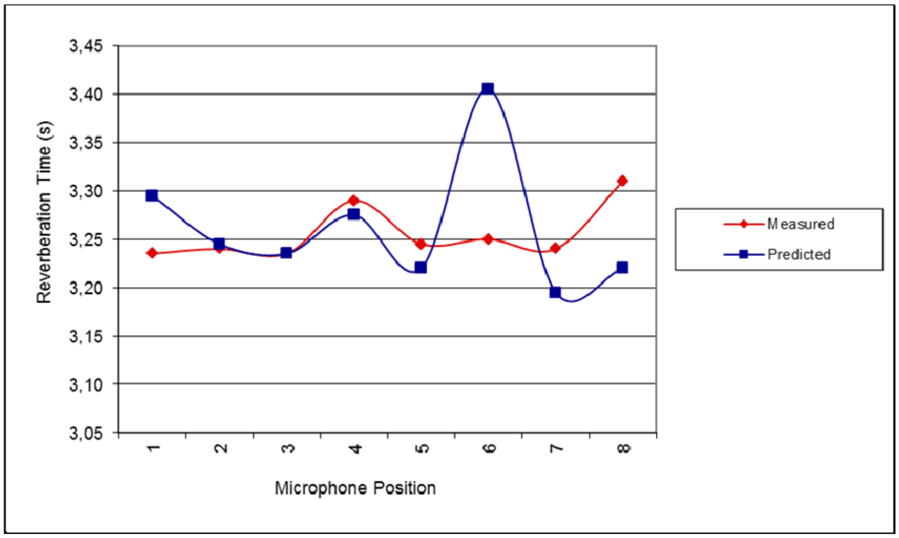

Figure 3. Measured and predicted reverberation time ($T_{500+1000Hz}$) for Loudspeaker position S1

Combination Source/Microphone Position (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S1-MP1	2,98	3,27	3,19	3,16	2,89	2,05
S1-MP2	2,80	3,23	3,19	3,17	2,79	2,17
S1-MP3	2,71	3,41	3,34	3,37	2,96	2,15
S1-MP4	2,88	3,49	3,27	3,26	2,98	1,99
S1-MP5	2,74	3,41	3,40	3,36	2,95	2,04
S1-MP6	2,65	3,24	3,17	3,21	3,01	2,16
S1-MP7	2,82	3,68	3,26	3,33	3,00	2,02
S1-MP8	2,70	3,32	3,18	3,33	2,94	2,01

Table 11. Predicted Reverberation Time T_{30} for sound source in position S1

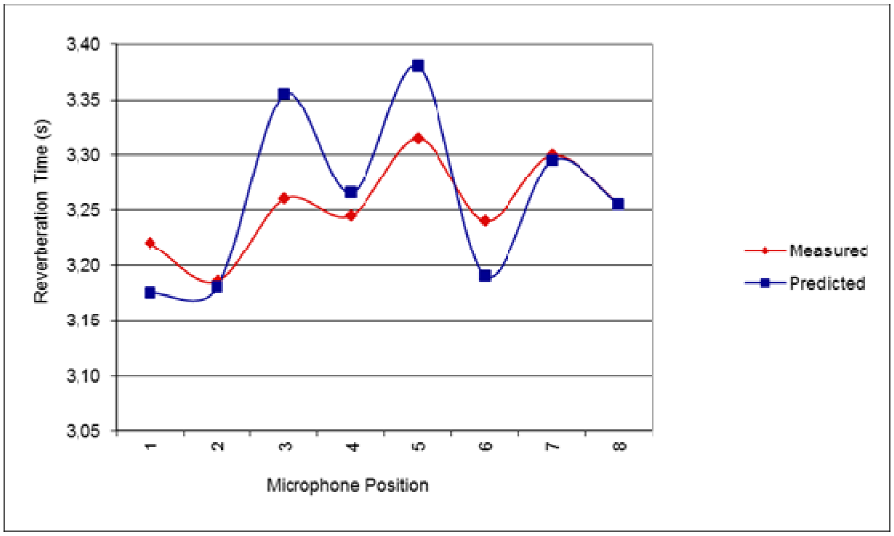

Figure 4. Measured and predicted reverberation times ($T_{500+1000Hz}$) for Loudspeaker position S2

Combination Source/Microphone Position (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S1-MP1	2,92	3,36	3,31	3,28	3,06	2,14
S1-MP2	2,97	3,38	3,21	3,28	3,01	2,07
S1-MP3	2,88	3,35	3,27	3,2	2,91	2,14
S1-MP4	2,92	3,49	3,23	3,32	3,05	2,13
S1-MP5	3,14	3,47	3,23	3,21	3,01	2,15
S1-MP6	3,53	3,63	3,42	3,39	2,98	1,96
S1-MP7	3,1	3,35	3,3	3,09	2,92	2,1
S1-MP8	3	3,18	3,26	3,18	2,87	2,11

Table 12. Predicted Reverberation Time T_{30} for sound source in position S2

3.4. Comparison of the measured and calculated results for EDT

The prediction of Early Decay Time (EDT) for the *N. Sra. Do Rosário* Church produced results which deviated by 5% to 16% from the measured values. These results indicate a random dispersion of the data with respect to the tendency of the measurements. Although the difference between the values is less than 5% for most of the points linked to Loudspeaker S1, the calculated results do not show a tendency consistent with the measured results (Figures 5 and 6). Tables 13 and 14 show measured levels of EDT and Tables 15 and 16 show predicted levels for EDT. The standard ISO/3382-1 [16] recommends that the results for (EDT) are presented as a "single number frequency averaging", according to Table 1: "*The single number frequency averaging denotes the arithmetical average for the octave bands, 500 to 1000 Hz*".

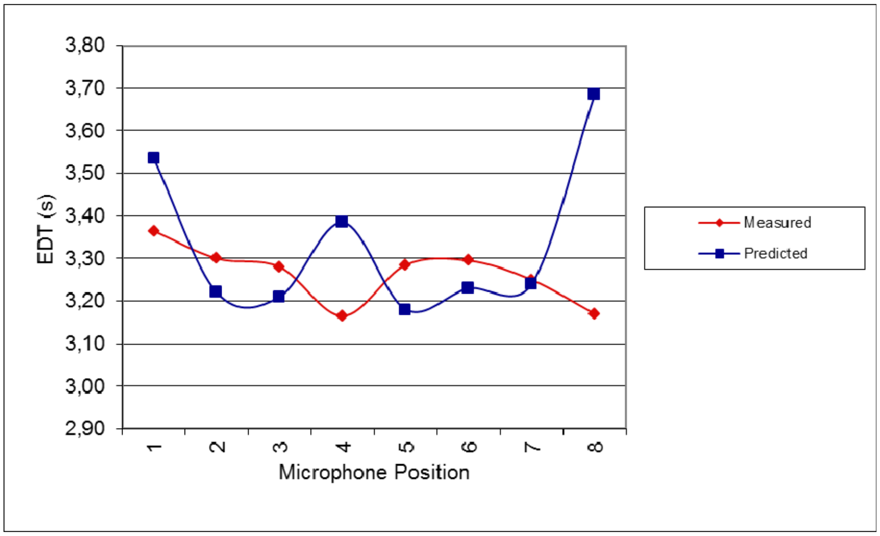

Figure 5. Measured and predicted Early Decay Times ($EDT_{500+1000Hz}$) for Loudspeaker position S1

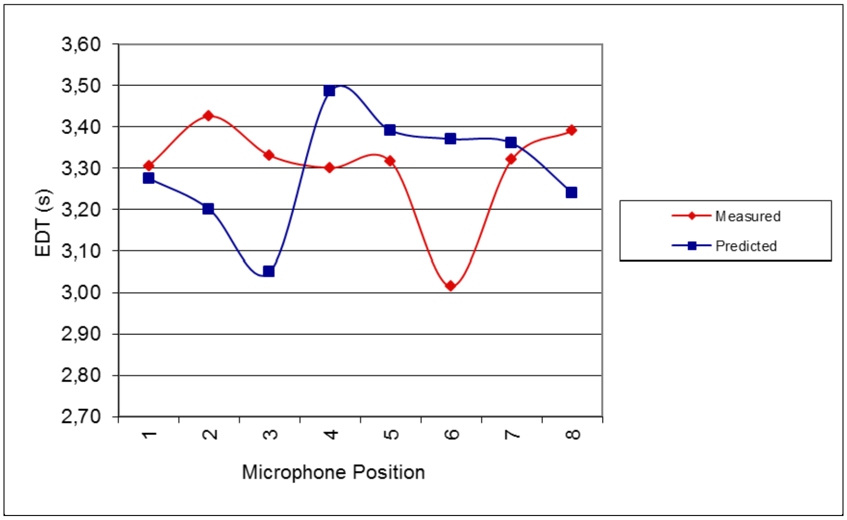

Figure 6. Measured and predicted Early Decay Times ($EDT_{500+1000\ Hz}$) for Loudspeacker position S2

Combination Source/Microphone Position (S-MP)	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1-MP1	3.12	3.24	3.59	3.14	3.05	2.40
S1-MP2	3.38	3.36	3.21	3.39	2.94	2.27
S1-MP3	3.18	2.71	3.34	3.22	2.98	2.29
S1-MP4	2.84	3.12	3.10	3.23	3.02	2.35
S1-MP5	2.93	2.90	3.23	3.34	2.91	2.34
S1-MP6	3.23	3.14	3.31	3.28	3.12	2.38
S1-MP7	3.20	2.79	3.30	3.20	2.98	2.50
S1-MP8	2.31	3.04	3.10	3.24	2.95	2.43

Table 13. Measured Early Decay Time EDT for sound source in position S1

Combination Source/Microphone Position (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S2-MP1	2.75	3.05	3.50	3.11	3.17	2.48
S2-MP2	2.57	3.05	3.48	3.37	2.86	2.20
S2-MP3	2.37	2.88	3.28	3.38	2.96	2.25
S2-MP4	2.81	2.94	3.36	3.24	2.97	2.33
S2-MP5	3.48	3.31	3.45	3.18	2.95	2.34
S2-MP6	3.12	3.21	3.10	2.93	3.02	2.31
S2-MP7	2.85	3.01	3.03	3.61	3.28	2.47
S2-MP8	2.95	3.03	3.42	3.36	3.22	2.55

Table 14. Measured Early Decay Time EDT for sound source in position S2

Combination (Source-Microphone Position) (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S1-MP1	3.22	3.78	3.53	3.54	3.13	2.22
S1-MP2	2.62	3.40	3.10	3.34	3.04	2.06
S1-MP3	2.87	3.42	3.21	3.21	2.88	2.18
S1-MP4	3.01	3.53	3.39	3.38	2.93	2.04
S1-MP5	2.88	3.45	3.19	3.17	2.94	2.11
S1-MP6	2.75	3.38	3.27	3.19	3.03	2.24
S1-MP7	3.10	3.56	3.28	3.20	3.16	2.20
S1-MP8	3.20	3.97	3.77	3.60	3.12	2.20

Table 15. Predicted Early Decay Time EDT for sound source in position S1

Combination (Source-Microphone Position) (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S2-MP1	2.93	3.44	3.27	3.28	3.00	2.07
S2-MP2	2.90	3.40	3.26	3.14	3.02	2.20
S2-MP3	2.48	3.15	3.09	3.01	2.83	2.05
S2-MP4	2.96	3.49	3.42	3.55	3.09	2.28
S2-MP5	2.77	3.60	3.45	3.33	2.98	2.07
S2-MP6	2.87	3.42	3.45	3.29	2.85	2.05
S2-MP7	3.00	3.58	3.33	3.39	3.20	2.10
S2-MP8	2.87	3.51	3.33	3.15	3.11	2.35

Table 16. Predicted Early Decay Time EDT for sound source in position S2

Large deviations in the simulations of Early Decay Time were also observed by other authors [8, 9, 15]. This descriptor of reverberation, unlike reverberation time, is significantly dependent on early sound (direct sound and early reflections), thus resulting in overestimated values for the points further away from the loudspeaker and, inversely, underestimated values for the closest points. The results indicate that, insofar as reverberation descriptors are concerned, computer models perform better in the calculation of reverberation time T_{30} than of Early Decay Time.

3.5. Comparison of the measured and calculated results for (C_{80})

For Clarity (C_{80}), the differences between the calculated values of (C_{80}) and the ones existing in the real room were described in Figures 7 and 8. The computer model overestimated most of the points for the configuration of loudspeaker S1. Nevertheless, the reproduction of the calculated values presented a difference of about 1 dB, the limit of the perceptible difference for this parameter, which characterizes a good performance of the model [16]. The predicted data for loudspeaker S2 presented a higher deviation at the points more distant from the loudspeaker (above 10 meters) and a better reproduction of the closer points. Tables 16 and 17 show measured values for C_{80}, and Tables 18 and 19 show predicted C_{80} values. The standard ISO/3382-1 [16] recommends that the results for (C_{80}) are presented as a "single number frequency averaging", according to Table 1: "*The single number frequency averaging denotes the arithmetical average for the octave bands, 500 to 1000 Hz*".

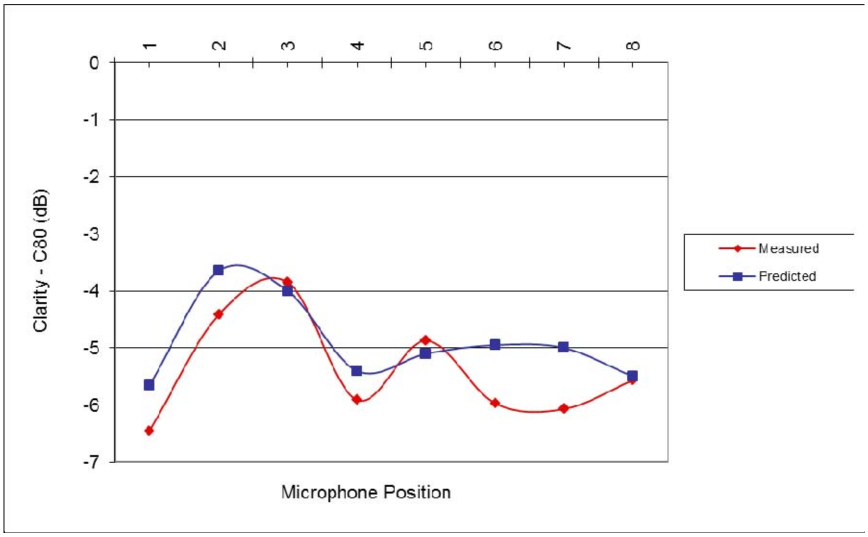

Figure 7. Measured and predicted values of Clarity (C_{80}) $_{(500+1000\ Hz)}$ for Loudspeaker position 1

Combination Source/Microphone Position (S-MP)	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1-MP1	-2.81	-6.16	-5.44	-7.46	-6.85	-3.82
S1-MP2	-3.00	-3.13	-4.68	-4.15	-3.25	-1.51
S1-MP3	-2.44	-2.21	-3.32	-4.38	-4.20	-1.55

S1-MP4	-4.92	-5.26	-6.55	-5.26	-4.25	-2.47
S1-MP5	-4.72	-3.82	-5.50	-4.24	-3.69	-1.47
S1-MP6	-4.77	-4.54	-5.91	-6.02	-4.84	-2.88
S1-MP7	-4.95	-6.99	-5.96	-6.18	-5.49	-2.80
S1-MP8	-4.35	-6.25	-6.74	-4.37	-4.97	-3.40

Table 16. Measured Clarity C_{80} for sound source in position S1

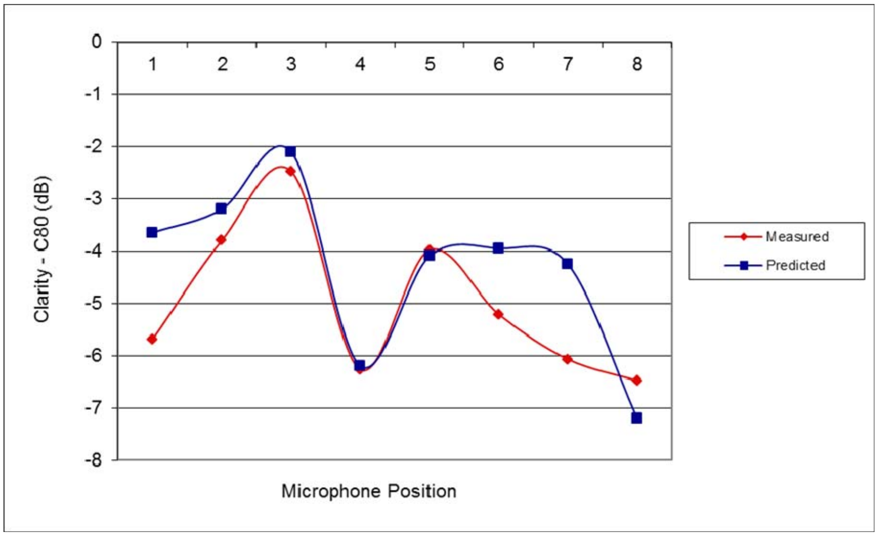

Figure 8. Measured and predicted values of Clarity (C80) (500+1000 Hz) for Loudspeaker position 2

Combination Source/Microphone Position (S-MP)	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S2-MP1	-0.86	-4.26	-4.99	-6.39	-5.06	-3.18
S2-MP2	1.76	-3.11	-4.07	-3.52	-3.29	-1.20
S2-MP3	-7.13	-4.16	-2.18	-2.75	-3.15	-1.66
S2-MP4	-3.93	-7.64	-7.02	-5.52	-3.89	-2.75
S2-MP5	0.18	-3.43	-3.21	-4.74	-4.50	-2.53
S2-MP6	-1.12	-2.82	-6.11	-4.31	-3.72	-3.14
S2-MP7	-8.13	-4.42	-7.02	-3.95	-4.13	-2.63
S2-MP8	-6.05	-5.22	-6.25	-6.70	-5.76	-3.71

Table 17. Measured Clarity C_{80} for sound source in position S2

Combination **Source/Microphone Position (S-MP)**	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1-MP1	-4.50	-5.70	-5.70	-5.60	-5.20	-3.40
S1-MP2	-2.40	-3.70	-3.70	-3.60	-2.90	-1.00
S1-MP3	-2.80	-4.00	-4.00	-4.00	-3.50	-1.70
S1-MP4	-4.50	-5.60	-5.40	-5.40	-5.00	-3.30
S1-MP5	-4.10	-5.20	-5.10	-5.10	-4.70	-2.80
S1-MP6	-4.20	-5.20	-5.00	-4.90	-4.40	-2.50
S1-MP7	-4.50	-5.60	-5.10	-4.90	-4.30	-2.40
S1-MP8	-4.90	-6.10	-5.60	-5.40	-4.90	-2.90

Table 18. Predicted Clarity C_{80} for sound source in position S1

Combination **Source/Microphone Position (S-MP)**	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S2-MP1	-2.70	-3.80	-3.70	-3.60	-3.20	-1.50
S2-MP2	-2.10	-3.30	-3.20	-3.20	-2.80	-0.70
S2-MP3	-1.00	-2.10	-2.10	-2.10	-1.60	0.30
S2-MP4	-5.20	-6.30	-6.20	-6.20	-5.70	-3.60
S2-MP5	-3.20	-4.30	-4.10	-4.10	-3.60	-1.60
S2-MP6	-3.10	-4.20	-4.00	-3.90	-3.40	-1.30
S2-MP7	-3.70	-4.80	-4.30	-4.20	-3.60	-1.60
S2-MP8	-6.50	-7.70	-7.20	-7.20	-6.50	-4.50

Table 19. Predicted Clarity C_{80} for sound source in position S2

3.6. Comparison of the measured and calculated results for (D_{50})

The simulation of Definition (D_{50}) presented lower deviations from the measured values than those obtained in the prediction of C_{80}. Differences of less than 0.05 (Figure 9 and 10) were observed between the measured and calculated data for both loudspeaker S1 and S2. The performance of the simulations for the second position of the loudspeaker, however, presented two points with differences of 0.05 to 0.10. In both these cases, the tolerance for the prediction was exceeded (Figure 10). Tables 20 and 21 show measured D_{50} values, and Tables 22 and 23 show predicted D_{50} values. The standard ISO/3382-1 [16] recommends that the results for (D_{50}) are presented as a “single number frequency averaging”, according to Table 1: “*The single number frequency averaging denotes the arithmetical average for the octave bands, 500 to 1000 Hz*”.

