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canadian acoustics
acoustique canadienne

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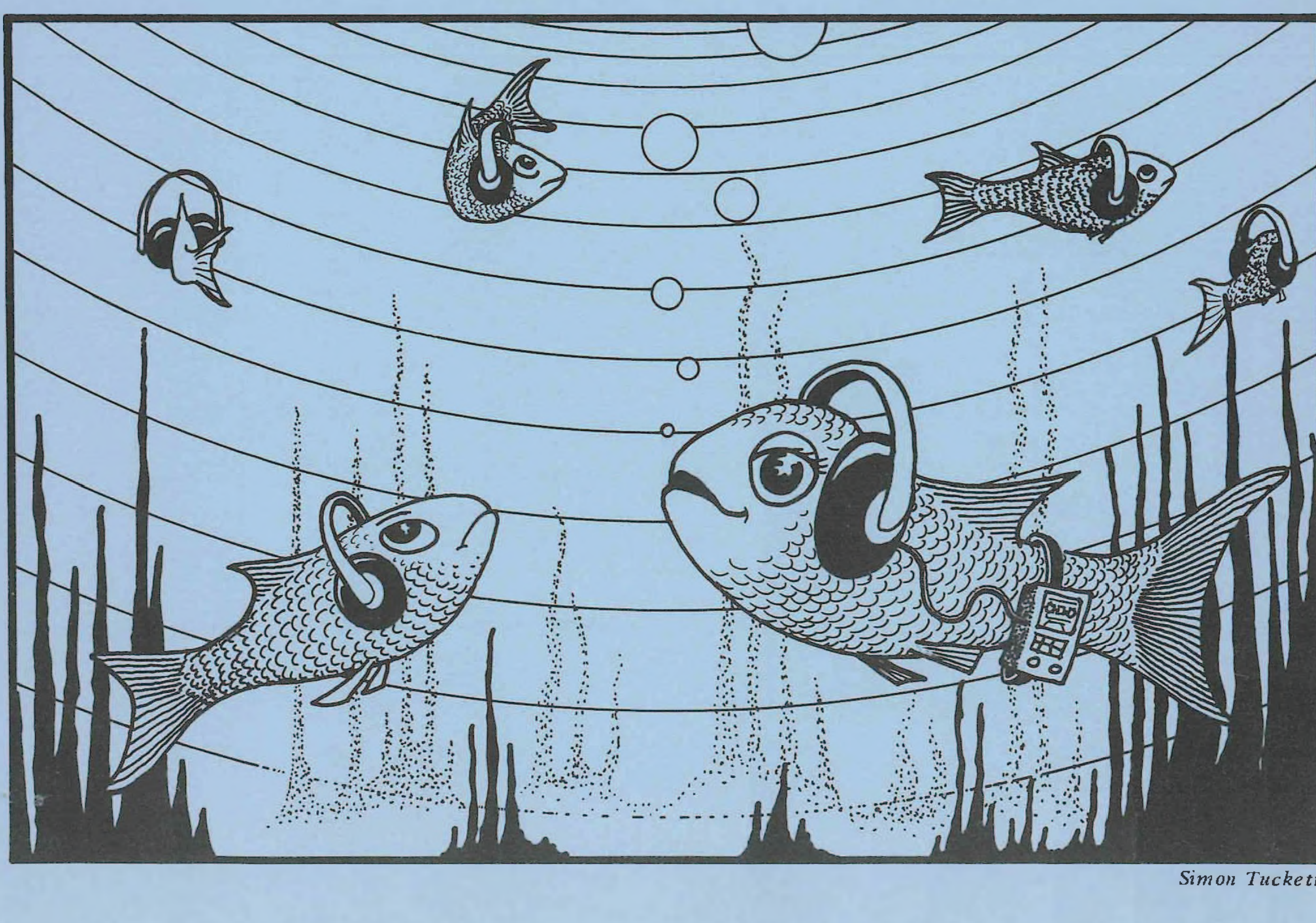

Simon Tuckett

canadian acoustics

acoustique canadienne

The Canadian Acoustical Association
P.O. Box 3651, Station C
Ottawa, Ontario K1Y 4J1

l'Association Canadienne de l'Acoustique
C.P. 3651, Succursale C
Ottawa, Ontario K1Y 4J1

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Prix: $4.00 (affranchissement inclus)

Articles an all aspects of Acoustics and Vibration in English and French are welcome, and should be addressed to any editor. All papers are reviewed.