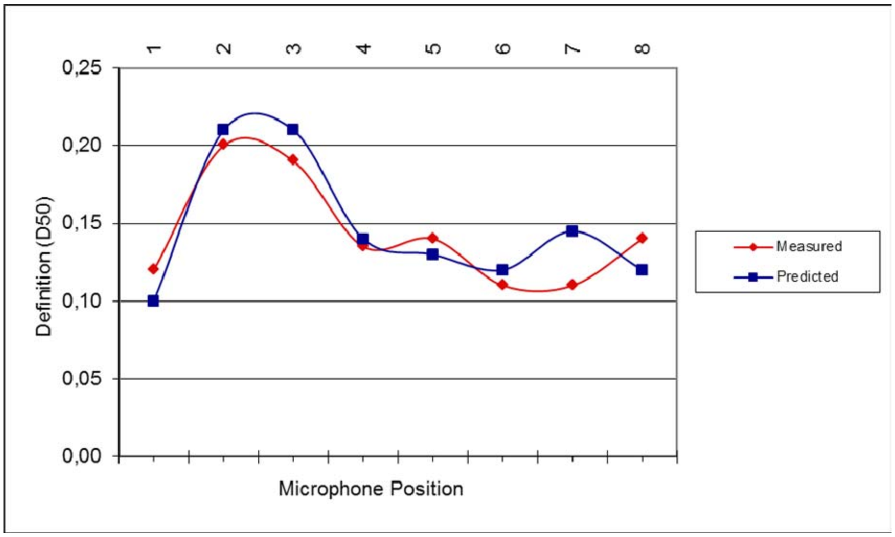

Figure 9. Measured and predicted values of Definition (D_{50}) **(500+1000 Hz)** for Loudspeaker position 1.

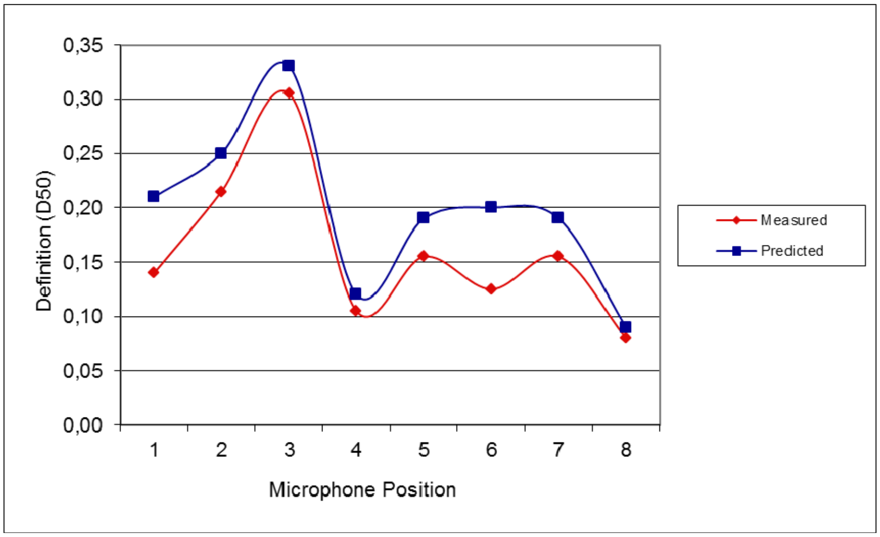

Figure 10. Measured and predicted values of Definition (D_{50}) (500+1000 Hz) for Loudspeaker position 2.

Combination Source/Microphone Position (S-MP)	**Frequency in octave bands (Hz)**					
	125	250	500	1000	2000	4000
S1-MP1	0.20	0.13	0.15	0.09	0.09	0.18
S1-MP2	0.21	0.24	0.21	0.19	0.23	0.30
S1-MP3	0.26	0.27	0.20	0.18	0.19	0.31
S1-MP4	0.17	0.16	0.12	0.15	0.17	0.23
S1-MP5	0.15	0.19	0.11	0.17	0.21	0.29
S1-MP6	0.20	0.19	0.09	0.13	0.17	0.22
S1-MP7	0.07	0.04	0.12	0.10	0.15	0.25
S1-MP8	0.19	0.14	0.12	0.16	0.13	0.22

Table 20. Measured Definition (D_{50}) for sound source in position S1

Combination Source/Microphone Position (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S2-MP1	0.42	0.18	0.17	0.11	0.14	0.23
S2-MP2	0.49	0.19	0.21	0.22	0.21	0.32
S2-MP3	0.10	0.19	0.33	0.28	0.23	0.31
S2-MP4	0.24	0.09	0.07	0.14	0.21	0.25
S2-MP5	0.34	0.15	0.17	0.14	0.16	0.24
S2-MP6	0.38	0.17	0.10	0.15	0.19	0.22
S2-MP7	0.07	0.11	0.09	0.22	0.20	0.24
S2-MP8	0.09	0.14	0.09	0.07	0.12	0.19

Table 21. Measured Definition D_{50} for sound source in position S2

Combination Source/Microphone Position (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S1-MP1	0.13	0.10	0.10	0.10	0.11	0.16
S1-MP2	0.26	0.21	0.21	0.21	0.24	0.33
S1-MP3	0.26	0.21	0.21	0.21	0.23	0.30
S1-MP4	0.17	0.14	0.14	0.14	0.15	0.21
S1-MP5	0.16	0.13	0.13	0.13	0.14	0.20
S1-MP6	0.15	0.12	0.12	0.12	0.14	0.19
S1-MP7	0.15	0.12	0.14	0.15	0.17	0.23
S1-MP8	0.13	0.11	0.12	0.12	0.14	0.19

Table 22. Predicted Definition D50 for sound source in position S1

Combination Source/Microphone Position (S-MP)	Frequency in octave bands (Hz)					
	125	250	500	1000	2000	4000
S2-MP1	0.25	0.20	0.21	0.21	0.22	0.29
S2-MP2	0.30	0.25	0.25	0.25	0.28	0.38
S2-MP3	0.39	0.33	0.33	0.33	0.36	0.46
S2-MP4	0.15	0.12	0.12	0.12	0.14	0.20
S2-MP5	0.22	0.18	0.19	0.19	0.21	0.28
S2-MP6	0.23	0.19	0.20	0.20	0.22	0.31
S2-MP7	0.20	0.17	0.18	0.19	0.21	0.29
S2-MP8	0.11	0.08	0.09	0.09	0.10	0.15

Table 23. Predicted Definition D50 for sound source in position S2

4. CONCLUSIONS

This study reports an evaluation of the acoustics of a Brazilian baroque church - *Nossa Senhora do Rosário* Church. The evaluation was performed in three stages: 1) *in situ* measurements of reverberation time (RT), early decay time (EDT), definition (D_{50}) and clarity (C_{80}); 2) reproduction of field conditions in a computational simulation using ODEON room acoustics prediction software, and 3) statistical analysis of the data.

The results were subjected to an analysis of variance (ANOVA) to test the accuracy of the model and can be considered accurate, especially insofar as reverberation times are concerned. The models tested here performed better in the calculation of reverberation time (RT) than of (EDT).

Statistical analysis is a useful tool for the selection of the best prediction. In this work, the prediction obtained by simulation of Group 7 (Table 8), which used the *engineering level of precision combined with Lambert's sound diffusion method applied to all materials*, produced results, when compared to the *in situ* measurements, within the deviation limits of ISO 3382-1:2009 for (RT_{60}) and (C_{80}), and relatively good correlations for (EDT) and (D_{50}).

5. ACKNOWLEDGMENT

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NOISE OUTPUT OF ROAD RACING MOTORCYCLES FROM MEASURED L_{eq} DATA

A.K. Mitchell[1]
[1]*School of Engineering, Acadia University, Wolfville, Nova Scotia, Canada*
[Andrew.Mitchell@acadiau.ca]

ABSTRACT

This paper reports the results of an experimental study of the noise output from road racing motorcycles competing in the Canadian Superbike race series. L_{eq} data from single-point measurements are presented for five events, which are then analyzed to determine an energy average noise output per competitor at each event. The analysis, which considers track geometry and total time spent on track by all competitors, seems to indicate a moderately rising trend in the noise output per participant over time that is attributed to the changing composition of the field. The single-number noise descriptor obtained is suggested as a useful tool for predicting noise levels at future events at this or other venues.

RÉSUMÉ

Cet article présente les résultats d'une étude expérimentale sur le bruit des motocyclettes de courses de la série «Canadian Superbike». Les valeurs L_{eq} enregistrées en un seul point pour les cinq courses sont présentées et sont ensuite analysée afin de déterminer une moyenne énergétique du bruit produit par chaque concurrent pour chaque évènement. L'analyse, qui comprend la géométrie de la piste et le temps passé par chaque concurrent sur la piste, semble indiquer une augmentation du niveau de bruit par concurrent au fil du temps. Ceci pourrait être attribué au changement de la composition du groupe de motocyclettes sur la piste durant l'évènement. Le descripteur de niveau à chiffre unique pourrait être utilisé outil pour prédire le niveau de bruit aux courses à l'avenir à cet endroit ou sur d'autres pistes de course.

1. INTRODUCTION

Road racing is a form of motorsport that sometimes produces noise annoying to those living nearby. This noise is often variable in level and intermittent, making it difficult to quantify with a single measurement. The courses used for competition are often several kilometers in length and cover significant geographical areas, which can also make it difficult to predict and/or monitor noise exposure at every potentially sensitive receiving location. Reference [1] describes some of the noise-related problems recently encountered at one prominent Canadian road racing site. Other venues have faced similar issues.

As part of an ongoing noise monitoring program, Atlantic Motorsport Park (a 2.56 km road racing facility located near Halifax, N.S.) has been recording A-weighted L_{eq} noise data at Canadian Superbike race series events held there since 2008. The equivalent continuous sound pressure level L_{eq} is a common measure used to describe time varying noise. In A-weighted form it is thought to reliably indicate the onset of community annoyance problems, and is used as the basis for many widely accepted noise control standards [2]. Data was collected for five events, but meaningful comparisons of the noise levels obtained from year to year were impossible because of inconsistencies in the recording techniques used, the variable numbers of competitors contributing to each recording and the intermittent, unpredictable way the race programs unfolded during the monitoring periods.

An investigation was begun to assess trends from year to year and determine the effectiveness of noise control regulations in effect at the time of each competition. This paper is the result of that effort. It describes a way to extract an energy-average noise output per competitor at each event from the available data. The analysis is based on the actual pattern of usage observed on track during each monitoring period and seeks to determine the noise level that a corresponding number of ideal, constant-output, uniformly radiating moving noise sources would have to produce in order to match the observed $L_{eq.}$ Although perhaps simplistic, this approach produces a single-number descriptor that is thought to be not only useful for comparing trends in the data from year to year but could also be used for other purposes such as making estimates of the noise impact of similar future events at this or other venues.

2. LITERATURE REVIEW

Several authors have explored ways to predict L_{eq}'s in the surrounding community resulting from motorsport noise, but none have attempted to determine information about the source from an observed result. In 1989 Dearden and Jennison [3] presented a technique for predicting levels near idealized circular and elliptical shaped race tracks with multiple moving sources. Also in 1989, Wilson [2] included an example community noise assessment of an imaginary go-kart track using a L_{eq} technique in his book. In 1997 Fillery and Thorpe [4] described how to estimate trackside L_{eq}'s for various types of car racing events from experimental pass-by measurements. And finally, Mitchell [5] in 2009 demonstrated how geomatics information for complex track shapes could be used to predict L_{eq}'s at surrounding arbitrary locations.

3. THEORY

Assume that every vehicle on a race track contributing to a measured L_{eq} can be represented as an identical point source, radiating sound uniformly in all directions at a constant level as it moves around the course. Neglecting directivity and shielding effects, a conservative (over) estimate of the instantaneous sound pressure level L from any one of these imaginary point sources at an arbitrary measurement location would be

$$L = L_0 + 10 \log\left(\frac{r_0^2}{r^2}\right)$$

Where L_0 is the level of the constant source measured at some known distance r_0 and r is the actual distance between source and the receiver. The L_{eq} is defined as

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T \left(10^{L/_{10}}\right) dt$$

Where T is the period over which the measurement is to be carried out, L is the level of the time-varying noise at the observation point and t is time. Combining the previous two expressions gives the following:

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T \left(10^{L_0/_{10}} * \frac{r_0^2}{r^2}\right) dt$$

Now introducing a summation to account for the possibility of m non-correlated sources contributing to the measured L_{eq} and recognizing that L_0 and r_0 are constant for all vehicles and with respect to time gives

$$L_{eq} = 10 \log \frac{1}{T} \sum_{i=1}^{m} 10^{L_0/_{10}} * r_0^2 \int_0^T \frac{1}{{r_i}^2} dt$$

Assuming that each vehicle completes an integer number of laps of the track during the measurement period (a reasonable assumption in a racetrack scenario), the integral term on the right can be approximately evaluated by subdividing the path around the track into k sectors of equal time duration Δt_i each and using a summation, i.e.

$$\int_0^T \frac{1}{r_i^2} dt \cong \sum_{j=1}^{k} \frac{\Delta t_i}{r_j^2} = T_i * \frac{1}{k} \sum_{j=1}^{k} \frac{1}{r_j^2}$$

Where T_i is the total time on track for the i$^{\text{th}}$ vehicle and the r_j's are the distances between the centers of the equal-time segments and the receiver. For simplicity, a new variable, r_{eff}, is defined as follows

$$\frac{1}{r_{eff}^2} = \frac{1}{k_j} = \frac{1}{k}\frac{1}{r_j^2} \qquad (1)$$

So that

$$\int_0^T \frac{1}{r_i^2} dt \cong \frac{T_i}{r_{eff}^2}$$

The L_{eq} expression then becomes

$$L_{eq} = 10 \log \frac{1}{T} \sum_{i=1}^{m} T_i * 10^{L_0/10} * \frac{r_0^2}{r_{eff}^2}$$

The r_{eff} term just introduced can be thought of as a single number descriptor of the "effective" distance between the source and the receiver. It is a function of the shape of the track, placement of the microphone and the relative speed of a given vehicle as it moves around the track. Most vehicles on a race track would experience similar relative speed variations as they move around the course (and all follow essentially the same path), so it seems reasonable to assume that r_{eff} will be nearly constant from vehicle to vehicle. Taking r_{eff} as a constant, the L_{eq} expression can be written as

$$L_{eq} = 10 \log \frac{r_0^2}{r_{eff}^2} * \frac{T_T}{T} * 10^{L_0/10}$$

Where T_T has replaced the summation of the individual T_i's and represents the total cumulative time that all vehicles spend on track during a measurement.

The previous expression may, for convenience, be separated into individual terms as follows:

$$L_{eq} = L_0 + 20 \log \frac{r_0}{r_{eff}} + 10 \log \frac{T_T}{T} \qquad (2)$$

Re-arranging Eq. (2) gives

$$L_0 = L_{eq} + 20 \log \frac{r_{eff}}{r_0} + 10 \log \frac{T}{T_T} \qquad (3)$$

which allows the sound pressure level L_o of the imaginary source proposed at the beginning of the derivation to be calculated from the observable data.

4. MEASUREMENTS

As mentioned in the introduction, L_{eq} results were obtained for five events in the Canadian Superbike series at Atlantic Motorsport Park. This is the premier motorcycle road racing series in Canada, crowning a national champion every year based on six to eight events held at venues across the country.

Fig. 1: Aerial view of Atlantic Motorsport Park.

A typical Superbike event consists of three days of practice, qualifying and racing for various classes of rider and machine. More on-track time is spent practicing than actually racing, which happens only on the final afternoon of an event. Some events are run as four day "doubleheaders" with racing on two consecutive afternoons, but this is unusual.

The series makes an annual visit to AMP, which is located about 60 km west of Halifax, Nova Scotia, Canada. An aerial view of the facility is shown in Figure 1. Sound levels were recorded for two events forming a "doubleheader" weekend on August 9-10 2008, a second double weekend on August 7-8 2010 and a single event August 7, 2011. No data was obtained in 2009 because of inclement weather.

Two different recording locations were used in obtaining the noise data, approximately located as shown in Figure 1. Measurement location A straddled a property line at the eastern end of the facility while location B was in a cleared infield area normally reserved for emergency medical helicopter landings. Both areas were off-limits to the public to prevent non-racing related noise from contaminating the measurements. Background noise at these locations due to external events (i.e. airplane flyovers, thunder, etc.) was insignificant compared to that generated by the motorsports activity during each measurement period. Location A was used for the two events held in 2008, after which data collection shifted to location B.

Measurements at both sites were made using a Larson-Davis model 712 integrating sound level meter, calibrated before use by a matching Larson-Davis CAL150 pistonphone calibrator. Data was collected in the form of a series of consecutive ½ hour duration L_{eq}'s each day using "A" weighting and the slow meter constant. A tripod held the microphone approximately 0.25 m above ground at each site and directed towards the nearest approach of the track surface. A hand-held GPS device was used to precisely determine the longitude and latitude of each measurement location for use in later calculations.

The results obtained each day are given in Table 1. Although recording generally began each day at 8:30 A.M. and continued until the end of on-track activity, values are only reported here for the afternoon sessions when racing was actually taking place.

Interval Start, P.M.	Aug. 9th, 2008	Aug. 10th, 2008	Aug. 7th, 2010	Aug 8th, 2010	Aug. 7th, 2011
1:00	69.2	70.6	79.5	77.6	76.3
1:30	53.1	61.9	71.1	73.6	64.6
2:00	72.3	73.3	74.2	73.4	73.1
2:30	62.3	68.9	76.1	70	76.2
3:00	70.4	67.5	76.6	74.9	77.1
3:30	66.5	66.1	77.5	69.4	76.9
4:00	65.7	73.1	66	76.4	78.4
4:30	72.2	61.3	72	72.2	-
5:00	67.6	72.3	73.9	74.9	-
5:30	69.4	-	-	-	-

Table 1. Recorded ½ hour L_{eq} data (dBA).

5. Calculations

Before the average output level L_o of the competitors on a given race afternoon could be calculated from Equation 3, it was necessary to determine the overall L_{eq} value and measurement time T for the particular day, the total cumulative time T_T spent on track by all competitors and the r_{eff} value for the microphone location used.

The overall time duration T for each measurement day was found by adding the time together for all intervals in Table 1 that have recorded data. The L_{eq} results were consolidated into a single overall L_{eq} for each day using the formula

$$L_{eq} = 10 \log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{L_i/10}\right)$$

where L_i are the individual ½ hour L_{eq}'s recorded for the day and i is the total number of intervals used. Both sets of calculated values appear in Table 3.

T_T values for each event were calculated from published race results. Since no activity other than racing took place on the track on the afternoons studied, these provided an accurate record of all on-track activity during each measurement period. Table 2 shows a summary of lap data from the five afternoons studied. Total time on track T_T each day was calculated from this data by multiplying all of the laps run in each class on a given day by the representative lap time for that class listed in the table and summing the results. The calculated values are again listed in Table 3. The r_{eff} value at each of the measurement sites was determined using experimental data captured by a GPS data acquisition system mounted on a race motorcycle.

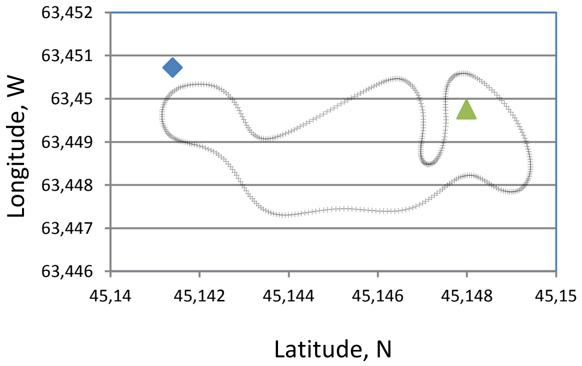

Figure 2. GPS data used to calculate r_{eff}.

This GPS system recorded five longitude and latitude position samples each second as it was carried around the track at speed. A 76 second s practice lap was used in the analysis, which gave 383 equally-time-spaced data point pairs outlining the track shape. The recorded position data was transferred to an excel spreadsheet, where it was used with the previously obtained positions of the microphone locations in Eq. (1) to calculate r_{eff} values for each site. Figure 2 graphically displays the GPS data used in calculations and the relative positions of the two recording locations (the diamond marker is at location A and the triangle marker is position B). These results are also given in Table 3.

6. RESULTS AND DISCUSSION

The final calculated L_o results for each event are listed at the bottom of Table 3 and are presented graphically in Figure 3. An arbitrary r_o value of 15.24 m was used in these calculations, primarily because this allowed an easy comparison with a previously obtained set of “pass by” measurements for similar motorcycles at that distance. The agreement between calculated L_o values for events on the same weekend is quite good, but there seems to be a trend towards increasing levels as time moves forward.

Race Class	Aug. 9th, 2008	Aug. 10th, 2008	Aug. 7th, 2010	Aug 8th, 2010	Aug. 7th, 2011	T_{lap}, sec.
Pro 600	211	251	269	239	136	70
Thunder	220	211	-	-	-	71
AM 600	262	288	251	278	166	73
Pro SBK	415	371	392	322	306	69
SV cup	99	113	84	77	-	74
AM SBK			166	155	-	73
CB 125			266	132	-	95
XR 1200			-	-	204	73

Table 2. Laps by class and event.

Calc’d Value	Aug. 9th, 2008	Aug. 10th, 2008	Aug. 7th, 2010	Aug 8th, 2010	Aug. 7th, 2011
L_{eq},dBA	68.89	70.03	75.44	74.31	76.00
T, sec	18000	16200	16200	16200	12600
T_T, sec	85477	87536	107805	88795	57644
r_{eff}, m	172.5	172.5	136.9	136.9	136.9
L_o, dBA	83.19	83.77	86.26	85.98	88.45

Table 3. Calculated values.

Several explanations can be advanced to account for the variations seen in the calculated levels. Foremost would be the fact that at location A the microphone was partially screened from the track by 2-3 meters of light vegetation, while at location B it had an unimpeded line of sight access to the racing surface. This would tend to artificially reduce the recorded noise levels at the 2008 events. The amount of attenuation caused by the screening is impossible to calculate exactly, but it does not seem unreasonable to attribute at least part of the roughly 3 dBA difference seen between the 2008 and 2010 results to this effect.

Another factor thought to have a significant effect on the observed results was the changing mix of machines participating in the events. In 2011 a new class of large-capacity, air-cooled twin cylinder machines was added to the race schedule and these machines accounted for quite a high percentage of the laps run. Air-cooled motorcycles are known to generate higher noise levels than the more common water-cooled machines used for other classes, so this could well account for the higher calculated L_o value obtained for the 2011 event.

A more subtle effect that might contribute to the depression of the 2008 values involves the placement of the recording microphones. Recall that the L_o value is calculated from the L_{eq}, which is an energy average that is disproportionately affected by the loudest sounds received during a measurement. The loudest sounds here would tend to occur as the moving vehicles reach their point of nearest approach to the measurement locations. At location A this would occur on a gently curving section of the track normally taken at part throttle; at location B it was on a straight section where the vehicles were under maximum acceleration. The sound power output from the same vehicle might be quite different in these two situations. The L_o values would tend to reflect this, as the sound power of the sources at the sections of track having the greatest influence on the L_{eq} measurement would be different. It is unclear just how significant this effect might be, but in any case it could not be used to explain the observed difference between the 2010 and 2011 results.

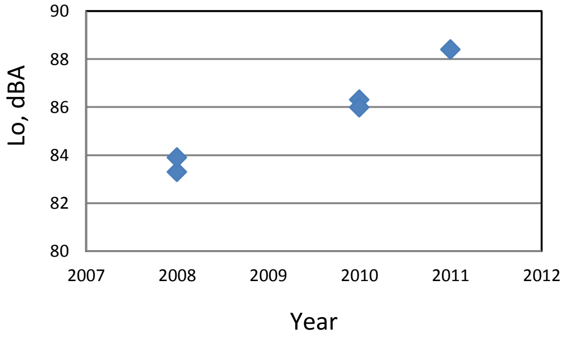

Figure 3. Calculated L_o values by year.

As mentioned in the introduction, part of the rationale for the study was to determine the effectiveness of noise control regulations in effect at the time of the competition. Unfortunately, this still proved difficult to do. The Canadian Superbike series (in common with most other North American road racing series for motorcycles) sets its maximum allowable noise level for competitors based on a test procedure loosely following the SAE J1287 standard. In this type of test, the microphone is held at a distance of 0.5m away from the exit of the exhaust pipe and at a 45 degree angle to the long axis of the motorcycle while the engine is run at part of its maximum speed. In 2010, the series limit was set to be 106 dB under ½ throttle conditions (with no mention of A-weighting appearing in the rules as written). Re-calculating the L_o values given in table 3 with a new r_o value of 0.5m simply adds 29.68 dB to each measurement obtained. This would put all of the L_o values obtained above the 106 dB maximum allowed in the series noise test when corrected for distance, with the 2011 event being the worst offender at 118.1 dBA. However, these values were obtained under racing conditions where engine speeds would be at or near their maximum, while the limit was specified at partial throttle. It is impossible to account for the difference in engine speed between the observed results and that called for in the test procedure, so no conclusions regarding overall compliance can be drawn.

The effect of the using the A-weighting network during recording (versus lack of same during series noise testing) would always be to reduce the levels obtained to less than would otherwise be observed though, so this would tend to make the calculated results a bit more conservative with respect to the rules than might actually be true.

As a point of discussion, it should be noted that despite the widespread acceptance of L_{eq} measurements for community noise monitoring, real-time systems for trackside noise control have proven difficult and costly to implement. Watson [6,7,8] has written quite extensively describing his experiences in the UK on this topic. Simpler testing methods such as the SAE test just mentioned are much more commonly used for on-site noise control at race tracks. These generally break down into two types of tests, static or pass-by. In North America motorcycle racing organizations tend to favor the static test, whereas car racing organizations such as the Sports Car Club of America prefer the pass-by technique. The advantages and disadvantages of both types of tests are discussed in Reference [9]

Even when searching for data collected using these simpler techniques, relatively little material appears in the literature that can be used for directly comparative purposes. In 1967 Ford [10] reported levels of 110-112 dBA for 1000 c.c. racing motorcycles when measured at a distance of 10 yards, but the machines he studied were all unsilenced. Modern superbikes such as those studied here are required to carry commercial silencers certified for street use. In 1999 Roberts [11] published an extensive study carried out at a number of Australian tracks in which he claims to have measured a noise level of 96 dBA at a distance of 30 m for a group of modern superbikes. No mention is made of how many machines made up the group, however.

The results do agree well with a secondary study carried out by the author that measured the noise output of a group of club racing motorcycles broadly similar to those in the Superbike series. In this study 191 measurements were obtained using the pass by technique described in Ref. [9], with the sound level meter in “peak hold” mode and located a distance r_0=15.24m from the racing surface. The average result obtained was 88.6 dBA, which compared well with the calculated L_o results from the first four events, considering that these were peak values and the calculated results were of the “equivalent continuous” type. No XR1200 type machines (thought to be responsible for the rise in overall levels observed at the 2011 event) were present when the club racing results were recorded.

It would be straightforward to use the L_o data obtained here in Eq. (2) to predict L_{eq} levels for future events provided the composition of the field was similar. All that would be required would be the selection of an appropriate r_{eff} value and the specification of new values for the overall time spent on track T_T and event duration T. Because of the relatively large amount of data used in this study (Five events comprising 5,884 laps of competition for 8 different classes of machine) it might reasonably be expected that the L_o values obtained here would have some statistical validity when used in this way. Equation 2 could even be used as a planning tool, allowing organizers to adjust the planned T_T for a hypothetical event to achieve a desired L_{eq} at some selected location.

The L_o results could also be used to predict levels at other venues holding similar events provided an appropriate r_{eff} value could be obtained. This would require obtaining a GPS trace for the new venue similar to the one used here and performing new calculations. For best accuracy, the type of vehicle used to obtain the trace should match as closely as possible the characteristics of the motorcycles used to obtain the original L_o values.

It would be quite easy to obtain L_o data for specific classes of machine with the technique described here by recording individual L_{eq}’s for the individual races and/or practice sessions and analyzing them separately. This method might have allowed more definite conclusions to be drawn regarding the cause of the rise observed in the overall 2011 results by isolating results for the various groups participating. It would also be possible to incorporate separate L_o information for different classes in any future predictions made using Equation 2.

Finally, the accuracy of results obtained in either the analysis or predictive stages could be improved by modifying the r_{eff} calculation to include equivalent distances to match known excess attenuation at individual points around the track resulting from topographical changes, barriers, etc.

The reader is reminded that L_0 values of the type obtained here are not L_{eq}'s in the normal sense; they are simply an abstraction used to describe the observed energy average noise output per competitor. Also, L_{eq} measurements, although widely used, do not always accurately predict the onset of community noise annoyance problems.

7. CONCLUSIONS

A method for obtaining the aggregate energy averaged equivalent continuous noise level per competitor at motorsport events from L_{eq} data has been presented. The analysis takes into account track geometry, the speed variation of the vehicles and the number of competitors present during each measurement period. The noise model obtained could plausibly be used to predict noise impact of similar constituted fields of competitors at other events or venues.

The analysis, when applied to the events in the Canadian Superbike race series studied, seems to indicate a moderately rising trend in the noise output per participant over time that is primarily attributed to the changing composition of the race field.

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EFFECT OF CYLINDER LOCATION INSIDE A RECTANGULAR DUCT ON THE EXCITATION MECHANISM OF ACOUSTIC RESONANCE

N. Arafa[1], A. Tariq[1], A. Mohany[1], M. Hassan[2]
[1] AeroAcoustics and Noise Control Laboratory, Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, Oshawa, ON, Canada.
[2] Fluid-Structure Interaction Laboratory, School of Engineering, University of Guelph, Guelph, ON, Canada.

ABSTRACT

The flow-sound interaction mechanism of a single cylinder in cross-flow is investigated experimentally. The cylinder is located at different vertical locations inside a rectangular duct in order to investigate the effect of the cylinder location on the excitation mechanism of acoustic resonance. During the tests, the acoustic cross-modes of the duct housing the cylinder are self-excited. It is found that the cylinder location affects the process of the flow-excited acoustic resonance and the levels of the generated acoustic pressure. The resonance of a specific acoustic cross-mode is excited when the cylinder is located at its acoustic pressure node, which is the acoustic particle velocity anti-node. However, when the cylinder is shifted away from the pressure node of a certain acoustic cross-mode, a combination of cross-modes is excited and their intensity seems to be proportional to the ratio of the acoustic particle velocities of these modes at the cylinder's location. Moreover, as the cylinder moves closer to the top wall (or the bottom wall) of the rectangular duct, the Strouhal number value decreases due to the interference between the wake of the cylinder and the duct wall. Therefore, the onset of acoustic resonance for this case occurs at a higher value of reduced flow velocity.

RÉSUMÉ

Le mécanisme d'interaction d'un seul cylindre soumis à un écoulement transverse est étudié expérimentalement. Le cylindre est placé à des endroits différents dans un conduit rectangulaire afin de découvrir les effets de l'emplacement du cylindre sur le mécanisme d'excitation de résonance acoustique. Pendant les tests, les modes transversaux du conduit sont auto-excités. Les résultats montrent que le phénomène de résonance acoustique excitée par l'écoulement ainsi que le niveau de pression acoustique sont affectés par l'emplacement du cylindre. La résonance d'un certain mode acoustique transversal est excitée quand le cylindre se situe au nœud de pression acoustique, ce qui est également l'anti-noeud de vitesse de particule acoustique. Néanmoins, lorsque le cylindre est décalé loin du nœud de pression d'un certain mode acoustique transversal, une combinaison de mode transversaux est excitée et leur intensité semble être proportionnelle au rapport entre la vitesse de particule acoustique de ces modes à l'emplacement du cylindre. De plus, le nombre de Strouhal diminue si le cylindre approche la paroi du conduit paroi du haut ou du bas à cause de l'interférence entre le sillage du cylindre et la paroi du conduit. Par conséquent, le début de la résonance acoustique pour ce cas a lieu à une valeur plus élevée de la vitesse réduite de l'écoulement.

1. INTRODUCTION

The aeroacoustic sound or 'Aeolian tones' was first observed by Strouhal in 1878. The phenomenon was attributed to the friction between the air stream and any moving body and thus referred to by a 'friction tone' [1]. Subsequently, this phenomenon became of interest for many researchers, (e.g. Rayleigh [2], Bernard [3], and Relf [4]) who concluded that the sound is actually a result of the periodic vortex shedding behind any bluff body [5]. For a bluff body contained inside a duct, when the vortex shedding frequency coincides with one of the acoustic natural frequencies of the duct, a feedback cycle may occur where the vortex shedding acts as a sound source and excites an acoustic standing wave which, in turn, enhances the shedding process and thereby creates a strong acoustic resonance. This process is known as the flow-excited acoustic resonance and it often leads to the generation of acute noise problems and/or excessive vibrations [6]. Since the acoustic resonance phenomenon is not yet fully understood, it can be dangerously unpredictable and may cause catastrophic failures in many applications such as power generation and transport. Acoustic resonance in tube bundles of heat exchangers has received a considerable amount of attention over the past few decades because of its relevance to many industrial applications (e.g. Blevins and Bressler [7], Ziada et al. [8], Ziada and Oengoren [9, 10], Oengoren and Ziada [11], Eisinger et al. [12], Eisinger and Sullivan [13], and Feenstra et al. [14]). Nevertheless, the excitation mechanisms of acoustic resonance are still not fully understood. The primary reason for this is that most of the previous studies were directed toward finding solutions to specific existing problems rather than understanding the underlying physics of these excitation mechanisms, as discussed in detail by Weaver [15]. Several techniques have been suggested to supress the acoustic resonance in tube bundles. One of these techniques is to change the frequency of the excited acoustic mode of the system by placing baffles in the tube bundle. Basically, this technique shifts the acoustic resonance frequency above the vortex shedding frequency and therefore the acoustic resonance would not occur at a specific range of flow velocities. However, this technique is not effective to supress the higher acoustic modes [16]. Zdravkovich and Nuttall [17] investigated the suppression of the acoustic resonance in staggered tube arrays by eliminating different cylinders from specific locations inside the tube bundle. They have found that the removal of any of the cylinders that are located in the first row would eliminate the acoustic resonance. However, for the second row, only removal of the cylinders that are located at the acoustic pressure node of a certain cross-mode would be effective to suppress the acoustic resonance. Furthermore, for the third row, the removal of any cylinder did not suppress the acoustic resonance even when the cylinders located at the acoustic pressure node were removed. These results are quite surprising and thus, the relationship between the cylinder location inside a tube bundle and the acoustic resonance mechanism needs to be further investigated. Therefore, the main objective of this work is to investigate the flow-sound interaction mechanism of single cylinder located at different locations inside a rectangular duct and subjected to cross-flow. The outcome of this work shall clarify how the tubes located away from the location of the maximum acoustic particle velocity contribute to the excitation mechanism of acoustic resonance.

2. ACOUSTIC CROSS-MODES IN A DUCT

The acoustic cross-modes of a duct are the modes that excite acoustic standing wave inside the duct that oscillate in a direction perpendicular to both the cylinder axis and the main flow velocity. These acoustic cross-modes oscillate with a simple harmonic motion in time [18]. The frequencies of these cross-modes are given by:

$$f_{a,n} = n\frac{c}{2h}\ , \qquad n = 1,\ 2,\ 3,\ \ldots \tag{1}$$

where f_a is the natural frequency of a certain acoustic mode, n is an index that indicates the order of this mode, c is the speed of sound, and h is the duct height. Figure (1) shows the distribution of both the acoustic pressure and the acoustic particle velocity along the duct height for the first three cross-modes. The acoustic pressure for the build-up standing wave follows a sinusoidal distribution along the duct height. The acoustic particle velocity will also take a similar sinusoidal distribution with 90° phase shift. The acoustic pressure field inside the duct for the first acoustic cross-mode is simulated and shown in Figure (2). The resonant fields in the duct housing the cylinder are obtained using finite-element analysis (FEA) in ABAQUS. The acoustic pressure of the resonant mode can be expressed as:

$$p = \varphi\ e^{i(2\pi f)t} \tag{2}$$

where φ is a variable that satisfies the following Helmholtz equation:

$$\nabla^2\varphi + k^2\varphi = 0 \tag{3}$$

where k is the wave number ($k = 2\pi f_a / c$) and c is the speed of sound. At the inlet and the outlet section of the duct, the boundary condition for the lowest acoustic modes is approximately zero acoustic pressure. More details about the simulation technique can be found in Mohany and Ziada [19]. It is observed from Figure (2) that the cylinder is located at the acoustic pressure node for the first cross-mode. The relation between the cylinder location and the pressure node of each cross-mode will dictate the excitation mechanism, which is discussed in detail in the results section.

3. VORTEX SHEDDING FREQUENCY

The value of the vortex shedding frequency behind a circular cylinder depends on the flow velocity and cylinder's diameter. The vortex shedding frequency is given by:

$$f_v = \frac{St\ \mathrm{U}}{D} \tag{4}$$

where f_v is the vortex shedding frequency, St is the Strouhal Number, U is the flow velocity, D is the diameter of the cylinder. For a single cylinder, the Strouhal number has a constant value around 0.2 over a wide range of Reynolds numbers [20]. This indicates that the relationship between the flow velocity and the vortex shedding frequency will be linear. The flow-excited acoustic resonance will occur upon the coincidence of the vortex shedding frequency with one of the acoustic cross-modes frequencies of the duct, provided that the excitation energy of the flow is high enough to overcome the acoustic damping of the system.

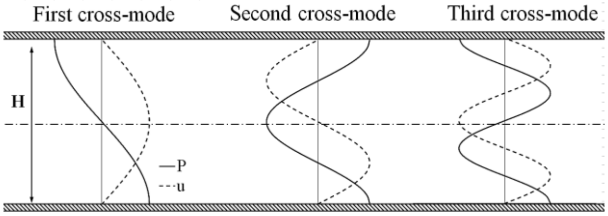


Figure 1: Normalized acoustic pressure and acoustic particle velocity distribution along the duct height (H).

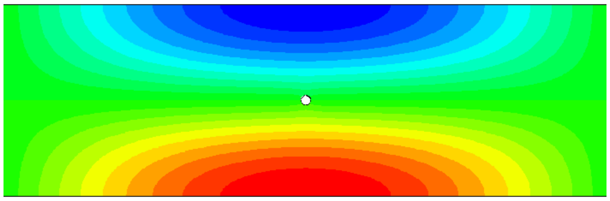


Figure 2: Acoustic pressure field inside the duct housing the cylinder for the first cross-mode. The cylinder is located in the middle of the duct height.

4. EXPERIMENTAL SETUP

An experimental set-up was designed specifically for this work, which is conducive to self-generation of acoustic resonance for the first three acoustic cross-modes of the duct housing the cylinder. The experimental setup consists of an open loop wind tunnel connected to a centrifugal air blower that is driven by an electrical motor with a variable frequency drive to control the air velocity inside the duct, as shown schematically in Figure (3). The test section height is 254 mm and the width is 127 mm. The test section is connected to a single-sided diffuser with an inclusion angle of 14^{o} and both of them are manufactured out of plywood with 19 mm thickness. The diffuser is connected to the blower via a flexible connection in order to reduce any vibration transmission to the test section. The maximum flow velocity achievable in this test section is 160 m/s. The tested cylinder is rigidly mounted between the walls of the test section at various heights and subjected to cross-flow air stream. The aeroacoustic response is measured for each position by a pressure-field microphone. Figure (4) shows the microphone position with respect to the cylinder's location. The microphone is located at the position of the maximum acoustic pressure, which was determined in a separate experiment as shown in Figure (5).

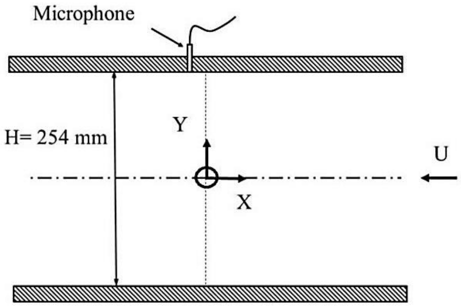


Figure 4: Schematic side view of the test section showing the coordinates system, the cylinder is positioned at Y/H= 0 and X/H= 0, the microphone is flush-mounted on the top wall at X/H= -0.1.

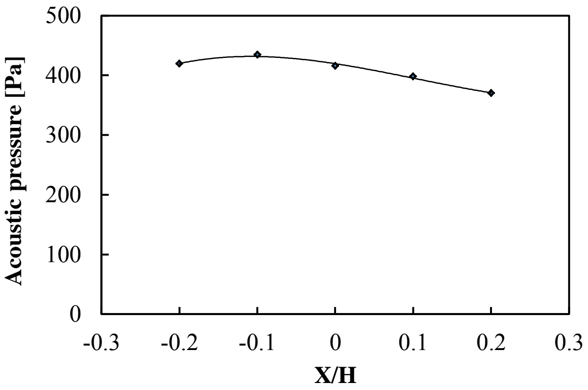


Figure 5: Peaks of the acoustic pressure of the first cross-mode versus the microphone positions for a single cylinder, D= 19 mm and U= 70.3 m/s. The cylinder is located at Y/H= 0 and X/H=0. Negative values represent the downstream direction.

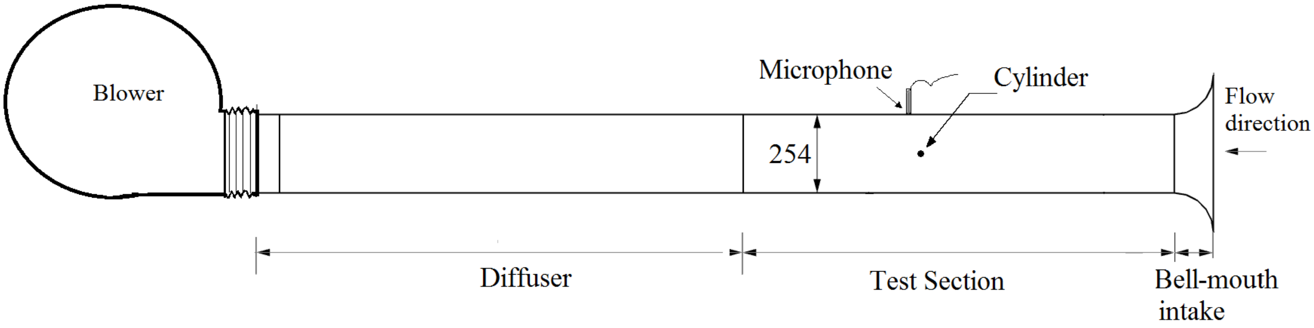


Figure 3: Schematic drawing of the experimental setup, all dimensions are in millimeters.