Vous êtes invités à soumettre des articles sur tous les domaines de l'Acoustique et des Vibrations, en français ou en anglais. Prière de les envoyer à un des rédacteurs. Tout article est révisé.

EDITORIAL

This last issue of Volume 12 brings much information concerning our annual meeting in Quebec city. There are nominations for new executive members, the program of the meeting, abstracts of the papers, and of course some comments from our president concerning matters to be discussed at our business meeting. With the combined seminars and CSA meetings, it looks as if acoustics week in Canada will be a very busy and interesting time. Of course, don't forget that the 12th ICA is approaching and planning for that is steadily intensifying. There will be a report on that in our next issue as well as reports on the Quebec City meeting for those who could not attend.

Don't forget our efforts to encourage more libraries to subscribe, and to obtain a few more advertisers. We need your help.

EDITORIAL

Ce dernier numéro du volume 3 se consacre au congrès annuel à Québec. Vous trouverez le programme du congrès, les sommaires des conférences, les nominations pour les nouveaux membres de l'éxécutif et quelques mots du président. Avec les deux séminaires et la réunion de la CSA, la semaine d'acoustique au Canada promet d'être active et intéressante.

Il ne faut pas oublier que l'ICA-12 approche et la planification s'intensifie. Dans le prochain numéro il y aura un rapport sur cette planification ainsi qu'un rapport sur le congrès de Québec pour ceux qui n'ont pas pu s'y rendre.

NEWS FROM THE PRESIDENT

Your CAA directors have been doing some thinking on your behalf. Consideration is being given to drawing up some broad outlines for the annual meetings of the future. One of the ideas is that we preset the annual meetings charge the year before. Do you have an opinion?

Another consideration is the amount of time and effort that is to be required in developing a day and a half of formal papers. How structured should our annual meetings be? Do you like the present format or should it be changed? Talk to one or more of our directors and tell them what you think.

Our membership chairman has been very active in trying to recruit new members. Have you been doing you share?

Plans are progressing for our ICA meeting in 1986. Have you submitted your paper? Do you think we should have an annual meeting that year? If so, with what format?

I would like you all to answer the many questions posed but most of all I want to see you at our annual meeting in Quebec City.

Cameron W. Sherry
President

CAA NOMINATIONS

The bylaws of the Canadian Acoustical Association require that the past-president nominate persons to fill vacancies that occur on the Board of Directors and Officers of the Association.

Past-President, Tom Northwood, has advised us that he will make the following nominations: President, Cameron Sherry (continuing); Executive Secretary, Deirdre Benwell (continuing); Editor, John Bradley (continuing); Treasurer, Tom Ho.

Directors: Two of our directors, Stuart Eaton and Moustafa Osman, retire this year. To replace them, Lola Cuddy (Queen's University) and Jean Nicolas (Université de Sherbrooke) will be nominated to serve for a four-year term.

Further nominations are invited and should be in the hands of the Executive Secretary (Deirdre Benwell), together with the consent of the Nominees to serve, prior to the 1984 annual business meeting.

NOMINATIONS DE L'ACA

Selon des réglement de l'Association Canadienne d'Acoustique, l'ancien président doit nommer des personnes pour occuper les postes vacants au conseil d'administration et au comité directeur de l'Association.

L'ancien président de l'ACA, Tom Northwood, nous a appris qu'il nommera les personnes suivantes: Président, Cameron Sherry; Secrétaire, Deirdre Benwell; Editeur, John Bradley; Trésorier, Tom Ho.

Directeurs: Deux de nos directeurs, Stuart Eaton et Moustafa Osman, démissionne cette année. Pour les remplacer, Lola Cuddy (Queen's University) et Jean Nicolas (Université de Sherbrooke) seront nommés pour servir une période de quatre ans.