In that experiment, the microphone was flush-mounted at the top wall of the test section and moved to several stream-wise locations, with respect to the cylinder, in order to determine the location of the maximum acoustic pressure when a specific acoustic resonance mode is excited. The microphone signal is recorded with a data acquisition card (National Instruments, model number: PCI-6035E) and a LabView program is used for spectral analysis. Each spectrum is obtained by averaging 100 samples and the data is collected at a sampling rate of 10 kHz.

5. RESULTS

The aeroacoustic response of the cylinder is obtained by performing spectral analysis for the measured acoustic pressure. Figure (6) shows a waterfall plot of the acoustic pressure spectra for a cylinder positioned in the middle of the duct height, Y/H= 0, while Figure (7) shows the aeroacoustic response for the same case. Figure (7) is extracted from the waterfall plot of the acoustic pressure spectra where each point represents the amplitude and frequency of the vortex shedding component taken from the pressure spectrum at each flow velocity. Since the values of the vortex shedding frequency depend on the cylinder's diameter as shown in Eqn. (4), the frequency coincidence will occur over different velocity range depending on the cylinder's diameter. Thus, the reduced velocity, U_r, will be used to represent the flow velocity. The reduced velocity is given by:

$$U_r = \frac{U}{f_a D} \qquad (5)$$

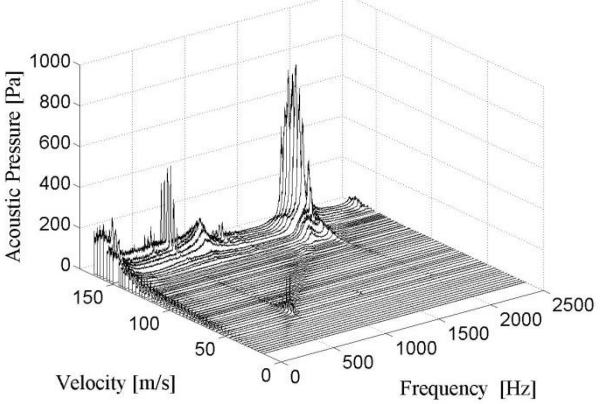


Figure 6: Waterfall plot of the pressure spectra for a cylinder positioned at Y/H=0, D= 15.7 mm.

Figure (7) shows that the frequency of the vortex shedding progresses with the flow velocity following a linear relationship with an average Strouhal number of 0.196. When the value of the vortex shedding frequency coincides with the frequency of the first acoustic cross-mode, acute acoustic pressure is generated. Moreover, the frequency is retrained at the value of the first acoustic cross-mode over a certain range of velocities, which is referred to by the *lock-in* region. As the flow velocity increases, the vortex-shedding frequency exits the lock-in region and follows the same linear relationship until reaching the frequency of the third acoustic cross-mode, where another lock-in region is obtained and severe noise is generated. The second acoustic cross-mode is not excited in this case as the cylinder is located at its acoustic pressure anti-node, which is an acoustic particle velocity node, as shown in Figure (1). Figure (8) shows a waterfall plot of the acoustic pressure spectra for a cylinder positioned at 63.5 mm away from the duct's centerline, i.e. Y/H=0.25, while Figure (9) shows the aeroacoustic response for the same case.

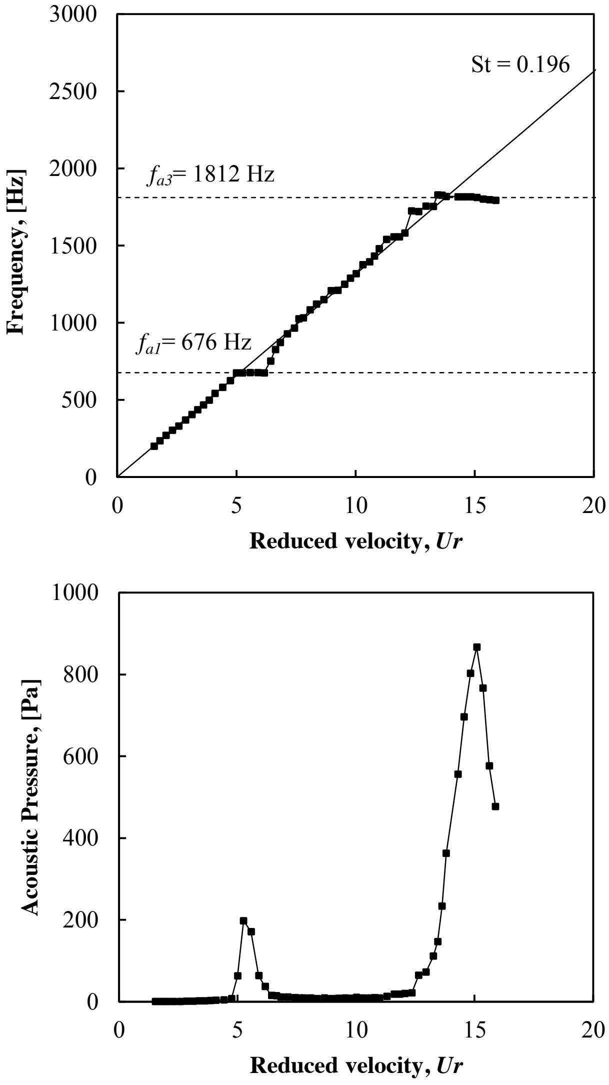


Figure 7: Aeroacoustic response of a single cylinder in cross-flow positioned at Y/H=0, D= 15.7 mm.

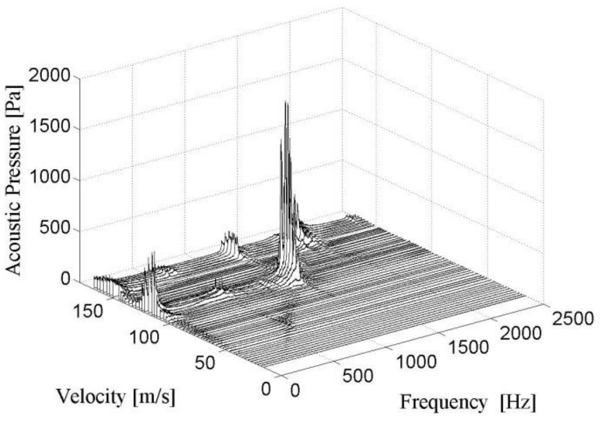
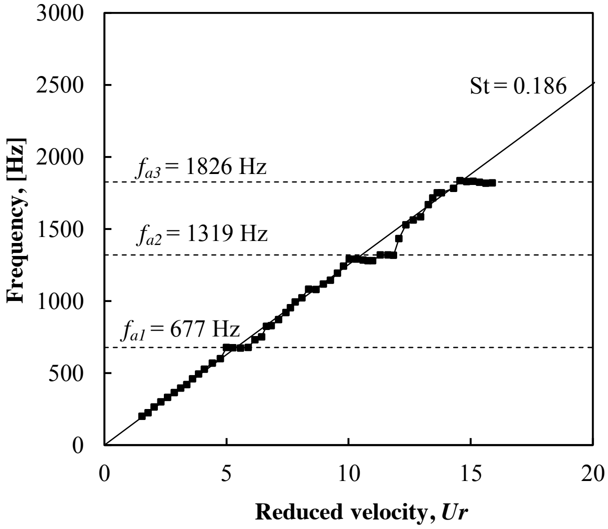


Figure 8: Waterfall plot of the pressure spectra for a cylinder positioned at Y/H=0.25, D= 15.7 mm.



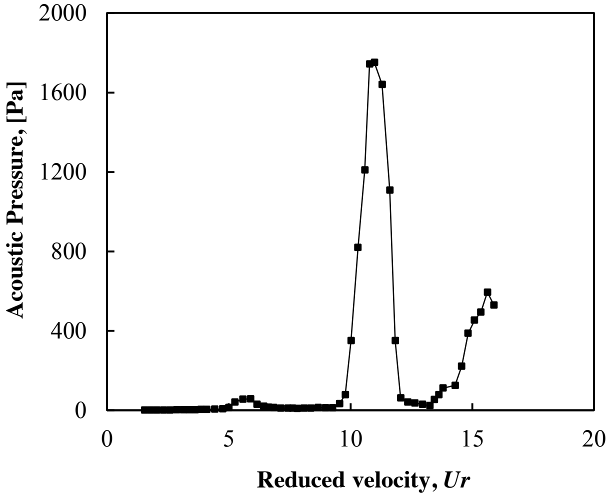


Figure 9: Aeroacoustic response of single cylinder in cross-flow positioned at Y/H=0.25, D= 15.7 mm.

It is clear from Figure (9) that the second acoustic cross-mode excitation is dominant as the cylinder is located at its acoustic pressure node. However, the first and the third cross-modes are also excited in this case as the cylinder is not located at any of their acoustic pressure anti-nodes. The generated acoustic pressure depends on the dynamic head of the flow and thus, on the flow velocity. As mentioned before, the velocity of frequency coincidence depends on the cylinder diameter. This indicates that different levels of acoustic pressures will be obtained when using different cylinder diameters. Thus, the logarithmic sound pressure level (SPL) will be used to represent the acoustic pressure in order to compare the results. The sound pressure level (in dB) is calculated by:

$$SPL = 20 \ \log\left(\frac{P_{rms}}{P_{ref}}\right) \tag{6}$$

Where P_{rms} is the root mean square value of the acoustic pressure and P_{ref} is a reference pressure value that equals to 20 μPa.

Figure (10) shows a comparison of the sound pressure levels for a single cylinder with a diameter of 12.7 mm, at several vertical locations inside the duct. Figure (11) shows the same comparison for another cylinder with a diameter of 15.7 mm, at the same vertical locations. It is observed that when the cylinder is located in the middle of the duct height, i.e. Y/H=0, the excitation of the first and the third acoustic cross-modes is the highest among the other locations. This is due to the fact that this location is the acoustic particle velocity anti-node for both the first and the third acoustic cross-modes; refer to Figure (1). Moreover, it is clear from Figure (10) that as the cylinder moves away from the duct centerline, the excitation levels of the first and the third acoustic cross-modes around reduced velocity values of 5 and 15, respectively, decreases. It is also observed that as the cylinder approaches Y/H = 0.25, which is the acoustic particle velocity anti-node of the second mode, the level of excitation of the second cross-mode increases. Yet, this level decreases as the cylinder moves beyond the acoustic pressure node, i.e. at Y/H = 0.375. Similar results are observed for another single cylinder with a diameter of 15.7 mm, as shown in Figure (11), which indicates that this behaviour is independent of the cylinder diameter.

It is clear from Figures (10) and (11) that the level of the excited acoustic pressure for each acoustic cross-mode varies depending on the cylinder's location. Since the acoustic resonance mechanism seems to be triggered by the acoustic particle velocity at the cylinder's location, it is interesting to determine if the levels of the excited acoustic pressure at different cylinder locations are proportional to the normalized acoustic particle velocity distribution for each cross-mode. Figure (12) shows the ratio of the acoustic particle velocity at the cylinder's location to the maximum acoustic particle velocity for each cross-mode. This ratio is equal to the ratio of the acoustic pressure excited at a specific cylinder's location to the maximum acoustic pressure obtained when the cylinder is located at the acoustic pressure node of a certain cross-mode.

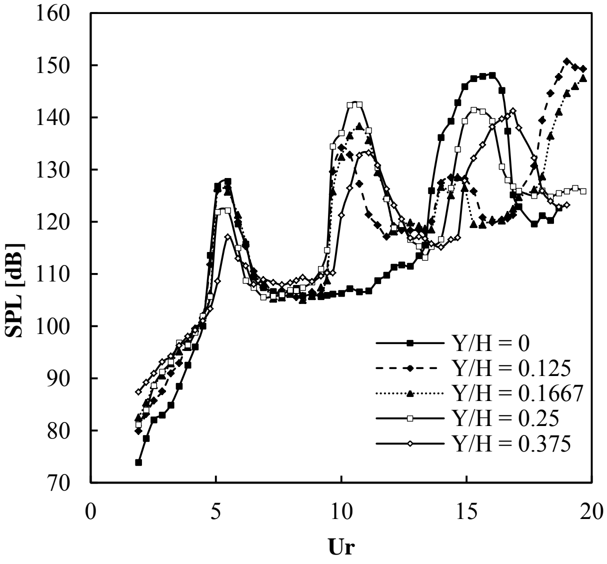


Figure 10: Comparison of the sound pressure levels at different vertical cylinder's locations, D= 12.7 mm.

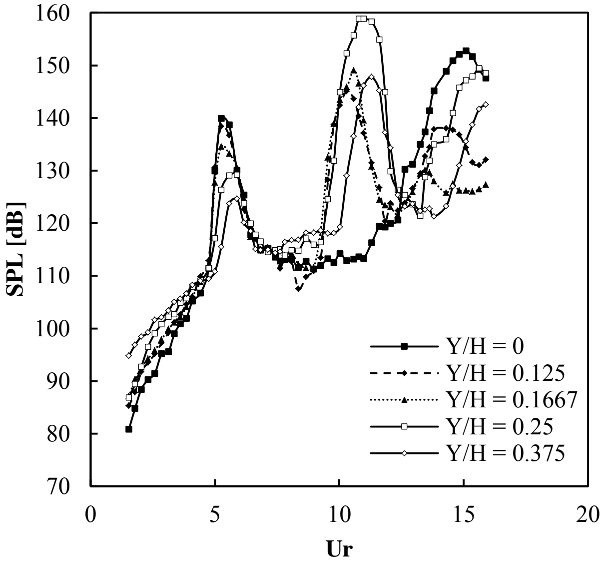


Figure 11: Comparison of the sound pressure levels at different vertical cylinder's locations, D= 15.7 mm.

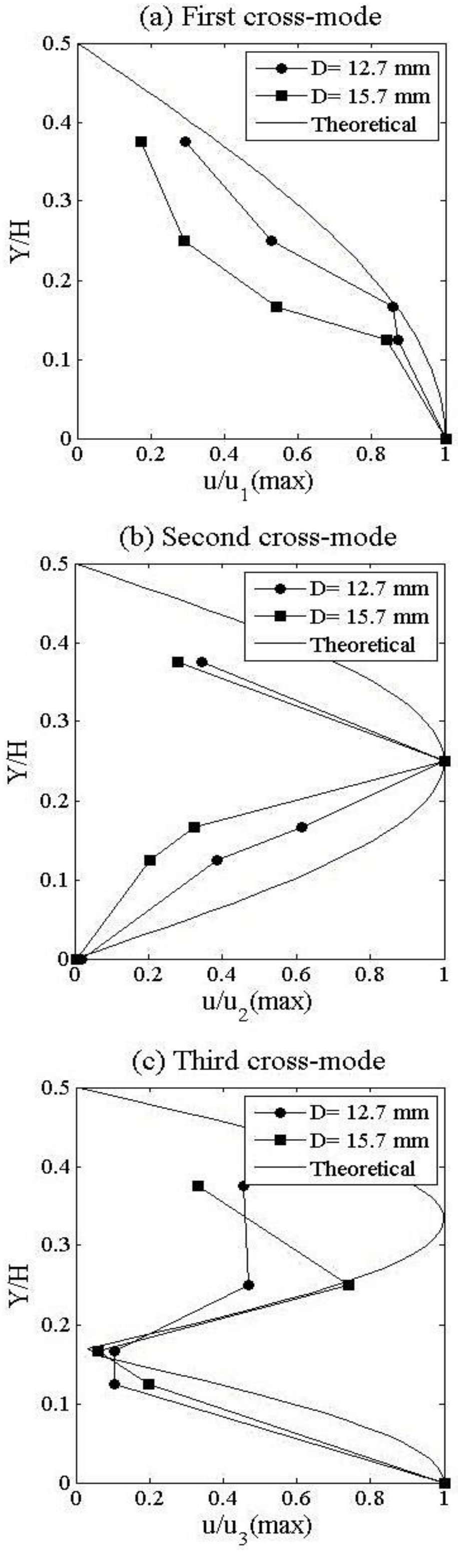


Figure 12: Distribution of the ratio of acoustic particle velocity to the maximum value of acoustic particle velocity along the duct height for (a) first, (b) second, (c) third cross-modes. The theoretical normalized distribution of the acoustic particle velocity is shown in each case.

It is observed from Figure (12) that the distribution seems to follow the theoretical sinusoidal distribution of the acoustic particle velocity. This indicates that the excitation mechanism depends, to some extent, on the acoustic particle velocity distribution rather than the acoustic pressure distribution. It is also worth to mention that the frequency values of each excited acoustic cross-mode were not constant for all the tested cases. Tables (1) and (2) show the acoustic resonance frequencies for the first three cross-modes for a cylinder diameter of 12.7 and 15.7 mm, respectively. The variation in the resonance frequencies can be explained by the fact that the existence of the cylinder changes the path of the oscillating fluid particles, and hence the frequency will differ for different cylinder diameters. However, this effect is more pronounced for the third acoustic cross-mode, which could be the result of an added acoustic damping. Caughey and O'Kelly [21] observed similar trend for a linear dynamic system and reported that the highest natural frequency decreases because of the added damping effect.

Table 1: Frequency values of each excited acoustic cross-mode, D=12.7 mm.

Y/H	First cross-mode (Hz)	Second cross-mode (Hz)	Third cross-mode (Hz)
0	678	(not excited)	1884
0.125	682	1327	1921
0.1667	679	1323	(not excited)
0.25	681	1326	1886
0.375	681	1324	1914

Table 2: Frequency values of each excited acoustic cross-mode, D=15.7 mm.

Y/H	First cross-mode (Hz)	Second cross-mode (Hz)	Third cross-mode (Hz)
0	676	(not excited)	1812
0.125	676	1319	1855
0.1667	676	1321	(not excited)
0.25	677	1319	1826
0.375	679	1327	1846

Finally, the Strouhal number values were investigated for different cylinder's locations. Rao et al. [22] investigated the characteristic of the wake of a cylinder close to solid boundary. They have shown that the average Strouhal number value varies with the gap distance. This Strouhal number variation affects the relationship between the frequency and flow velocity and thus may change the onset of acoustic resonance. Figure (13) shows the variation of Strouhal number with the cylinder's locations. As the cylinder moves closer to the wall, the average Strouhal number decreases due to the interference between the wake of the cylinder and the duct's wall. Therefore, the onset of acoustic resonance for such cases occurs at higher flow velocities, as can be seen in Figures (10) and (11).

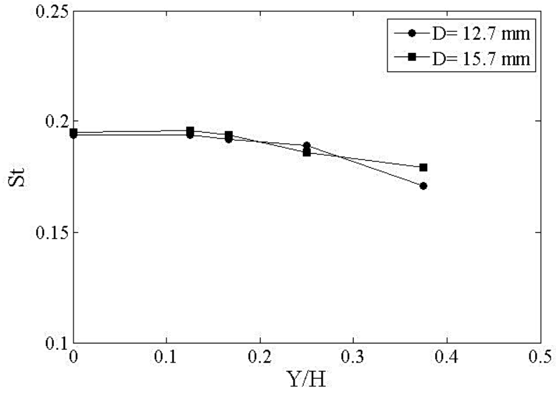


Figure 13: Average Strouhal number versus the cylinder's location.

6. CONCLUSIONS

The effect of cylinder location on the excitation mechanism of the flow-excited acoustic resonance is presented in this work. It has been found that the cylinder's location affects the level of acoustic excitation for each cross-mode. It is observed that when the cylinder is placed at the acoustic pressure node of a certain cross-mode, which is the acoustic particle velocity anti-node, the excitation of this particular cross-mode is dominant. It is also observed that as the cylinder moves away from the acoustic particle velocity anti-node of a certain cross-mode, the levels of the generated acoustic pressure decrease. This variation in the excitation levels seems to follow the theoretical sinusoidal distribution of the acoustic particle velocity which indicates that the excitation mechanism depends on the acoustic particle velocity distribution rather than the acoustic pressure distribution. The Strouhal number is calculated for different cylinder locations and is shown to decrease as the cylinder moves away from the duct's centerline. This, in turn, shifts the onset of acoustic resonance to occur at higher flow velocities for these cases.