Autres nominations sont invitées et doivent être reçues avec le consentement des nominés par le Secrétaire (Deirdre Benwell) avant le réunion générale 1984 à Québec.

EMPLOYMENT WANTED

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Work experience related to: mechanical systems noise control, commercial and residential noise isolation, small auditoria, environmental and traffic noise studies.

Rod E. Hayden
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Vancouver, British Columbia
V6H 1H8

Telephone: (604) 738-7320

SUSTAINING MEMBERS UPDATE

Due to the costs of typesetting the list of sustaining members on the rear covers, new sustaining members will only be added once each year in the July issue. Additional sustaining members are listed below.

Acoustec Inc.
Conseillers en Acoustique et Controle du Bruit
106 Chaudière
St. Nicolas, Quebec GOS 2Z0
Tel.: (418) 839-0101

Canada Post Corporation

McCarthy Robinson Inc.
"Matrix Industrial Silencers"
321 Progress Avenue
Scarborough, Ontario M1P 2Z7
Tel.: (416) 298-1630

TORONTO REGIONAL CHAPTER NEWS

The Toronto Chapter of the C.A.C. held its final meeting of the 1983/84 season on Tuesday, 29 May 1984 at 7:00 p.m. in the Ontario Hydro Auditorium, 700 University Avenue, Toronto.

Conveners for the meeting were C.A. Krajewski and W.V. Sydenborgh. Addendence: 58. Refreshments courtesy of H.L. Blachford, Ltd. of Mississauga, Ontario.

The theme of the meeting was "Transportation Noise."

The first of the speakers introduced was Bren Brownlee of Leq Measurements Ltd. Bren showed the instrumentation and the hardware layout used to monitor noise levels in and around Pearson International Airport.

Ken Hoffer of Transport Canada told what happens with the information received and how it coincides with complaints received from the residents in these areas, how individual pilots are made aware of excessive noise levels and how specific types of aircraft are identified for reference in future solutions.

After the Intermission, Annabel Cohen spoke on the progress of the Membership Committee and asked for volunteers to help her.

Tim Kelsall's presentation covered Rail Noise ... the ranking of causes such as engine, drive train, etc., and the reactivation of the Railroad Pass-By regulations.

Roman Krawczyniuk of the Ontario Ministry of the Environment covered "Improved Procedures for Highway Traffic Noise Prediction." He discussed the aspects and implications of these procedures.

John Manuel discussed the 12th ICA and all the exciting things happening around it.

This concludes a most successful year for the Toronto Chapter, both in attendance and the quality of the speakers. We can look forward with confidence to the 1984/85 season. The first meeting will be held in September. All particulars will be in the mail well in advance of the date.

TORONTO CHAPTER 1984/85

Tuesday, 27 November 1984:
Ontario Hydro Auditorium, 7:00 p.m.
Topic: Speech Perception and Pathology
Convenors: A. Behar and S. Abel

Tuesday, 29 January 1985:
Ontario Hydro Auditorium, 7:00 p.m.
Topic: Vibration: Perception and Criteria
Convenors: C. Krajewski and M. Barman

Tuesday, 19 March 1985:
Technical Visit: Location to be announced
Convenors: A. Behar and A. McKee

Tuesday, 21 May 1985:
Ontario Hydro Auditorium, 7:00 p.m.
Topic: Industrial Noise
Convenors: W.V. Sydenborgh and M. Barman

UNIVERSITY OF ALBERTA, ACOUSTICAL RESEARCH FACILITY

On 1 August 1984, the University of Alberta will assume control of the former Bolstad Engineering reverberation chambers and associated laboratory facilities. These chambers (226 m^3 and 310 m^3), which have been used for standard transmission loss and absorption coefficient measurements, will continue to provide a testing service for commercial and governmental concerns. In addition, this centre will be involved in fundamental studies relating to reverberation rooms, acoustical materials and testing techniques. Both undergraduate and graduate studies in several university departments will be using this laboratory.

If you would like further information on either the capabilities of this facility or the possibilities for research/development work, please contact either Gary Faulkner (403-432-3446) or Tony Craggs (403-432-4517) in the Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta, T6G 2G8.

NEW ADDRESS

Annable J. Cohen, Membership Committee
Centre for Research in Human Development
Erindale Campus
University of Toronto
Mississauga, Ontario
L5L 1C6
Tel.: (416) 828-5303

NEW CANADIAN CONSULTING COMPANY

Mr. D.J. Whicker has announced the formation of a new Vancouver acoustical consulting company, Whicker Associates. They will specialize in architectural acoustics, building noise and vibration control, community acoustics, and industrial acoustics.

1102 Heywood Avenue
North Vancouver, British Columbia
V7L 1H4.

AUDIO ENGINEERING SOCIETY

Issues: Digital Audio

The Audio Engineering Society has published DIGITAL AUDIO, a collection of 25 significant papers presented at the AES premiere conference on digital technology in Rye, New York. The papers, authored by the world's foremost experts on digital audio and its applications, are now available in an expertly edited and handsomely bound volume.

Loudspeakers, Volume 2

A new anthology of papers by distinguished experts in loudspeaker theory and practice collected from the Journal of the Audio Engineering Society.

Audio Engineering Society Inc.
60 East 42nd Street
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CALENDAR 1984/85

1-4 October 1984
Aerodynamics and Acoustics of Propellers
Toronto

8-12 October 1984
Acoustical Society of America
Minneapolis, MN, U.S.A.
(Deadline for abstracts 22 June 1984)

22-26 October 1984
CAA Annual Meeting and Seminars
Quebec City, Quebec

4-6 November 1984
Institute of Acoustics Autumn Conference
Windemere, U.K.

3-5 December 1984
INTER-NOISE 84
Honolulu, Hawaii, U.S.A.
(Deadline for abstracts 15 March 1984)

9-13 December 1984
ASME Symposium on Flow-Induced Vibration
New Orleans, U.S.A.

15-17 April 1985
Institute of Acoustics Spring Conference
York, England

22-26 April 1985
International Symposium on Acoustical Imaging
The Hague, The Netherlands

6-8 May 1985
International Symposium on Hand-Arm Vibrations
Helsinki, Finland

3-5 June 1985
Noise Con 85
Ohio State University
Columbus, Ohio
U.S.A.

2-4 July 1985
Ultrasonics International '85
Kings College, London, England
4-9 August 1985
International Congress on Education of the Deaf
Manchester, England

18-20 September 1985
INTER-NOISE 85
Munich, West Germany

26-27 September 1985
Canadian Acoustical Association Symposium
Ottawa, Ontario

NEW RESEARCH CONTRACTS

To Canarctic Shipping Company Limited, Ottawa, Ontario, $21,000, for "Initial design analysis and fitting of underwater installation for sonar and viewing ports to observe ice milling." Awarded by the Department of Transport.

To Arctic Sciences Limited, Sidney, British Columbia, $69,988, for "Acoustic measurements of flows in channels." Awarded by the Department of Fisheries and Oceans.

To Jasco Research Limited, Sidney, British Columbia, $162,600, for "Development of an undersea acoustic technique to determine rainfall." Awarded by the Department of Fisheries and Oceans.

To Bolt Beranek and Newman Incorporated, Cambridge, Massachussetts, $82,590, for "Update and modification of Canadian design guide for acoustical analysis of a warship." Awarded by the Department of National Defence.

To Technical University of Nova Scotia, Halifax, Nova Scotia, $79,000, for "Extrapolation of spatially-limited signals for application in sonar array processing." (Dr. E.I. El-Masry, Department of Electrical Engineering.) Awarded by the Department of National Defence.

To Offshore Survey and Navigation Limited, North Vancouver, British Columbia, $20,719, for "Survey of acoustic profiling of an Arctic ice keel." Awarded by the Department of Fisheries and Oceans.

INTRODUCTION AUX THEORIES DE L'ACOUSTIQUE

Auteur: Michel Bruneau
Publication de l'Université du Maine
1 vol. offset 670 p. (15,5 x 24 cm)
Prix: 36$ US + 4$ US frais postaux

Ce livre s'adresse spécifiquement aux physiciens mais peut servir tout aussi bien à l'ingénieur. La présentation de la matière se situe au niveau du 2e ou 3e cycle. D'ailleurs il est utilisé pour l'enseignement du Diplôme d'Etudes Approfondies d'Acoustique à l'Université du Maine. L'ouvrage est divisé en deux grandes parties.