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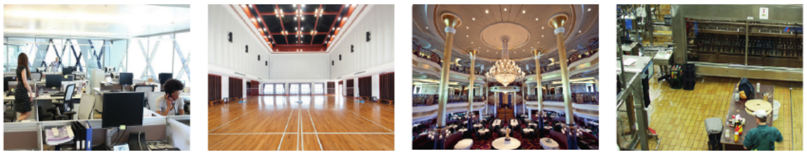


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Shocks / Vibrations - Chocs / Vibrations

Pierre Marcotte		marcotte.pierre@irsst.qc.ca
IRSST		

Hearing Sciences - Sciences de l’audition

Kathleen Pichora Fuller	(905) 828-3865	k.pichora.fuller@utoronto.ca
University of Toronto		

Speech Sciences - Sciences de la parole

Linda Polka	514-398-7235	linda.polka@mcgill.ca
McGill University		

Physical Acoustics / Ultrasounds - Acoustique physique / Ultrasons

Werner Richarz		wricharz@echologics.com

Bio-Acoustics - Bio-acoustique

Jahan Tavakkoli	(416) 979-5000	jtavakkoli@ryerson.ca
Ryerson University		

Engineering Acoustics/Noise Control - Génie Acoustique/Contrôle du bruit

Vacant

Larson Davis
76.1
STOP/STORE
RUN/PAUSE
ENTER
RESET
ON/OFF
TOOLS
SOUND EXPERT

FLOYD E. TOOLE HONOURED WITH AES GOLD MEDAL AWARD

by Andrew Lauzon

Congratulations goes out to Dr. Floyd E. Toole, this year's recipient of the Audio Engineering Society's (AES) prestigious Gold Medal Award, given in recognition of outstanding achievements, sustained over a period of years in the field of audio engineering. He is being honoured by the society for "outstanding contributions to theory, practice, and international standards in the area of subjective and objective evaluation of loudspeakers in rooms."

Dr. Toole holds a B.Sc. in electrical engineering from the University of New Brunswick and a PhD from the Imperial College of Science and Technology, University of London. From 1965-1991 he worked at the National Research Council of Canada, (NRC) reaching the level of Senior Research Officer in the Acoustics and Signal Processing group. There he conducted influential research that ultimately contributed to the founding of the loudspeaker industry in Canada. After leaving the NCR, he joined Harman International as Vice-President, Acoustical Engineering where he worked with all Harman-owned companies such as JBL Infinity, Harman/Kardon, Mark Levinson, Revel, Lexicon, AKG, DOD, Studer and Soundcraft, until his retirement in 2007. One of the advantages of working for a corporation as large as Harman is that "they can afford to do real research", he explains. "I was allowed to set up and run a research group that was not obligated to product development or marketing."

While still at the NRC conducting research on the subjective perception of sound localization, Dr. Toole uncovered a surprising lack of standardization in regards to loudspeaker systems. To quote his oft-used illustration, "there is more useful and reliable information on the side of a tire than there is in a loudspeaker specification sheet." With the opportunities for research facilitated by his position at Harman, he founded their multichannel listening lab where he and his team successfully established methods for subjective and objective evaluations used to clarify the relationships between technical measurements of loudspeakers and listeners' perceptions. Working with Dr. Sean E. Olive (another ex NRC researcher) processes were created that confidently predict consumer preferences from comprehensive anechoic measurements, removing much of the uncertainty that has plagued the industry.

Dr. Toole is still a liaison for the research team at Harman, and is actively involved with the Society of Motion Picture and Television Engineers. He says of his current work, "We are attempting to elevate the quality and consistency of sound in cinemas and sound tracks by developing a more effective calibration process for display and production facilities. This is much needed; audio is a multi-billion dollar industry with no effective rules, and the consequence is that consumers rarely get to hear the art as it was created."

Dr. Toole's credo is "using science in the service of art" and he is a believer in the idea that product development via scientific methodology, paired with consumer awareness translates not only into better products, but a more satisfied end-user. "In fact" he says, "just as the NRC connection became a marketing theme for Canadian loudspeaker manufacturers, Harman uses our continuing research as a means of differentiating us from our competitors.

Science works, it serves the audio arts, and, used thoughtfully, it ‘sells’.”

The current Gold Medal award is added to previous AES recognition in the form of two Publications Awards, the Board of Governors Award and the Silver Medal (1996). He is a Fellow and Past President of the AES, a Fellow of the Acoustical Society of America and a Fellow of CEDIA (Custom Design and Installation Association). He has been awarded Lifetime Achievement awards by CEDIA and ALMA (Association of Loudspeaker Manufacturing & Acoustics International).

Dr. Toole is also currently active as an educator and author. His book, *Sound Reproduction: The Acoustics and Psychoacoustics of Loudspeakers and Rooms* was published by Focal Press in 2008, and he has described it as the culmination of his life’s work. That said, life goes on, and he is contemplating a new book.

Floyd Toole, 2013

Canadian Acoustical Association
Association canadienne d'acoustique

2013 PRIZE WINNERS / RÉCIPIENDAIRES 2013

SHAW POSTDOCTORAL PRIZE IN ACOUSTICS /
PRIX POSTDOCTORAL SHAW EN ACOUSTIQUE

Kate Dupuis (University of Toronto)

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

Carolyn Binder (Dalhousie University)

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL /
PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT

Martin Brummund (École de Technologie Supérieure)

RAYMOND HÉTU UNDERGRADUATE PRIZE IN ACOUSTICS /
PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE

Harman Sawhney (University of Toronto at Mississauga)

CANADA-WIDE SCIENCE FAIR AWARD / PRIX EXPO-SCIENCES PANCANADIENNE

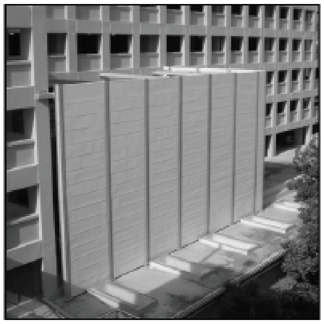
Érika Blackburn-Verreault (Saguenay-Lac St-Jean, Qc)

DIRECTORS' AWARDS / PRIX DES DIRECTEURS

Non-student / Non-étudiant:
Alexander MacGillivray (JASCO)

Student / Étudiant:
Dugald Thompson (University of Victoria)

CONGRATULATIONS / FÉLICITATIONS



Canadian Acoustical Association

Minutes of the Board of Directors Meeting

Teleconference
November 9th, 2013

Present: Christian Giguère (chair), Jérémie Voix, Hugues Nélisse, Stan Dosso, Dalila Giusti, Chantal Laroche, Roberto Racca, Kathy Pichora-Fuller, Frank Russo, Bill Gastmeier

Regrets: Sean Pecknold, Bryan Gick, Clair Wakefield

The meeting was called to order at 10:07AM. Minutes of the previous Board of Directors' meeting on June 4th 2013 were approved with a minor correction to the Membership table. The 2nd column should have read "Paid 2013" instead of "Paid 2011" *(Moved by J. Voix, seconded by S. Dosso, carried).*

President's Report

Christian Giguère thanked everyone involved in various initiatives over the past six years, such as the online membership, online publication of Canadian Acoustics, the new website, and new awards. He is looking forward to supporting the Association in his new role as Past President. He welcomed Frank Russo as the new President-Elect, effective after the Board Meeting, and thanked him for his continued and accrued involvement in the CAA. He also expressed gratitude towards the exiting Past President Stan Dosso for many years of service with the Executive and as Convenor of the 2010 and 2012 AWC meetings. *(Approval of report moved by C. Laroche, Seconded by F. Russo, carried)*

Board members thanked Christian for his very valuable contribution as President of CAA for the last 6 years.

Secretary's Report

Chantal Laroche reported 452 active members, up by 31 from last year (See Table). Not included in the total are 61 ICA special members who received a 6-month free membership at ICA in Montreal (free internet access to Canadian Acoustics). Seeing that they did not have access to the June and September issues, due to a delay in production, it was suggested that these members only be solicited in January (after a special mail offer of the September issue) to renew their membership as regular paying members.

Category	**Paid 2013 (Nov. 2013)**	**Paid 2013 (June)**	**Change from 2012**
Member	292	290	+ 18
Emeritus	1	1	0
Student	81	78	+ 7
Sustaining subscriber	53	51	+ 6
Indirect subscribers			
- Canada	9	9	0
- USA	6	6	0
- International	5	5	0
Direct subscribers	5	5	0
ICA Special (free)	61*	-	-
Total	452	445	+ 31

*Not included in the total

There were no operating costs from June 1st to October 31st 2013, and the account balance totals $724.38. Board members discussed mailing costs for international and USA indirect subscribers. Chantal will inquire about supplemental costs for shipping Canadian Acoustics outside Canada and send the 11 members concerned a notice regarding these extra costs.

(Approval of report moved by F. Russo, Seconded by Roberto Racca, carried)

Treasurer's Report

The Treasurer, Dalila Giusti, submitted a report comparing proposed and actual budgets. CAA finances are in reasonably good standing. While the Banff 2012 Conference generated $21300 in revenue and the ISRA meeting (Toronto) generated a surplus of $6800, a possible deficit may be incurred at ICA 2013 (Montreal). Finally, $6650 was distributed in awards at the 2013 ICA/CAA Joint Conference.

Dalila noted that revenue from advertising fees was down in 2013. Frank will inquire with the Advertising coordinator, Clair Wakefield, about this issue and his role in collecting these fees. A proposal was brought forward to review the "CAA Operation Manual", particularly to better define Board member roles. No increase in dues is proposed for 2014.

(Approval of report moved by J. Voix, seconded by Bill Gastmeier, carried)

Editor's Report

Frank Russo provided an update on the delay for the June and September issues, which are now expected to be sent out on Nov. 20th (June issue) and on Dec. 4th (September issue). The December issue is scheduled for Dec. 20th. Paper acceptance rate is about 2/3. Transition in the role of editor, from Frank Russo to Jérémie Voix, should be completed by March 2014.

After discussion, a motion was put forward to approve the EBSCO licensing agreement, and the Author's declarations and new copyright clauses for publishing in Canadian Acoustics *(Moved by F. Russo, Seconded by C. Laroche, carried)*

Christian Giguère and Roberto Racca will ask a lawyer to review the final version of the copyright clauses, before translation into French. Frank Russo and Chantal Laroche (or Dalila Giusti) will sign the final licensing agreement, which will be sent to EBSCO for approval. Christian will ensure adequate follow-up.

CAA Conferences – Past, Present & Future

2013 (Montreal, ICA 2013): This meeting is deemed to be the 3rd largest meeting ever held in in Acoustics and it was a huge success on the technical front. However, the meeting may be heading towards a financial deficit. Audit results conducted on behalf of ASA are expected by spring 2014. Board members thanked Mike Stinson for his work in organizing such a large conference.

2013 (Toronto, ISRA 2013): The Board thanked John Bradley and John O'Keefe for their detailed report on the very successful ISRA meeting. The meeting generated $6800 in surplus for CAA.

2014 (Winnipeg): Karen Turner, in charge of local organization, is still gathering information on hotel venues. Ramani Ramakrishnan will act as the Technical chair. The Exhibitor coordinator is still to be decided, but we have a prospect. Academics in Speech from U. of Manitoba will also be approached to get involved in the meeting's organization as well as Patrick Oliver at Price. Jérémie Voix proposed using an online conference system and will send information to Christian Giguère for consideration.

2015: Halifax is still an option. Sean Pecknold informed Christian Giguère through email that he'll check with his organization. Roberto Racca could be of some assistance in conjunction with JASCO Applied Sciences office in Halifax.

2016: The wider Toronto area was proposed as the venue by Christian Giguère since many active CAA members could help organize the conference, and some have approaching him in this regard. Kathy Pichora-Fuller mentioned that the World Congress in Audiology will be held in Vancouver (Sept. 18-22, 2016) and suggested Vancouver as an alternative, with a one-day overlap in the two meetings to facilitate session sharing or back-to-back meetings.

Christian Giguère will follow-up on these meetings.

Awards

Hugues Nélisse presented a report summarizing decisions from all individual prize coordinators. Winners were announced at the joint ICA/ASA/CAA Awards Ceremony on June 5th. The Directors' awards have been selected and Dalila Giusti will send awardees their prize money. The John Bradley scholarship, announced at the ISRA meeting in Toronto, will be discussed at a later date by an adhoc committee (Christian Giguère, Kathy Pichora-Fuller, Hugues Nélisse (Chair), John O'Keefe and John Bradley) to better define the designation of this scholarship, which should reflect the interdisciplinary work of John Bradley. Clair Wakefield will replace Murray Hodgson as the new coordinator of the Eckel Student Prize in Noise Control.

Acoustical Standards Committee

Tim Kelsall, Chair of the Committee, was invited to present the Terms of reference of the CAA Technical Committee on Standards, which started its activities in 2010, and asked the Board to approve these and to post them on the CAA website. *(Moved by Bill Gastmeier, Seconded, Kathy Pichora-Fuller, carried)*

Tim Kelsall also presented the Copyright Assignment between the Canadian Standards Association (owner of certain copyrights in the literary work entitled Z107.10, Guide For The Use Of Acoustical Standards In Canada) and the Canadian Acoustical Association. This assignment will be signed by two members of the Executive Board *(Moved by Bill Gastmeier, Seconded by F. Russo, carried).*

Before posting the CAA Guide for the Use of Acoustical Standards in Canada on the CAA website, Board members want to review the final document for approval. Production of the French version was also discussed, but no resources are readily available at the moment. Given the highly technical nature of the document, the Board indicated that the Committee could explore producing a bilingual Guide where the core structure of the document would be in both languages but the technical content (e.g. standards' summaries) only in the language(s) where it is available. Christian will follow-up with Tim Kelsall.

CAA Website

Sean Pecknold sent his report and Christian Giguère updated the Board members. Changeover to the new Wordpress website seems to have been smooth. Similarly, updated website contents are fairly straightforward. 2013 Awards listings will be posted on the website by December. As the online journal migration to the CAA website server remains problematic, the Board indicated that a move to another webhosting provider can be evaluated.

New logo

A proposal was made for the graphic designer to prepare a letterhead version of the logo and to improve its resolution. Replacing the current logo text (Canadian Acoustical Association/Association canadienne d'acoustique) by CAA/ACA was also recommended. Frank Russo will follow-up on these issues.

Adjournment

Meeting adjourned at 1:10PM *(Moved by J. Voix, seconded by C. Laroche, carried)*

Come To Winnipeg
The Heart of the Continent

ACOUSTICS WEEK IN CANADA

October 8-10, 2014

Canadian Museum For Human Rights, and the Riel Esplanade, with downtown Winnipeg beyond.
Photo by Dan Harper, Courtesy of Tourism Winnipeg

For the first time, Acoustics Week In Canada will be held in Winnipeg, Manitoba. This central location should make it easy for participants from all areas of the country to come together for 3 days of plenary lectures and technical sessions, along with the acoustical standards committee meeting, the exhibition of acoustical equipment and services, the Canadian Acoustical Association Annual General Meeting, the conference banquet and other special events. The conference will be held in the heart of Winnipeg, just off the famous corner of Portage and Main, surrounded by restaurants, theatres, and within easy walking distance of the spectacular new Canadian Museum of Human Rights, and The Forks recreation area, featuring more great shopping, restaurants, and activities. Conference participants can be among the first in Canada to view the new Canadian Museum Of Human Rights, which is scheduled to officially open in September 2014.

Venue & Accommodation – The conference will be held at **The Fairmont**, Winnipeg's premiere hotel. It features recently re-furbished comfortable rooms, and an excellent exercise facility, including a large salt-water pool, steam room, and luxury spa, all with excellent city views (http://www.fairmont.com/winnipeg/). The Velvet Glove restaurant is routinely rated as one of Canada's finest, and features inspired Manitoba sourced cuisine, and a unique wine list. A block of rooms is available until September 8, 2014 at the special rate of $149.00 per night, and a limited number of rooms will be available for students at $119.00. **Call 1-800-257-7744 to reserve your room before the deadline, and please be sure to specify that you are with the "Canadian Acoustical Association".**

Assiniboine River Walk
Photo by Ruehle Design, Courtesy Tourism Winnipeg

The Fork
Photo by Dan Harper, Courtesy Tourism Winnipeg

Plenary Lectures/Technical Sessions – There will be several plenary lectures slated covering current acoustical topics, and highlighting regional expertise and situations. Technical sessions will cover all major areas of acoustic interest, including Hearing Loss Prevention, Acoustical Standards, Architectural Acoustics, Noise Control, Shock and Vibration, Hearing and Speech Sciences, Musical Acoustics, Underwater Acoustics and other topics. **If you would like to propose and/or organize a special session on a specific topic please contact the Technical Chair as soon as possible.**

Exhibition & Sponsorship – There will be an exhibition area for acoustical equipment, products, and services on Thursday October 9. If you or your company is interested in exhibiting, or if you would be interested in sponsoring a conference social event, technical session, coffee breaks, or student prizes, please contact the Exhibition Coordinator. The conference offers an excellent opportunity to showcase your company and products or services.

Student Participation – Students are enthusiastically encouraged to attend the conference. Travel subsidies and reduced registration fees will be available, along with the special $119.00 hotel rate. Student presenters are eligible to win prizes for best presentations.

Paper Submissions – The abstract deadline is June 15, 2014. Two-page summaries for publication in the proceedings of Canadian Acoustics are due by August 1, 2014. Please see further details on the conference website.

Registration – Details will be available shortly at the conference website. Early registration at a reduced fee is available until September 8, 2014.

Contacts/Organizing Committee

Conference Chair: Karen Turner, Protec Hearing Inc.
Technical Chair: Ramani Ramakrihnan, Ryerson University

CONFERENCE WEBSITE AT: www.caa-aca.ca/meetings

Venez à Winnipeg!
Au cœur du continent

SEMAINE CANADIENNE D'ACOUSTIQUE

8 au 10 octobre 2014

Canadian Museum for Human Rights
Photo par Josel Catindoy, courtoisie de Tourism Winnipeg

Pour la toute première fois, la Semaine canadienne d'acoustique se tiendra à Winnipeg au Manitoba. Cette destination centrale facilitera la venue des participants de tous les coins du pays pour 3 jours de séances plénières et sessions scientifiques, ainsi que la rencontre du comité des normes en acoustique, l'exposition d'équipement et de services en acoustique, l'assemblée générale annuelle de l'Association canadienne d'acoustique, le banquet du congrès et autres événements spéciaux. Le congrès aura lieu au cœur même de Winnipeg tout près de la célèbre intersection Portage et Main, entourée de restaurants et théâtres, à une courte distance à pied du spectaculaire nouveau « Musée canadien des droits de l'homme » et du quartier « The Forks » avec plusieurs grands magasins, restaurants et une foule d'activités. Les participants au congrès seront parmi les premiers au Canada à voir le tout nouveau Musée canadien des droits de l'homme dont l'ouverture officielle est prévue pour septembre 2014.

Lieu du Congrès et Hébergement – Le congrès se tiendra à l'hôtel **Fairmont**, le meilleur hôtel de Winnipeg. Il dispose de chambres confortables récemment rénovées et d'un excellent centre de mise en forme, y compris une grande piscine d'eau salée, un sauna et un spa de luxe, le tout avec une vue imprenable sur la ville (http://www.fairmont.com/winnipeg/). Le restaurant Velvet Glove est régulièrement coté l'un des meilleurs au Canada et offre des plats inspirés de la cuisine du Manitoba et une carte de vins unique. Un bloc de chambres est offert au taux préférentiel de $149,00 par nuit avant le 8 septembre 2014. Un nombre limité de chambres seront disponibles pour les étudiants au taux de

$119,00. **Veuillez composer le 1-800-257-7744 pour réserver votre chambre avant la date limite. Il est important préciser que vous êtes avec l 'Association canadienne d'acoustique.**

Centre de mise en forme, Photos courtoisie de l'hôtel Fairmont Winnipeg

Séances plénières et sessions scientifiques – Plusieurs présentations plénières dans des domaines d'intérêt en acoustique sont prévues, mettant en évidence l'expertise et le cadre régional. Des sessions scientifiques seront organisées dans tous les domaines principaux de l'acoustique, incluant la prévention de la perte auditive, la normalisation, l'acoustique architecturale, le contrôle du bruit, les chocs et vibrations, les sciences de la parole et de l'audition, l'acoustique musicale, l'acoustique sous-marine et autres sujets. Si vous désirez suggérer ou organiser une session spéciale, veuillez communiquer avec le directeur scientifique le plus tôt possible.

Exposition technique et Commandite – Il y aura une exposition d'équipement, produits et services en acoustique le jeudi 9 octobre. Si vous ou votre entreprise êtes intéressés à réserver une table d'exposant ou commanditer des événements sociaux, des sessions scientifiques, des pauses café, ou des prix étudiants, veuillez communiquer avec le coordinateur de l'exposition technique. La conférence offre une excellente occasion de promouvoir votre compagnie, vos produits, ou vos services.

Participation étudiante – La participation étudiante est fortement encouragée. Des subventions de voyages et des frais d'inscription réduits seront offerts en plus d'un taux spécial de $119.00 pour la chambre d'hôtel. Des prix seront décernés pour les meilleures présentations étudiantes.

Soumissions de communications – La date d'échéance pour la soumission des résumés de présentation est le 15 juin 2014. Les articles de deux pages pour publication dans le numéro spécial des actes de congrès dans l'*Acoustique canadienne* sont dus le 1 août 2014. Plus de renseignements suivront sur le site internet du congrès.

Inscription – Les renseignements seront disponibles sous peu sur le site internet du congrès. L'inscription hâtive à taux réduit sera disponible jusqu'au 8 septembre 2014.

Personnes contacts/Comité organisateur

Président de congrès:	Karen Turner, Protec Hearing Inc.
Directeur scientifique:	Ramani Ramakrihnan, Ryerson University

SITE INTERNET DU CONGRÈS: www.caa-aca.ca/fr/meetings

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

Prize

Edgar and Millicent Shaw Postdoctoral Prize in Acoustics
Alexander G. Bell Graduate Student Prize in Speech Communication and Hearing
Eckel Graduate Student Prize in Noise Control
Fessenden Graduate Student Prize in Underwater Acoustics
Raymond Hetu Undergraduate Student Prize in Acoustics
Thomas D. Northwood Graduate Student Prize in Architectural and Room Acoustics
Albert S. Bregman Graduate Student Prize in Psychological Acoustics

Prix

Prix Post-doctoral Edgar et Millicent Shaw en Acoustique
Prix etudiant Alexander G. Bell en Communication orale et audition (2e ou 3e cycle)
Prix etudiant Eckel en Controle du bruit (2e ou 3e cycle)
Prix etudiant Fessenden en Acoustique sous-marine (2e ou 3e cycle)
Prix etudiant Raymond Hetu en Acoustique (1er cycle)
Prix etudiant Thomas D. Northwood en Acoustique Architecturale et Acoustique des Salles (2e ou 3e cycle)
Prix etudiant Albert S. Bregman en Psychoacoustique (2e ou 3e cycle)

Deadline for Applications:
April 30th 2014

Date limite de soumission des demandes:
30 Avril 2014

Consult CAA website for more information
Consultez le site Internet de l'ACA pour de plus amples renseignements
(http://www.caa-aca.ca)

President' Message
Message du Président

This address marks my first official correspondence as President of our Association. It is with considerable humility that I put together my reflections on the year just passed and the year ahead. I would like to thank Christian Giguère for over six years of outstanding service as President. Under his thoughtful leadership, the Association has continued to extend its reach and impact. Christian has cultivated a number of national and international initiatives that have helped to advance research, practice, and education in Acoustics. With 452 members we are 22% larger than we were when Christian started his term in 2007. Christian will continue to serve as Past-President, which will help immensely during this transition period. I also expect to rely heavily on the wisdom and experience of Chantal Laroche (Secretary) and Dalila Giusti (Treasurer).

This past year our Association co-sponsored the 21st International Congress on Acoustics (ICA) together with the Acoustical Society of America. The meeting was held in Montréal and chaired by Michael Stinson. It was an absolute success with respect to technical content as well as attendance, apparently the third largest Acoustics meeting on record. The Association also sponsored ISRA (International Symposium on Room Acoustics), a satellite meeting of ICA that was co-chaired by John Bradley and John O'Keefe. I hope to see many of you join us for Acoustics Week in Canada (AWC), held this year for the first time in Winnipeg! The meeting will take place between October 8th and 10th. Karen Turner will serve as conference chair and Ramani Ramakrishnan will serve as technical chair. A team consisting of

Cette adresse marque ma première correspondance officielle en tant que président de notre Association. C'est avec beaucoup d'humilité que j'ai rassemblé mes réflexions sur l'année passée et l'année à venir. Je tiens à remercier Christian Giguère pour un service exceptionnel en tant que président pendant plus de six ans. Sous son leadership réfléchi, l'Association a continué à élargir les frontières de son impact et de sa portée. Christian a mis sur pied un certain nombre d'initiatives nationales et internationales qui ont contribuées à l'avancement de la recherche, la pratique et l'éducation de l'acoustique. Comptant maintenant 452 membres, nous sommes 22% plus nombreux que nous l'étions lorsque Christian a commencé son mandat en 2007. Christian continuera à servir en tant qu'Ancien-Président, ce qui aidera énormément durant cette période de transition. Je prévois aussi prendre grande avantage de la sagesse et de l'expérience de Chantal Laroche (secrétaire) et Dalila Giusti (trésorier).

Cette dernière année, notre Association coparrainé avec la Acoustical Society of America le 21e International Congress of Acoustics (ICA). La réunion a eu lieu à Montréal et a été présidé par Michael Stinson. Ce fut un succès complet par rapport au contenu technique ainsi qu'à la participation, apparemment la troisième plus grande foule que l'on ait connue à une réunion sur l'Acoustique. L'Association a également parrainé l'ISRA (International Symposium on Room Acoustics), une réunion satellite de l'ICA qui a été co-présidée par John Bradley et John O'Keefe. J'espère que beaucoup d'entre vous vont se joindre à nous pour la Semaine canadienne d'acoustique, qui se tient cette année pour la première fois à

Christian Giguère, Ramani Ramakrishnan and Jérémie Voix, are working on the adoption of a system that will allow for automation of many conference management tasks (registration, abstract submissions, program & schedule, etc.).

The current issue of the journal marks the official transition to Jérémie Voix as Editor-in-Chief. Jérémie has recently completed a 6-year term on the Board of Directors and has been instrumental in shifting the journal content and membership administration online over the last few years. Jérémie will continue to advance the profile of the journal in consultation with the newly established Advisory Board, consisting of Bryan Gick, Ramani Ramakrishnan and myself.

Alberto Behar has replaced Jérémie on the Board of Directors. Many of you will be familiar with Alberto as a long-standing member of the Association and as a previous Board member.

In sum, the Association is in a good place with respect to its membership and its mandate. However, as a volunteer organization, we are always in need of helping hands. If you wish to get involved, there are several ways to do so and with varying levels of commitment. Please speak with me or another member of the Board of Directors if you think you might want to volunteer. Finally, as the outgoing Editor of Canadian Acoustics, it would be remiss of me to not encourage you to publish your work in our Association's journal. Canadian Acoustics is a peer-reviewed, open access, interdisciplinary journal providing rapid publication of research from all subfields of Acoustics.

Frank A. Russo
President

Winnipeg! La réunion aura lieu du 8 au 10 octobre. Karen Turner présidera la conférence et Ramani Ramakrishnan servira en tant que président technique. Une équipe composée de Christian Giguère, Ramani Ramakrishnan et Jérémie Voix s'efforce pour adopter un système qui permettra l'automatisation de nombreuses tâches de gestion de conférence (inscription, soumissions de résumés).

Le présent numéro de la revue marque la transition officielle du rôle de rédacteur en chef à Jérémie Voix. Jérémie a récemment terminé un mandat de 6 ans en tant que membre au conseil d'administration et au cours des dernières années a contribué à la transition du contenu de la revue et de l'administration d'adhésion en ligne. Jérémie continuera à promouvoir le profil de la revue en concertation avec le comité consultatif nouvellement créé, composé de Bryan Gick, Ramani Ramakrishnan et moi-même.

Alberto Behar a pris la place de Jérémie au conseil d'administration. Beaucoup d'entre vous seront familiers avec Alberto en tant que membre de longue date de l'Association et ancien membre du conseil.

En somme, l'Association est en bonne position par rapport à sa composition et son mandat. Cependant, comme organisation bénévole, nous sommes toujours en besoins d'aide de nos membres. Si vous êtes intéressé, il y existe plusieurs rôles bénévoles avec différents niveaux d'engagement. S'il vous plaît vous adresser à moi ou un autre membre du conseil d'administration si vous pensez vouloir vous impliquer en tant que bénévole. Enfin, comme éditeur sortant d'Acoustique Canadienne, il serait négligent de ma part de ne pas vous encourager à publier vos travaux dans la revue de notre association. Acoustique Canadienne est une revue interdisciplinaire à libre accès, soumis à l'évaluation par les pairs, offrant une publication rapide de la recherche de tous les sous-domaines de l'acoustique.

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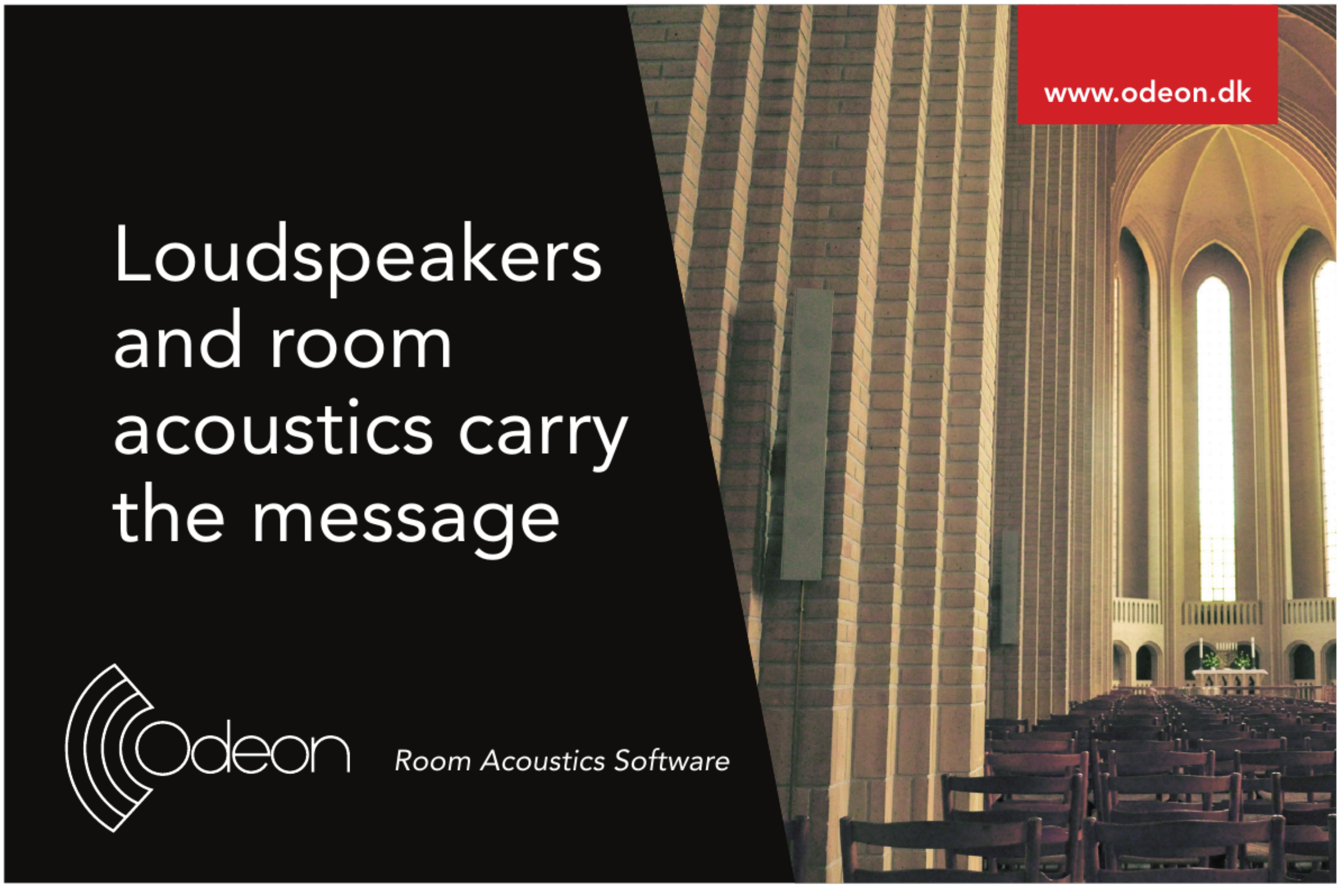
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Adel A. Abdou
Architectural Engineering Dept. P.O. Box 1917
Dharan 31261
SA
adel@kfupm.edu.sa

Dr. Sharon Mildred Abel
Defence Research & Development Canada
Individual Behaviour & Performance
Section 1133 Sheppard Ave West Toronto M3K
2C9
CA
sharon.abel@drdc-rddc.gc.ca
(416) 635-2037

Dr. Steve James Aiken
Dalhousie University
1256 Barrington St, PO Box 15000, Halifax, NS,
CANADA, B3J 4R2,
CA
steve.aiken@dal.ca
902-494-1057

Francis Allard
38 Dr Wilfrid Local N #5, J0K 3H0
CA
francis.allard@lesecransverts.ca

Jean-Luc Allard
2271 Fernand-Lafontaine Blvd., Longueuil,
QC, J4G 2R7
CA
jeanluc.allard@snclavalin.com
514-393-1000

Nadim Arafa
University of Ontario Institute of Technology
2000 Simcoe Street , L1H 7K4Oshawa, ON,
Canada
CA
nadim.arafa@uoit.ca
905 721 8668 ex: 3949

Andres Arciniegas
FR
arciniegas@lma.cnrs-mrs.fr

Marc Asselineau
10 B rue des Messageries Paris, F75010
FR
m.asselineau@peutz.fr
33-1-45230500

Noureddine Atalla
G.A.U.S., D, 2500 boul. Universit, Sherbrooke,
J1K 2R1
CA
Noureddine.Atalla@USherbrooke.ca

Melanie Austin
2305 - 4464 Markham Street, V8Z 7X8
CA
melanie@jasco.com

Meital Avivi
3359 Mississauga Road North, L5L 1C6
CA
meital.avivi@utoronto.ca

Mr. Frank Babic
AMEC
160 Traders Blvd. E., Suite 110 Mississauga,
ON L4Z 3K7
CA
frank.babic@amec.com
905.568.2929

Mr. Cédrik Bacon
1 Infinite Loop, MS26-AE, Cupertino, CA,
95014,
US
cedrik.bacon@ens.etsmtl.ca

Santiago Barreda
7614 110 st., , Edmonton, AB, T6G 1G1 CA
CA
sbarreda@ualberta.ca

Mr. Alberto Behar
Ryerson University
45 Meadowcliffe Dr. M1M 2X8
CA
albehar31@gmail.com
(416) 265-1816

. Beijing Publishing
Beijing Publishing
PO Box 830470, Birmingham, AL, 35283
US
indirectUSA1@caa-aca.ca

Mr. Elliott H. Berger
3M Personal Safety Division
7911 Zionsville Rd 46268
US
elliott.berger@mmm.com

Lucie Beriault
Centre de documentation, 1255, rue
Beauregard, Longueuil, J4K 2M3
CA
lucie.beriault.agence16@ssss.gouv.qc.ca

Chris Bibby
4208 7th ave SW, Calgary, T3C0E4,
CA
chrisbibby@gmail.com

Mark Bliss
BKL Consultants Ltd.
BKL Consultants Ltd., 308 - 1200 Lynn Valley
Road, North Vancouver, BC, V7J 2A2,
CA
bliss@bkl.ca
604-988-2508

Stephen Bly
Consumer & Clinical Radiation Protection,
775 Brookfield Rd., Room 317, A.L. 6301B,
Ottawa, K1A 1C1
CA
stephen.bly@hc-sc.gc.ca

Jacques Boilard
1260 boulevard Lebourgneuf, Bureau 250,
Québec, QC, G2K 2G2
CA
jacques.boilard@dessau.com
418-839-6034

Ian Bonsma
HGC Engineering
2000 Argentina Road, Plaza 1, Suite 203, L5N
1P7
CA
ibonsma@hgcengineering.com

Dr. Davide Borelli
University of Genova
davide.borelli@unige.it

. British Library
British Library
Acquisitions Unit (DSC-AO), Boston Spa,
Wetherby, LS23 7BQ
GB
indirectint1@caa-aca.ca

Félix Brochier
critias@etsmtl.ca

David W. Brown
Brown Strachan Assoc., Two Yaletown Sq.,
1290 Homer St., Vancouver, BC, V6B 2Y5
CA
bsa@brownstrachan.com

Robin Brown
Pinchin Environmental Ltd
2470 Milltower Court, Mississauga, ON, L5N
7W5
CA
rbrown@Pinchin.com

Ellen Buchan
Alberta Infrastructure, Technical Services
Branch, 3rd Floor, 6950-113 St, Edmonton, AB,
T6H 5V7
CA
ellen.buchan@gov.ab.ca

Claudio Bulfone
531 - 55A St. Delta, BC V4M 3M2
CA
cbulfone@gmail.com

Todd Busch
Todd Busch Consulting, #803-615 Belmont
Street, New Westminster, B.C. V3M 6A1,
CA
toddbusch@hotmail.com

Omar Alejandro Bustamante
ESIME IPN Mexico, ASA, IMA
MX
omarb.p@hotmail.com

Wil Byrick
1370 Don Mills Rd, Unit 300, Toronto, ON,
M3B 3N7
CA
wbyrick@pliteq.com
416-449-0049

. Canada Institute for STI
Serial Acquisitions, National Research
Council, Ottawa, ON, K1A 0S2
CA
indirectcan1@caa-aca.ca

Scott Carr
32 Troop Ave, Dartmouth, NS, B3B 1Z1
CA
scott@jasco.com
902-405-3336

Caroline Casey
100 Shaffer Road, , Santa Cruz, CA, 95060 US
US
cbcasey@ucsc.edu

Mandy Chan
HGC Engineering, 2000 Argentia Road, Plaza
1, Suite 203, Mississauga, ON, L5N 1P7 ,
CA
machan@hgcengineering.com

Brian Chapnik
HGC Engineering Ltd., 2000 Argentia Rd.,
Plaza One, Suite 203, Mississauga, ON, L5N
1P7
CA
bchapnik@hgcengineering.com

Tim Charlton
727 Tapscott Rd, Scarborough, ON, M1X 1A2
CA
tcharlton@vibro-acoustics.com
1-800-565-8401

Mark Cheng
Vancouver Airport Authority, PO Box 23750,
Airport Postal Outlet, Richmond, BC, V7B 1Y7
CA
mark_cheng@yvr.ca

Cheng-Hao Chiu
Totem Field Studio, 2613 West Mall,
Vancouver, BC,
CA
chenhao@alumni.ubc.ca

Ms Ina Chomyshyn
True Grit Consulting Ltd
1263 Innovation Drive, Thunder Bay, Ontario,
P7B 0A2,
CA
ina@tgcl.ca
807-626-5640

Stanley Christopher
31 Ready Crt., Brampton, ON, L6Y 4T4
CA
info@wccl.ca
905-595-1107

Wladyslaw Cichocki
University of New Brunswick
University of New Brunswick Dept. of French
Fredericton, NB E3B 5A3
CA
cicho@unb.ca
506-447-3236

Greg Clunis
907 Admiral Ave., Ottawa, ON, K1Z 6L6
CA
greg@integraldxengineering.ca
613-761-1565

John Coulter
1210 Sheppard Ave. E, Suite 211, Toronto, ON,
M2K 1E3
CA
jecoulter@jecoulterassoc.com
416-502-8598

Ann Cox
ARCADIS SENES Canada Inc.
121 Granton Drive, Unit 12 Richmond Hill,
ON L4B 3N4
CA
acox@senes.ca

. CSIC - Biblioteca
Ctro Tecnol Fisicas L Torres Quevedo, Serrano
144, 28006 MADRID
ES
indirectint2@caa-aca.ca

Lola Cuddy
Professor Emeritus, Queen’s University
Queen’s University Dept. of Psychology
Kingston, ON K7L 3N6
CA
Lola.Cuddy@queensu.ca

Peter D’Angela
2313 St-Clair, Windsor, ON, N9E 4S7
CA
dangelp@uwindsor.ca
519-890-3652

Nathalie Dabin
nathalie@jerevox.com

Tom Dakin
Ocean Networks Canada
2098 Skylark Lane Sydney, BC V8L 1Y4
CA
TDakin@UVic.ca
250-853-3541

Steve Davidson Davidson & Associés Inc.
12 Lafleur St. N St-Sauveur, QC J0R 1R0
CA
sdavidson@davidson-assoc.com

Peter Davis
FDI Acoustics, Suite 250, 600 Crowfoot
Crescent NW, Calgary, AB, T3G 0B4
CA
peterd@fdiacoustics.com

Jack Davis
6331 Travois Cres NW, Calgary, AB, T2K 3S8,
CA
davisjd@telus.net
403-275-6868

Prof. Bert De Coensel
Acoustics Group, Department of Information
Technology, Ghent University, Ghent, Belgium
Sint-Pietersnieuwstraat 41, B-9000 Ghent,
Belgium,
BE
bert.decoensel@intec.ugent.be

Henk de Haan
dBA Noise Consultants RR1, Site 14, Box 55
Okotoks, AB T1S 1A1
CA
dBAnoiseconsultants@gmail.com

Mr. Terry J. Deveau
Jasco Applied Sciences
3 Shore Road Herring Cove, NS B3V 1G6
CA
deveau@chebucto.ns.ca
902-479-3398

abhijit krishna dhamanekar
Indian Institute of Technology, Madras India
IN
abhikd11@gmail.com

Stan Dosso
University of Victoria
University of Victoria, School of Earth and
Ocean Sciences, P.O. Box 3055, Victoria, BC,
V8W 3P6
CA
sdosso@uvic.ca

Gregory Downey
greg@parklanemechanical.com
905-844-5020

Bertrand Dubus
Institut d'Electronique de Microelectronique
et de Nanotechnologie UMR8520 CNRS
IEMN dpt ISEN UMR8520, 41 boulevard
Vauban, 59046 Lille cedex,
FR
bertrand.dubus@isen.fr

Alex Dundon
AECOM
5600 Cancross Court, Suite A, Mississauga,
Ontario L5R 3E9
CA
alex.dundon@aecom.com

David Egan
Egan Acoustics
P.O. Box 365, Anderson, SC, 29622-0365,
US
eegan@clemson.edu
864-226-3832

Dale D. Ellis
18 Hugh Allen Drive, Dartmouth, NS B2W
2K8
CA
daledellis@gmail.com
902-464-9616