La première contient les six premiers chapitres et donne les théories fondamentales de l'acoustique. Le chapitre 1 introduit les équations de propagation. Au chapitre 2 on trouve l'équation d'onde en coordonnées cartésiennes et ses solutions ainsi que la propagation du son dans les guides. L'équation d'onde en coordonnées sphériques et cylindriques est traitée au chapitre 3. Le chapitre 4 se consacre à la mécanique des milieux continus et l'acoustique - déformations, contraintes, équation de Stokes-Navier, loi de Hooke, équation de la thermodynamique, équations, de continuité et aux discontinuités de la mécanique. La propagation en milieu dissipatif fait le sujet du chapitre 5 et inclut les principaux mécanismes d'absorption atmosphérique, les phénomènes d'amortissement dans les petites cavités et les solutions pour les fluides visco-thermiques. Finalement le chapitre 6 élabore les problèmes aux limites de l'acoustique - problèmes de Dirichlet, Neumann et mixte, solution de l'équation de Helmholtz, fonction de Green et résonateur de Helmholtz.

Le second partie contient quatre chapitres et appliquent ces théories à des problèmes fondamentaux de l'acoustique. Le chapitre 7 se consacre aux théories de la diffraction alors que le chapitre 8 traite de la transparence acoustique. Le chapitre 9 introduit les notions de l'acoustique des salles - théorie ondulatoire, théorie statistique et les champs acoustiques diffus. Finalement le dernier chapitre contient une variété de sujet dont l'acoustique non linéaire dans les fluides, l'acoustique des milieux mobiles, l'approximation géométrique et l'aéroacoustique.

La matière est abordée de façon systématique dans un style qui est bien classique. En général le traitement est complet. Le seul regret qu'on pourrait avoir c'est que le livre s'inspire peu de progrès et connaissances récents dans plusieurs domaines de l'acoustique. Cependant il en demeure que ce livre trouvera sa place dans toutes bibliothèques parmi les nouveaux volumes d'acoustique.

Gilles Daigle

CANADIAN ACOUSTICAL PUBLICATIONS

RECENTLY PUBLISHED CANADIAN ACOUSTICAL MATERIAL IS LISTED BELOW AS AN INFORMATION SERVICE. PLEASE INFORM THE EDITOR OF OTHER NEW CANADIAN ACOUSTICAL PUBLICATIONS.

Title *Author(s)*	*Publisher (& Address if not a Journal)* *Reference & Date*
Precise Measurement of Phase Difference and the Amplitude Ratio of Two Coherent Sinusoidal Signals G.W.K. Wong	J. Acoust. Soc. Am. 75(3), 967 (1984)
Under Ice Measurements of the Noise Produced by a Helicopter and a Tracked Vehicle P. deHeering and B.F. White	J. Acoust. Soc. Am. 75(3), 1005 (1984)
Resolution Below the Least Significant Bit in Digital Systems with Dither J. Vanderkooy and S.P. Lipshitz	J. Aud. Eng. Soc. 32(3), 106 (1984)
Dynamic Response of a Gymnasium Floor J.H. Rainer	Division of Building Research National Research Council Canada Ottawa, Ontario, Canada K1A 0R6 Building Research Note 213 (1984)
Comparison of Outdoor Microphone Locations for Measuring Sound Insulation of Building Facades F.L. Hall, M.J. Papakyriakou and J.D. Quirt	J. Sound Vib. 92(4), 559 (1984)
A Reverberation Room Round Robin of the Determination of Absorption Coefficients (by U. Kath) Translated by: A.C.C. Warnock	Division of Building Research National Research Council Ottawa, Ontario, Canada K1A 0R6 Technical Translation 2079

CANADIAN ACOUSTICAL PUBLICATIONS

RECENTLY PUBLISHED CANADIAN ACOUSTICAL MATERIAL IS LISTED BELOW AS AN INFORMATION SERVICE. PLEASE INFORM THE EDITOR OF OTHER NEW CANADIAN ACOUSTICAL PUBLICATIONS.