. Elsevier Science Engineering
Information, PO Box 2227, 1000 CE
Amsterdam
NL
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T2P 0R4
CA
indirectcan2@caa-aca.ca

Pascal Everton
HFP Acoustical Consultants
#1140, 10201 Southport Road S.W., Calgary,
AB, T2W 4X9
CA
pascal.everton@hfpacoustical.com

James Farquharson
FDI Acoustics, Suite 250, 600 Crowfoot
Crescent NW, Calgary, AB, T3G 0B4
CA
jamesf@fdiacoustics.com

Andrew Faszer
Noise Solutions Inc., 210 N Franklin Atrium,
3015 - 5th Ave NE, Calgary AB , T2A 6T8
CA
andrew.faszer@ualberta.net

Clifford Faszer
FFA Consultants in Acoustics & Noise
Control Suite 210 3015 - 5th Avenue N.E.
Calgary, AB T2A 6T8
CA
cfaszer@ffaacoustics.com

Clifford Faszer
Suite 210N, 3015-5th Ave NE Calgary, AB T2A
6T8 T2A 6T8
CA
info@ffaacoustics.com
403.508.4996

Tom Fedenczuk
Dept. of Ocean Resources Engineering
University of Hawaii, 2540 Dole Street,
Holmes Hall 402, Honolulu, Honolulu, HI,
96822 US
US
tmf@hawaii.edu

Shaye Folk-Blagbrough
#416, 3600 Windcrest Drive, North Vancouver,
BC, V7G 2S5
CA
Shaye_Folk-Blagbrough@yvr.ca

Harold Forester
1434 Franklin, Laval, QC H7W 1K6
CA
hforester@outlook.com
450-681-2333

Claude R. Fortier
State of the Art Acoustik Inc, Suite 43, 1010
Polytek St., Ottawa, ON, K1J 9J3
CA
cfortier@sota.ca
613-745-2003

Mr. Joshua Richard Foster
Gradient Microclimate Engineering
127 Walgreen, Road, Ottawa, K0A 1L0,
CA
joshua@gradientwind.com
613-836-0934

Roger Foulds
9 Doble St., PO Box 388, Sunderland, ON, L0C
1H0
CA
roger@soundtrap.ca
705-357-1067

Leslie Frank
HFP Acoustical Consultants Corp., 1140, 10201 Southport Rd. SW, Calgary, AB, T2W 4X9
CA
les.frank@hfpacoustical.com

Reinhart Frosch
ETH and PSI (retired)
Sommerhaldenstrasse 5B CH-5200 Brugg,
CH
reinifrosch@bluewin.ch

Ron Galloway
70 Frid Street, Suite 1 Hamilton, ON L8P 4M4
CA
ron.galloway@armtec.com
289-975-4404

Bill Gastmeier
HGC Engineering
12 Roslin Ave S., Waterloo, ON, N2L 2G5
CA
gastmeier@rogers.com

Dale Gaston
AIL Sound Wall Division, 640 Waydom Drive, Ayr, ON, N0B 1E0
CA
dgaston@ail.ca

Paul J. Gendron
pgendron@umassd.edu

Behrou Ghazizadeh
364 Lawrence Ave. W., Toronto, ON, M5M 1B7
CA
behrou@vendatech.com
416-787-8797

Prof. Bryan Gick
University of British Columbia
CA
gick@mail.ubc.ca

Mr. Mr. Hazem Gidamy
M.Eng. P.Eng.
S.S. Wilson & Assoc. 15 Wertheim Court, Suite 211 Richmond Hill, ON L4B 3H7
CA
admin@sswilsonassociates.com
905-707-5800

Prof. Christian Giguère
University of Ottawa
Audiology/SLP Program, 451 Smyth Road, Ottawa, Ontario, K1H8M5,
CA
cgiguere@uottawa.ca
(613) 562-5800 x4649

Ms. Dalila Giusti
Jade Acoustics Inc.
411 Confederation Parkway Unit 19 Concord, Ontario, L4K 0A8
CA
dalila@jadeacoustics.com
905-660-2444

Isidor Gliener
Acoustic Solutions Ltd., 11602-119 Street, Edmonton, AB, T5G 2X7
CA
izzy@acousticsolutions.com

Blaise Gosselin
2, Complexe Desjardins, Tour de l'est - 10th floor, Montréal, QC, H5B 1H7
CA
gosselin.blaise@hydro.qc.ca
514-879-4100 xx5309

Huiwen Goy
University of Toronto
University of Toronto Mississauga, Dept. of Psychology, DV2037, 3359 Mississauga Road North Mississauga, ON L5L 1C6,
CA
huiwen.goy@utoronto.ca
905-569-4634

Catherine Grant
Gradient Microclimate Engineering Inc., 127 Walgreen Road , Ottawa, ON K0A 1L0
Gradient Microclimate Engineering Inc., 127 Walgreen Road, Ottawa, ON, K0A 1L0
CA
kate@gradientwind.com

Dr. Anant Grewal
National Research Council
National Research Council, 1200 Montreal Road, Ottawa, Ontario, K1A-0R6,
CA
anant.grewal@nrc-cnrc.gc.ca
(613) 991-5465

Ariel Groisman
ariel.groisman@gmail.com

Manfred Grote
ARCOS Acoustical Consulting Ltd.
2828 Toronto Cres. N.W., Calgary, AB, T2N 3W2
CA
arcosacoustic@shaw.ca
403-283-1191

J. Michel Guevremont
Specmont Inc., 625 Rue du Parc-industriel, Longueuil, QC, J4H 3V7
CA
specmont@specmont.com

Mr. Kaveh Habibi
McGill University
CA
kaveh.habibi@mail.mcgill.ca
514 663 6000

Peter Hanes
National Research Council Bldg M-36 Ottawa, ON K1A 0R6
CA
ph3238@yahoo.ca

. Harriet Irving Library
University of New Brunswick, PO Box 7500, Fredericton, NB, E3B 5H5
CA
indirectcan3@caa-aca.ca

Robert Harrison
Hospital for Sick Children, Toronto
Department Otolaryngology - HNS, The Hospital for Sick Children, 555 University Ave, Toronto, ON, M5G 1X8
CA
rvh@sickkids.ca
(416) 813-6535

Gillian Hatcher
Stantec Consulting Ltd
40 Highfield Park Drive,, Dartmouth, NS, B3A 0A3,
CA
gillian.hatcher@stantec.com
902-468-7777

Garry J. Heard
Defence R&D Canada Atlantic Research Centre
Defence R&D Canada, Atlantic Research Centre , PO Box 1012, Dartmouth, NS B2Y 3Z7,
CA
garry.heard@drdc-rddc.gc.ca
902-426-3100 x310

Bernard Hétu
1690 Grand Trunk Montréal, QC H3K 1L7
CA
bernardhetu@videotron.ca

Andrew Elmer Heuer
1650 Military Road, Buffalo, NY, 14217 ,
US
aeheuer@ngctestingservices.com
716-873-9750 ext 253

shizuo hiki+Waseda University, Japan
5246 Yamaguch #90-1-402i, Tokorozawa,
359-1145 Japan,
hiki@waseda.jp
81 4 2923-2917

Matt Hildebrand
Wenger Corporation
Wenger Corporation 555 Park Drive PO Box
448 Owatonna, MN 55060
US
matt.hildebrand@wengercorp.com
507-774-8716

James Hill
AAF Ltd
james.hill@aafgb.com

Dr. Megan Hodge
University of Alberta, Speech Pathology &
Audiology, Rm 2-70 Corbett Hall, Edmonton,
AB, T6G 2G4
CA
megan.hodge@ualberta.ca

Dr. David Holger
Noise Control Engineering Journal, Iowa State
University, College of Engineering, 104
Marston Hall, Ames, IO, 50011-2151
US
holger@iastate.edu

Joe Hood
Akoostix Inc.
Akoostix Inc. Suite 12, 10 Akerley Blvd
Dartmouth, NS B3B 1J4
CA
jhood@akoostix.com
(902) 404-7464

Mr. Brian Howe
HGC Engineering Ltd., Plaza One, Suite 203,
2000 Argentia Rd., Mississauga, ON, L5N 1P7 ,
CA
bhowe@hgcengineering.com

Daniel Hutt
Defence R&D Canada Atlantic
DRDC Atlantic P.O. Box 1012 Dartmouth, NS
B2Y 3Z7
CA
daniel.hutt@drdc-rddc.gc.ca

Khalil Iskarous
University of Southern California
kiskaro@gmail.com

Prof. Nickolay I. Ivanov
Baltic State Technical University, P.O. Box
08A9, 1st Krasnoarmeyskaya St., 1, St.
Petersberg, , 198008 Russia
RU
noise@mail.rcom.ru

Gurpreet Janjua
Six Hills Way, STEVENAGE, SG1 2AY
GB
indirectint4@caa-aca.ca

Yong Min Jiang
NATO Science and Technology Organization -,
Centre for Maritime Research and
Experimentation (STO-CMRE)
Viale S. Bartolomeo, 40019126 La Spezia
IT
jiang@cmre.nato.int

. John Hopkins University
Serials / Acquisitions - 001ACF5829, Milton S.
Eisenhower LibraryBaltimore, MD, 21218
US
indirectusa2@caa-aca.ca

Allison Johnson
University of Wisconsin-Madison
trickyallie@gmail.com

Sarah Kaddatz
gr8address@hotmail.com

Bill Kapralos
University of Ontario Institute of Technology
2000 Simcoe Street North, Oshawa, Ontario,
Canada, L1H 7K4,
bill.kapralos@uoit.ca
905-721-8668 x2882

Dr Stephen E. Keith+Health Canada
Radiation Protection Bureau, Health
Acoustics, Non-ionizing Radiation Section Rm
228, 775 Brookfield Rd., 6301B Ottawa, ON
K1A 1C1
CA
stephen_keith@hc-sc.gc.ca
1 613 941-8942

Tim Kelsall
Hatch
2800 Speakman Dr. , Mississauga, ON, L5K
2R7
CA
tkelsall@hatch.ca
905-403-3932

Ms. Kathryn Joanne Kennedy Katsiroumpas
None
17 Linnsmore Crescent, Toronto, Ontario, M4J
4J8,
CA
kkatsiroumpas@hotmail.com
4164660625

Andrew Khoury
6600 Trans Highway, Suite 511, Pointe-Claire,
QC, H9R 4S2
CA
andrew.khoury@bksv.com
514-695-8225

Frances King
National Research Council , IRC, Acoustics,
M-27, Ottawa, ON, K1A 0R6
CA
frances.king@nrc-cnrc.gc.ca

Ezequiel Kinigsberg
Universidad Nacional de Tres de Febrero
AR
ekinig@gmail.com

Sonja Kromann
NOAA National Marine Mammal Lab Library
NOAA National Marine Mammal Lab Library,
NMFS AFSC, 7600 Sand Point Way NE Bld 4,
Seattle, WA, 98115-6349
Sonja.Kromann@noaa.gov

Tatiana Kryuchkova
4-32 Assiniboia Hall, University of Alberta,
Edmonton, AB, T6G 2E7 CA
CA
tatiana.kryuchkova@ualberta.ca

André L'Espérance
1040, avenue Belvédère, suite 215, Sillery, QC, G1S 3G3
CA
contact@softdb.com
418-686-0993

Josée Lagacé
University of Ottawa
451 Smyth Rd Room 3053, Roger Guindon Hall Univeristy of Ottawa Ottawa, ON K1H 8M5
CA
josee.lagace@uottawa.ca
613-562-5800

Professor Joseph Lai
University of New South Wales, Canberra, AU
j.lai@adfa.edu.au

Sylvain Lalonde
Acoustifab Inc., 677 de la Sabliere,
Bois-des-Filion, QC, J6Z 4T8
CA
info@acoustifab.com

Natalia Lapinskaya
292 Dupont St, PO box 40077 Dupont PO, Toronto,, Ontario
CA
natalia.lapinskaya@utoronto.ca

Jean Laporte
c.p.52-523, 324 rue Castelneau, Montréal, QC, H2R 1P0
CA
jlaporte@acoustikalab.com
514-692-1147

Dr. Chantal Laroche
Programme d'audiologie et d'orthophonie, École des Sciences de la réadaptation, Faculté des Sciences de la santé, Université d'Ottawa, 451 Chemin Smyth Ottawa, ON, K1H 8M5
CA
claroche@uottawa.ca

Daniel Larose
193 Joseph Carrier, Vaudreuil-Dorion, QC, J7V 5V5
CA
daniel@dalimar.ca
514-424-0033

Cécile Le Cocq
334 4ème Ave Lasalle, QC H8P 2J6
CA
copyeditor@caa-aca.ca

. Learning Res. Center
A T Still Univ Hlth SCI5850 E Still Circ, Mesa, AZ, 85206-3618
US
indirectusa3@caa-aca.ca

Buddy Ledger
5248 Cedar Springs Road, Burlington, Ontario L7P 0B9,
CA
buddyledger@gmail.com

Noland Lewis
2604 Read Ave., Belmont, CA, 94002
US
acopac@acopacific.com
650-595-8588

Al Lightstone
30 Wertheim Court, Unit 25, Richmond Hill, ON, L4B 1B9
CA
solutions@valcoustics.com
905-764-5223

Serials Department Linda Hall Library
5109 Cherry Street, Kansas City, MO, 64110
US
direct1@caa-aca.ca

Lisa Liskovoi
Ryerson University
lisa.liskovoi@psych.ryerson.ca

Banda Logawa
University of British Columbia
216-7052 Linden Avenue, Burnaby BC V5E 3G6
CA
logawa_b@yahoo.com

Enrique Alejandro Lopez-Poveda+University of Salamanca
Instituto de Neurociencias de Castilla y Leon, Universidad de Salamanca, Calle Pintor Fernando Gallego 1, 37007 Salamanca, Spain,
ES
ealopezpoveda@usal.es
34923294500

Tristan Loria
11 Kendal Ave, Toronto, ON, M5R 1L5 ,
CA
smpc2013@psych.ryerson.ca

Alexander P. Lorimer
HGC Engineering Ltd., Plaza One, Suite 203, 2000 Argentia Rd., Mississauga, ON, L5N 1P7 ,
CA
alorimer@hgcengineering.com

Huancai Lu
huancai.lu@gmail.com

Henry Luo
Unitron Hearing
20 Basely Drive, Kitchener, ON, N2G 4X1
CA
henry.luo@unitron.com

Boy Raymond Mabuza+Department of NDT and Physics, Vaal University of Technology, Private Bag X021, Vanderbijlpark, 1900
Department of NDT and PhysicsVaal University of TechnologyPrivate Bag X021Vanderbijlpark1900
ZA
raymondm@vut.ac.za
27836304708

Ewen MacDonald
Hearing Systems Group,, Dept. of Electrical Engineering,, Technical University of Denmark
Orsteds Plads, Building 352, Hearing Systems Group, Elektro, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark,
emcd@elektro.dtu.dk

Roderick Mackenzie
SoftdB
1240 Beaumont Avenue, Suite 206, Montreal, QC, H3P 3E5
CA
r.mackenzie@softdb.com

Ewan Andrew Macpherson
Western University
Western University, 1201 Western Rd, Elborn
College Room 2262, London, ON N6G 1H1,
CA
ewan.macpherson@nca.uwo.ca
519-661-2111 x88072

John Peter Manning
l'Université de Sherbrooke
5983 6th Line RR1, Egbert, ON, L0L 1N0,
CA
John.Peter.Manning@usherbrooke.ca

Pierre Marcotte
IRSST
IRSST 505, boul. de Maisonneuve Ouest
Montreal, QC H3A 3C2,
CA
marcotte.pierre@irsst.qc.ca

William Leigh Martens
University of Sydney
Wilkinson Building G04, University of Sydney
2006 NSW, Australia,
AU
william.martens@sydney.edu.au
61291140865

Mr. Nigel Maybee
HFP Acoustical Consultants Corp., 1140, 10201
Southport Rd. SW, Calgary, AB, T2W 4X9
CA
nigel.maybee@hfpacoustical.com

Wade McGregor
323 - 901 West 3rd St, North Vancouver, BC,
V7P 3P9
CA
info@mcsquared.com
604-986-8181

Steve Meszaros
4567 Valley Road, North Vancouver, BC, V7K
2M1,
CA
steve_meszaros@hotmail.com

J.G. Migneron
90 rue Poirier, Saint-Nicolas (Lévis), QC, G7A
2W1
CA
courrier@acoustec.qc.ca
418-834-1414

Denise Mallette
IRSST
I.R.S.S.T. - Informathèque 11e étage 505 boul
de Maisonneuve O Montréal, QC H3A 3C2
CA
mallette.denise@irsst.qc.ca
514-288-1551

Hossein Mansour
#92-3465 Ch. Cote Des Neiges, Montreal, QC,
H3H 1T7
CA
hossein.mansour@mail.mcgill.ca

Steve Marshall
Scantek, Inc.
Scantek, Inc.6430 Dobbin Road, Suite
CColumbia, MD 21045,
US
S.Marshall@scantekinc.com
1-410-290-7726

John Martyn
Right to Quiet Society, 359 - 1985 Wallace
Street, Vancouver, BC, V6R 4H4
CA
info@quiet.org

Nick McCabe
HGC Engineering, 2000 Argentia Road Plaza 1
Suite 2003, Mississuaga, ON, L5N 1P7
CA
nmccabe@hgcengineering.com

. MDDEP
Dir politique de la qualite de l'atmosphere,
675 Rene-Levesque Est 5E-B30, Québec, QC,
G1R 5V7
CA
indirectcan4@caa-aca.ca

Mr. Andy Metelka
SVS Canada Inc.
RR 2 13652 Fourth Line Acton, ON L7J 2L8
CA
ametelka@cogeco.ca
519-853-4495

. Ministère des transports
Centre Documentation, 930 Ch Ste-Foy, 6e
étage, Québec, QC, G1S 4X9
CA
indirectcan5@caa-aca.ca

AProf Richard Manasseh
AU
rmanasseh@swin.edu.au

Jacob T. Maracle
#3 Navy Wharf Court. - Unit 317 Toronto,
Ontario M5V 3V1
CA
jacob.maracle@utoronto.ca

Christian Martel
Octave Acoustique Inc., 963, chemin Royal,
Saint-Laurent-de-l'Ile-d'Orleans, QC, G0A 3Z0
CA
octave@videotron.ca

Eric Matheson-Jones
9628 Austin O'Brien Road NW Edmonton, AB
T6B 2C2
CA
mathesonjones@gmail.com

Stephen McCann
597 Homewood Avenue, Peterborough,
Ontario K9H2N4
CA
stephen.mccann@cambium-env.com

Mr. T. Medwedyk
Group One Acoustics Inc., 1538 Sherway Dr.,
Mississauga, ON, L4X 1C4
CA
goainc@bellnet.ca

M. Jean-Philippe Migneron
Université Laval
1393-204, rue des Tourterelles St-Romuald, QC
G6W 8J3
CA
jean-philippe.migneron.1@ulaval.ca
418-906-0333

Takashi Mitsuya
University of Western Ontario
National Centre for
AudiologyCommunication Sciences and
DisordersElborn College, Room
1207University of Western
OntarioLondon, OntarioCanada N6G 1H1
CA
tmitsuya@uwo.ca

Parnia Lotbi Moghaddam
100 Commerce Valley Drive West, Thornhill, ON, L3T 0A1
CA
lotfimoghaddamp@mmm.ca

Scott Reid Moisik
University of Victoria
srmoisik@uvic.ca

Joaquin E. Moran
Hatch Ltd., 4342 Queen St,, Suite 500, Niagara Falls, ON, L2E 7J7
CA
jmoran@hatch.ca

Michel Morin
6555 Cote des Neiges, Suite 440 Montréal, QC H3S 2A6
CA
mmorin@mjm.qc.ca
514-737-9811

Dr Geoffrey Stewart Morrison
University of Alberta, University of New South Wales
803-4438 West 10th Avenue, Vancouver BC V6R 4R8
CA
geoff-morrison@forensic-evaluation.net
604 637 0896

Flora Nassrallah
University of Ottawa
1691 Fieldstone CrescentOttawa, OntarioK1C1R6,
CA
fnass039@uottawa.ca

. National Library of Science and technology
TIB und Universitaetsbibliothek Hannover, DE/5100/G1/0001, ZO 1935, Welfengarten 1 B, 30167 HANNOVER
DE
indirectint5@caa-aca.ca

Hugues Nelisse
IRSST 505 Boul de Maissonneuve Ouest Montréal, QC H3A 3C2
CA
nelisse.hugues@irsst.qc.ca

Gabe Nespoli
Ryerson University
gabe@psych.ryerson.ca

David Nicholson
920 Hamel Road, PO Box 253 Hamel, MN 55340
US
dave@maxxon.com
763-478-9626

Zahra Nili Ahmadabadi
425, rue de la Montagne, apartment no. 4152, Montreal, Quebec , Canada. Postal code: H3C 0J9
CA
ak09890@ens.etsmtl.ca