Title *Author(s)*	*Publisher (& Address if not a Journal)* *Reference & Date*
Causes of Systematic Deviations From "True" Values of Absorption Coefficients Measured in Reverberation Rooms (by W. Kuhl) Translated by: A.C.C. Warnock	Division of Building Research National Research Council Canada Ottawa, Ontario, Canada K1A 0R6 Technical Translation 2080
Sound Absorption of Theatre Chair Components J.S. Bradley	Division of Building Research National Research Council Canada Ottawa, Ontario, Canada K1A 0R6 Building Research Note 208
A Calibrator for Noise Dosimeters A. Behar	Applied Acoustics Vol. 16, No. 6, pp. 471-478 (1983)
Sound Transmission Loss of Masonry Walls A.C.C. Warnock and D.W. Monk	Division of Building Research National Research Council Canada Ottawa, Ontario, Canada K1A 0R6 Building Research Note 217
The 1982 New Brunswick Earthquakes: Survey of Building Damage G. Pernica and A.H.P. Maurenbrecher	Division of Building Research National Research Council Canada Ottawa, Ontario, Canada K1A 0R6 Building Research Note 198
Vancouver International Airport Engine Run-Up, Noise Analysis March 1982 - April 1983	Transport Canada Air Navigation Systems Requirements Planning 800 Burrard Street Vancouver, British Columbia V6Z 2J8 TP5531E, June 1984

Canadian Electrical Association | Association Canadienne de l'Electricité

Engineering & Operating Division | Research & Development Division

Seminar On

Audible Noise From Transmission Lines

Quebec Hilton Hotel
Quebec City
Quebec, Canada
October 31, 1984
9.00 am to 5 pm

This one day seminar will be of interest to those involved in audible noise measurement, the environmental effects of noise, the setting of design standards for transmission lines and the route selection and approvals process for new lines. The main themes will be:

- Results of recent research on the environmental effects of transmission line audible noise
- Dealing with Noise complaints along rights-of-way
- Utility design standards
- Regulatory Standards & trends

Speakers Include:

- J.E.K. Foreman — Faculty of Engineering Science, University of Western Ontario, presenting results of over 5 years of research on classification of corona sound from AC lines and the attitudinal response of people.
- T.J. McDermott, D.A. Driscoll — New York Power Authority and Public Service Commission, State of New York, presenting experience with noise measurement and noise complaints along 765 kV transmission rights-of-way
- A.J. Lees — B.C. Hydro, presenting the current status of utility and regulatory standards and future trends
- P.S. Maruvada — Institut de Recherche d'Hydro-Quebec (I.R.E.Q.), presenting the results of psychoacoustic studies of audible noise from D.C. transmisson lines.
- J.R. Stewart — Power Technologies.Incorporated (PTI), reviewing current analytical techniques for predicting noise levels and attenuation patterns for AC and DC transmission lines.

Papers:

A summary of each presentation will be available at the seminar for each participant.

Accommodations:

Please make your own arrangements directly with the Quebec Hilton Hotel – Telephone (418) 647-2411. You should advise that you are attending the CEA meeting to get the conference rate. Reservations should be made before October 1, 1984.

Seminar Registration:

- No registration fee
- Simply fill out the attached seminar registration form and mail before October 1, 1984

FOR FURTHER INFORMATION CONTACT:

Mr. G.L. Wortman
Chairman, Right-of-Way Section
Engineering & Operating Division, CEA

Telephone: (416) 592-4827
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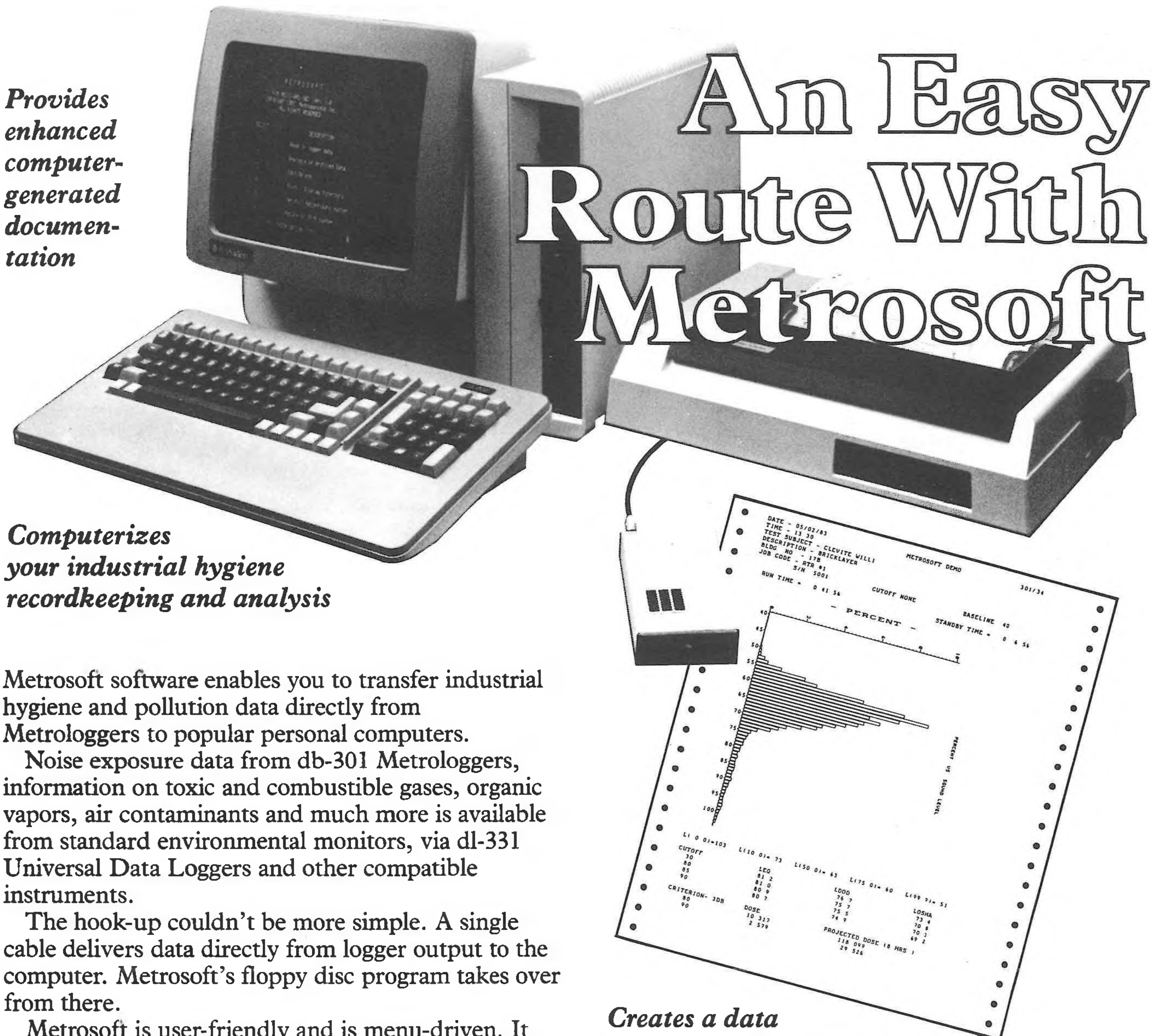

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SEMAINE CANADIENNE D'ACOUSTIQUE

Québec 22 au 26 octobre 1984
(Hotel Château Frontenac)

PROGRAMME

Lundi 22 octobre:

- 8h30 Enregistrement aux séminaires [1] et [2] (Université Laval)
- 9h30 Début des séminaires
- 11h30 Buffet (Université Laval)
- 19h30 C.S.A. Chairmen's Meeting (Hôtel Château Frontenac)

Mardi 23 octobre:

- 9h00 C.S.A. Main Committee (Hôtel Château Frontenac)
- 9h30 Début de la deuxième session des séminaires (Université Laval)
- 11h30 Buffet (Université Laval)
- 13h00 Reprise des séminaires
- 16h30 Table ronde sur l'intensimétrie acoustique (Université Laval)
- 19h30 CAC/ISO-TC43/SC2 Committee (Hôtel Château Frontenac)