. NOAA National Marine Mammal Lab Library
NMFS AFSC, 7600 Sand Point Way NE Bld 4, Seattle, WA, 98115-6349
US
indirectusa4@caa-aca.ca

Blake Noon
77 Columbia Ave, Long Sault, ON, K0C 1P0
CA
blake@acousticproductsales.com

. Northern Illinois University
Periodicals Dept., University Libraries, 1425 West Lincoln Highway, DeKalb, IL, 60115-2868
US
indirectusa5@caa-aca.ca

Dr. Colin Novak
University of Windsor
515 Riverside Dr. West, Unit #1103 Windsor, ON N9A 7C3
CA
novak1@uwindsor.ca
519-253-3000 x2634

John O'Keefe
50 Ronson Drive, Suite 165, Toronto, ON, M9W 1B3
CA
johno@aercoustics.com

Patrick Oliver
EH Price Ltd., 638 Raleigh St, Winnipeg, MB, R2K 3Z9
CA
patricko@price-hvac.com

Guy W Oliver
University of California, Santa Cruz
233 Northrop Place , Santa Cruz, CA 95060, USA,
US
guywoliver@gmail.com
8314584121

Donald Olynyk
Acoustical Consultant
9224-90 Street Edmonton, AB T6C 3M1
CA
don.olynyk@shaw.ca
7804654125

Mr. Kevin Packer
FFA Consultants in Acoustics & Noise Control Ltd.
2811 Conrad Dr. NW, Calgary, AB, T2L 1B3,
CA
kpacker@ffaacoustics.com
403-922-0577

Richard Palczynski
EnviroChem Engineering Consultants, 2 Alline Street, Wolfville, NS, B4P 1J4
CA
ece@istar.ca

Michel Parent
FDI Acoustics, Suite 250, 600 Crowfoot Crescent NW, Calgary, AB, T3G 0B4
CA
mitchp@fdiacoustics.com

Richard Patching
Patching Associates Acoustical Eng. 9, 4825 Westwinds Dr. NE Calgary, AB T3J 4L4
CA
richard@patchingassociates.com

Sean Pecknold
DRDC
DRDC Atlantic, 9 Grove St., PO Box 1012, Dartmouth, NS, B2Y 3Z7
CA
sean.pecknold@drdc-rddc.gc.ca

Mme Anik Pelletier
Université de Sherbrooke
CA
workpelletier@me.com

Richard Joseph Peppin
Engineers for Change, Inc.
5012 Macon Rd, Rockville, MD 20852,
US
peppinR@asme.org
301-984-3375

Aaron Peterson
Brown Strachan Associates
Two Yaletown Square, 1290 Homer Street,
Vancouver, BC, V6B 2Y5
CA
bsadrafts@hotmail.com
(604) 689-0514

Prof. Kathleen Pichora Fuller
University of Toronto
Dept. of Psychology University of Toronto
3359 Mississauga Rd. N. Mississauga, ON L5L
1C6
CA
k.pichora.fuller@utoronto.ca
(905) 828-3865

Dr. Ciprian Pirvu
FPInnovations
2665 East Mall Vancouver, BC V6T 1W5
CA
ciprian.pirvu@fpinnovations.ca

Howard Podolsky
121 Sunset Rd., Mamaroneck, NY, 10543
US
info@pyrok.com
914-777-7770

Linda Polka
McGill University
McGill University Sch of Communication
Sciences & Disorders 1266 Pine Ave. West
Montréal, QC H3G 1A8
CA
linda.polka@mcgill.ca
514-398-7235

Vincent Porretta
9717 111 St, #407, Edmonton, AB, T5K 2M6 CA
CA
porretta@ualberta.ca

Gopu Potty
US
potty@egr.uri.edu

Daniel P. Prusinowski
Aurora Acoustical Consultants Inc., 745
Warren Drive, East Aurora, NY 14052, USA
Daniel P. Prusinowski, 745 Warren Drive, East
Aurora, NY 14052, USA,
US
dprusinowski@verizon.net
1-716-655-2200

Dr. John David Quirt
Consultant
1949 Mulberry Crescent, Ottawa, ON, K1J 8J8,
CA
jdq.acoustics@bell.net
613-745-2793

Roberto Racca
JASCO Applied Sciences
JASCO Applied Sciences Ltd. 2305 - 4464
Markham Street Victoria, BC V8Z 7X8,
CA
roberto.racca@jasco.com

Prof. Ramani Ramakrishnan
Ryerson University
27 Ashmount Crescent, Toronto, ON, pcode,
M9R 1C8
CA
rramakri@ryerson.ca

Allan Raun
Swallow Acoustic Consultants Ltd
Swallow Acoustic Consultants, 23 - 366 Revus
Ave. Mississuaga,, ON, L5G 4S5,
CA
araun@swallowacoustic.ca
905-271-7888

Zohreh Razavi
1100 - 111 Dunsmuir St, Vancouver, BC, V6B
6A3
CA
zohreh.razavi@stantec.com
604-606-8472

Erwin Rebke
Alberta Infrastructure, 3rd Floor 6950-113
Street NW, Edmonton, AB, T6H 5V7
CA
erwin.rebke@gov.ab.ca

Rebecca Reich
rreich@media.mit.edu

María Vanesa Reyes
Piedras 1980 7 A, , Ciudad Autónoma de
Buenos Aires, –, C1140ABP AR
AR
vanesa.reyes@cethus.org

Werner Richarz
Echologics Engineering 6295 Northam Drive,
Unit 1 Mississauga, ON L4V 1W8
CA
wricharz@echologics.com

. Robertson Library
University of PEI, 550 University Ave,
Charlottetown, PE, C1A 4P3
CA
indirectcan6@caa-aca.ca

Joana Rocha
Carleton University
234 Guigues Avenue, Apt. 504, Ottawa, ON,
K1N 5J2, ,
CA
joana.rocha@carleton.ca

Thomas Rossing
rossing@ccrma.stanford.edu

Pr. Jean Rouat
Université de Sherbrooke Département de
GEGI 2500, boul. de l'université Sherbrooke,
QC J1K 2R1
CA
jean.rouat@usherbrooke.ca
819-821-8000 x 63864

Jessie Roy
RWDI Air Inc.
1000, 736-8th Avenue S.W., Calgary, AB, T2P
1H4
CA
jessie.roy@rwdi.com
403-232-6771 6248

. Ryerson University Library
LIB-551, 350 Victoria Street, Toronto, ON, M5B 2K3
CA
indirectcan7@caa-aca.ca

Somana Sahadev
103 Rotary Drive, Scarborough, ON, M1B 2J4
sahadev.somana@gmail.com
(416)273-8221

Mehrzad Salkhordeh
1670 Bishop Street North, , Cambridge, Ontario , N1R 7J3
CA
msalkhordeh@kineticsnoise.com
905-670-4922

Lakshmanan Sannachi
Department of Radiation Oncology and Medical Biophysics, University of Toronto
CA
laksmanan@gmail.com

Amin Saremi
Linköping University, Technical Audiology, Linköping, –, 581 85 SE
SE
amin.saremi@liu.se

M. Claude Sauvageau
Centre de recherche industrielle du Québec
1201 boul. Crémazie est Bureau 1.210
Montréal, QC H2M OA6
CA
claude.sauvageau@criq.qc.ca
514-383-1550

Katrina Scherebnyj
14920 25A Avenue, Surrey, BC, V4P 1N7, Canada,
kscherebnyj@gmail.com

Isabelle Schmich-Yamane
isabelle.schmich@cstb.fr

Mark Schmidt
mark.schmidt@unitron.com

Stefan Schoenwald
Swiss Federal Laboratories for Materials Science and Technology
Überlandstrasse 129 , CH-8600 Dübendorf, Switzerland
CA
stefan.schoenwald@empa.ch
41 58 765 6579

Barbara Schustrich
2285 East Enterprise Parkway, Twinsburg, OH, 44087
US
sales@gras.us
330-425-1201

Dr. Mark Andrew Scott
Memorial University, Kobe Shoin University
shark_scott@hotmail.com

Franck Sgard
IRSST, 505, boul. de Maisonneuve Ouest, Montreal, QC, H3A 3C2
CA
franck.sgard@irsst.qc.ca

Cameron W. Sherry
1128 route 203, Howick, QC, J0S 1G0
CA
cameronsherry4@gmail.com

Caroline Sigouin
Université du Québec à Chicoutimi
caroline.sigouin@uqac.ca

Davor Sikic
Jade Acoustics Inc. 411 Confederation Parkway, Unit 19 Concord, ON L4K 0A8
CA
davor@jadeacoustics.com
905-660-2444

Michelle Sims
502 - 10933 - 124 Street, , Edmonton, AB
CA
mnsims@ualberta.ca

Jacob Sondergaard
G.R.A.S. Sound and Vibration, 2285 East Enterprise Parkway, Twinsburg, OH, 44087
Jacob@gras.us

Duncan Spence
2323 Royal Windsor Dr., Mississauga, ON, L5J 1K5
CA
amsales@blachford.ca
905-823-3200

Colin Spohr
2807 MacKay Road NW, Calgary, AB, T3B 1A6
CA
ccspohr@gmail.com

Robert D. Stevens
HGC Engineering Ltd., Plaza One, Suite 203, 2000 Argentia Rd., Mississauga, ON, L5N 1P7
CA
rstevens@hgcengineering.com

Clarence Stuart
City of Edmonton, Engineering Services Section, 11004 - 190 Street NW, Edmonton, AB, T5S 0G9
CA
clarence.stuart@edmonton.ca

Dr. Aimee Surprenant
Memorial University of Newfoundland
Memorial University of Newfoundland
Psychology Dept., Science Building St. John's, NL A1B 3X9
CA
asurpren@mun.ca
709-896-4786

John C Swallow
President, Swallow Acoustic Consultants Ltd
Swallow Acoustical Consultants 366 Revus Ave., Unit 23 Mississauga, ON L5G 4S5
CA
jswallow@swallowacoustic.ca
9052717888

John Swallow
366 Revus Ave., Unit 23 Mississauga, ON L5G 4S5
CA
info@swallowacoustic.ca

Prof. Jahan Tavakkoli
Ryerson University
Dept of Physics, Ryerson University, 350 Victoria Street, Toronto, ON M5B 2K3
CA
jtavakkoli@ryerson.ca
(416) 979-5000

Corey Telfer
#302 - 9955 114 St, , Edmonton, AB, T5K 1P7
CA
CA
cstelfer@gmail.com

Mr. Peter Terroux
Atlantic Acoustical Associates, 47 Boscobel Road, Halifax, NS, B3P 2J2
CA
peteraaa@eastlink.ca

Sonu K Thomas+Indian Institute of Technology, Madras.
IN
thomas.sonu91@gmail.com
91-9884307064

Dugald Thomson
1652 Henry St, Halifax, NS B3H 3K3,
CA
dugaldthomson@gmail.com

Dr David J Thomson
Retired
733 Lomax Road, Victoria, BC, V9C 4A4
CA
drdjt@shaw.ca
(250) 478-6325

Cristina Tollefsen
DRDC - Atlantic, PO Box 1012, Dartmouth, NS, B2Y 3Z7
CA
cristina.tollefsen@drdc-rddc.gc.ca

Mihkel Toome
Linnégatan 45, Lgh 1506, 41308 Gothenburg, SE
mtoome@gmail.com

Joana Luiz Torres da Rocha
234 Guigues Avenue, Apt. 504, Ottawa, ON, K1N 5J2
CA
jdarocha@uvic.ca

Prof. B. Truax
Simon Fraser University, School of Communication, Burnaby, BC, V5A 1S6
CA
truax@sfu.ca

Karen Turner
Protec Hearing, Unit E, 77 Redwood Avenue, Winnipeg, Manitoba, R2W5J5
CA
protec1@mymts.net

Dr. Helen Ule
Akoustik Engineering Limited
1258 Aubin Rd Windsor, ON N8Y 4E5
CA
ule@uwindsor.ca
519-566-6457

Jim Ulicki
Xscala Sound & Vibration
234 - 5149 Country Hills Blvd., Suite 516
Calgary, AB T3A 5K8
CA
caa@xscala.com
403-274-7577

. Université de Montréal
Bibliothèque Acquisitions Periodiques, CP 6128, Succ. Centre-Ville, Montréal, QC, H3C 3J7
CA
indirectcan8@caa-aca.ca

. USAE Engineer R&D Center
attn:Library/Journals, P.O. Box 9005, Champaign, IL, 61826
US
indirectusa6@caa-aca.ca

Svein Vagle
Ocean Science Division
Institute of Ocean Sciences PO Box 6000 9860 West Saanich Road Sidney, BC V8L 4B2
CA
Svein.Vagle@dfo-mpo.gc.ca
250 363 6339

Olivier Valentin
719 6eme avenue, VERDUN, QC, H4G 3A3
CA
m.olivier.valentin@gmail.com
514-885-5515

Xavier Valero
xvalerog@gmail.com

Peter VanDelden
650 Woodlawn Road West, Guelph, ON, N1K 1B8
CA
peter.vandelden@rwdi.com
519-823-1311

Vivek Vasudevan Shankar
University of British Columbia
CA
vivekvs1@gmail.com

Daniel Vaucher de la Croix
41 Rue Vendome, , Lyon, , 69006 FR
FR
daniel.vaucherdelacroix@acoemgroup.com

Guilhem Viallet
École de technologie supérieure
Ecole de technologie supérieure, département génie mécanique, 1100 rue Notre-Dame Ouest, Montreal, Québec, H3C 1K3
guilhem.viallet.1@ens.etsmtl.ca

Prof. Jérémie Voix+ÉTS, Université du Québec
1100 Notre-Dame Ouest, Montréal (QC), H3C 1K3,
CA
jeremie.voix@etsmtl.ca
1 514 396-8437

Mr. Clair W. Wakefield
Wakefield Acoustics Ltd.
301-2250 Oak Bay Ave, VICTORIA, British Columbia, V8R 1G5
CA
clair@wakefieldacoustics.com
250-370-9302

Thomas Walton
15 Allison Avenue, Morrisburg Ontario , K0C 1X0
CA
twalton@eckel.ca

Lina Wang
Stantec200 - 325 25th Street SE Calgary AB T2A 7H8,
CA
lina.wang@stantec.com

Graham Warner
2858 Graham St, , Victoria, BC, V8T 3Z4 CA
CA
grahamawarner@gmail.com

Max Weichert
AT
mp.weichert@gmail.com

Mr. Larry Alan Westlake
High-Impact Health & Safety Support Services
High-Impact Health & Safety Support Services, 126 Essex Court, Thunder Bay, ON P7A 7P1
CA
ohslaw@highimpacths.com
807-345-6691

Mr. Ronald G. White
Decoustics
7 Amberglen Court, Holland Landing, ON L9N 1J6
CA
Ron.White@saint-gobain.com
905-652-5257

Tim C Wiens
Conestoga-Rovers & Associates
651 Colby Drive Waterloo, ON N2V 1C2
CA
twiens@craworld.com
519-884-0510 xx2352

Don Wilkinson
1515 Matheson Blvd. E, Unit C 10, Mississauga, ON, L4W 2P5
CA
info@wilrep.com
905-625-8944

David Williams
PO Box 271, Grimsby, ON, L3M 4G5
CA
oza@ozagroup.com
1-800-664-8263 xx25

Hugh Williamson
Hugh Williamson Assoc. Inc. PO Box 74056 RPO Beechwood Ottawa, ON K1M 2H9
CA
hughwilliamson@hwacoustics.ca

Dr Douglas James Wilson
Imagenex Technology Corp.
3621 Evergreen Street Port Coquitlam, BC V3B 4X2
CA
dougww3@aol.com
604 468 9406

Suzi Wiseman+Texas State University-San Marcos
3901 North 30th St, Waco Texas 76708,
US
sw1210txstate@gmail.com
12542356298

Mr. Chris N. Wolfe
Vibra-Sonic Control & Mat. Hndlng.
4004 Gravely Street Burnaby, BC V5C 3T6
CA
chris@vibra-sonic.com
604-294-9495

Fred Woo
199 Courtland Ave, Vaughan, ON, L4K 4T2
CA
fred.woo@durasystems.com
905-660-4455

Richard G Wright
HFP Acoustical Consultants Corp
HFP Acoustical Consultants Corp. 1140, 10201 Southport Rd. SW Calgary, AB T2W 4X9
CA
richard.wright@hfpacoustical.com
403-259-6600

Richard Yanaky
492 Dover Cres. Newmarket ON L3Y6C7
CA
yanaky@ualberta.ca

Kristine Zielinski
CA
sales@fabra-wall.com

INTERNATIONAL COMMISSION FOR ACOUSTICS

The purpose of the ICA is to promote international development and collaboration in all fields of acoustics including research, development, education, and standardisation.

http://www.icacommission.org/

Contacts:
ICAPresident@icacommission.org
ICASecGen@icacommission.org
ICATreasurer@icacommission.org

Board Members

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January 2014

To all Member Societies and International Affiliates

Please receive best wishes for your organization for the New Year of 2014.

The highlight for the ICA in the year of 2013 was the 21st ICA congress in Montreal, Canada. This meeting was jointly organized by the Canadian Acoustical Association and the Acoustical Society of America and there was a record attendance during the 5 day congress with 2300 registrants and over 1600 technical papers presented and 49 Exposition booths. Sincere thanks are due to the excellent planning and organization by the local team around Mike Stinson, Gilles Daigle and Luc Mongeau.

The General Assembly for the ICA was held during this conference. The proposed changes in governance were all accepted and the new board elected under the new rules. The benefit of the new governance was immediately obvious from the number of nominees for the positions on the board. Following the election the Board now comprises Júlio A. Cordioli (Brazil), Dorte Hammershøi (Denmark), Bertrand Dubus (France), Roberto Pompoli (Italy), Kohei Yamamoto (Japan), Jeong-Guon Ih (Korea), Grazyna Grelowska (Poland), Monika Rychtarikova (Slovakia), Yiu Lam (UK) and Mark Hamilton (USA). The executive are Marion Burgess as President, Michael Vorlander as Past President, Jing Tian as Vice President, Mike Stinson as Secretary General and Antonio Perez-Lopez as Treasurer. Those board members retiring at the time of the General Assembly included some who had served many terms in various positions and were all warmly thanked for their contributions to the board and the ICA.

The ICA is continuing to grow with the new members, Israel and Nigeria welcomed at the General Assembly. This took our membership to 47 member organizations and 8 International Affiliates.

Increasing the awareness around the world of the science and technology of sound is an important task for the ICA. The ICA is an Affiliate Member of the global organization for science, the International Council for Science, ICSU as well as Associate Member of International Union for Pure and Applied Physics (IUPAP) and the International Union of Theoretical and Applied Mechanics (IUTAM).

L'Association canadienne d'acoustique
The Canadian Acoustical Association

Formulaire d'adhésion

L'adhésion à l'ACA est ouverte à tous ceux qui s'intéressent à l'acoustique. La cotisation annuelle est de 90.00$ pour les membres individuels, et de 40.00$ pour les membres étudiants. Tous les membres reçoivent ***l'Acoustique Canadienne***, la revue de l'association publiée quatre fois par année, et ont droit de vote à l'assemblée générale annuelle.

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Les abonnements à la revue ***Acoustique Canadienne*** sont disponibles pour les corporations et institutions au coût annuel de 90.00$. Plusieurs organisations choisissent de devenir bienfaiteurs de l'ACA en souscrivant à un abonnement de soutien de 400.00$ par année (sans droit de vote à l'AGA). La liste des abonnés de soutien est publiée dans chaque numéro de la revue ***Acoustique Canadienne*** et sur le site internet de l'ACA.

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The Canadian Acoustical Association
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CAA membership is open to all individuals who have an interest in acoustics. Annual dues total $90.00 for individual members and $40.00 for student members. This includes a subscription to ***Canadian Acoustics***, the journal of the Association, which is published 4 times/year, and voting privileges at the Annual General Meeting.

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CANADIAN ACOUSTICAL ASSOCIATION
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Frank A. Russo
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EXECUTIVE SECRETARY
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Chantal Laroche

secretary@caa-aca.ca

TREASURER
TRÉSORIER

Dalila Giusti
Jade Acoustics Inc.
905-660-2444
treasurer@caa-aca.ca

EDITOR-IN-CHIEF
RÉDACTEUR EN CHEF

Jérémie Voix
ÉTS, Université du Québec
+1 514 396-8437
editor@caa-aca.ca

WEBMASTER
WEBMESTRE

Sean Pecknold
DRDC

web@caa-aca.ca

OFFICERS / ADMINISTRATEURS

Alberto Behar
Ryerson University
(416) 265-1816
albehar31@gmail.com

Bill Gastmeier
HGC Engineering

gastmeier@rogers.com

Bryan Gick
University of British Columbia

gick@mail.ubc.ca

Hugues Nelisse
IRSST

nelisse.hugues@irsst.qc.ca

Sean Pecknold
DRDC

sean.pecknold@drdc-rddc.gc.ca

Kathleen Pichora Fuller
University of Toronto
(905) 828-3865
k.pichora.fuller@utoronto.ca

Roberto Racca
JASCO Applied Sciences

roberto.racca@jasco.com

Karen Turner

protec1@mymts.net

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