Mercredi 24 octobre:

- 8h00 Enregistrement au Symposium (Hôtel Château Frontenac)
- 8h30 Début des travaux du Groupe sur l'exposition au bruit pendant le travail et sur la protection de l'audition
- 9h00 Ouverture de l'exposition technique
- 9h00 Début des sessions 1, 2 et 3 des conférences (Hôtel Château Frontenac)
- 12h00 Buffet (Restaurant Le Champlain, compris dans l'inscription)
- 13h30 Reprise des sessions 4, 5 et 6
- 20h00 C.A.A. Directors' Meeting (Hôtel Château Frontenac)

Jeudi 25 octobre:

- 9h00 Poursuite des sessions, 7 et 8 (Hôtel Château Frontenac)
- 12h00 Buffet (Restaurant Le Champlain, compris dans l'inscription)
- 13h30 Conférence plénière (salle Jacques-Cartier)
- 16h30 Assemblée annuelle de l'Association (salle Jacques-Cartier)
- 19h30 Banquet annuel et concert (salle de bal du Château)

Vendredi 26 octobre:

- 9h00 Poursuite des sessions 9, 10 et 11 (Hôtel Château Frontenac)
- 17h00 Fin des travaux du Groupe sur l'exposition au bruit pendant le travail et sur la protection de l'audition
- 17h00 Fermeture de l'exposition technique

SYMPOSIUM 84

Le Symposium se tiendra cette année au Château Frontenac à Québec les 24, 25 et 26 octobre.

Les conférences seront données de 9h00 à 16h30 en deux ou trois sessions parallèles, en tenant compte des thèmes suivants:

[A] Techniques d'identification du bruit (J. Nicolas)
[B] Réduction du bruit (Y. Champoux)
[C] Acoustique prévisionnelle et matériaux (G. Lemire)
[D] Métrologie acoustique (G. Wong)
[E] Bruit et audition (R. Hétu)
[F] Physio et psycho-acoustique (N. Lalande)
[G] Phonation et perception (M. Boudreault)
[H] Acoustique architecturale (J. Rennie)
[I] Ecrans et bruit communautaire (M. Amram et G. Migneron)

De plus, l'après-midi du 25 octobre sera consacrée à une conférence plénière qui réunira différents conférenciers invités de 13h30 à 16h30.

Tel que mentionné aux auteurs, les articles sommaires de 2 pages relatifs aux exposés **sont attendus pour le 7 septembre 1984**, de telle manière que l'on puisse distribuer les notes correspondantes à tous les participants avant le début du Symposium.

Le banquet annuel sera servi dans la grande salle de bal du Château Frontenac et sera accompagné d'un concert de musique de chambre organisé par le Conservatoire de musique de Québec. Une exposition technique d'équipements de mesure et de matériaux acoustiques se tiendra parallèlement au Symposium, plusieurs compagnies ont déjà accepté d'y participer.

Les frais d'inscription au Symposium sont de $125.00, incluant les notes des conférences, les pauses café, les buffets des 24 et 25 octobre et le banquet annuel du jeudi 25 au soir.

SEMINAIRE [1]

L'ACOUSTIQUE GENERALE ET LE CONTROLE DU BRUIT

Coordonnateur: Yvan Champoux

Ce séminaire s'adresse aux professionnels, principalement du Québec, qui oeuvrent dans les domaines de l'hygiène industrielle du génie, de l'architecture ou de l'urbanisme. Il sera donné **en français** et se tiendra les 22 et 23 octobre de 9h30 à 17h00 à l'Université Laval.

PROGRAMME

Lundi 22 octobre:

- Introduction à l'acoustique (Yvan Champoux)
- Réglementation, effet du bruit et protection des travailleurs (Raymond Hétu)
- Acoustique architecturale (James Rennie)

Mardi 23 octobre:

- Réduction du bruit (Jean Nicolas)
- Acoustique urbaine (Jean-Gabriel Migneron)
- Instrumentation et matériaux acoustiques (René Archambault et Yvan Champoux)

Frais d'inscription au Séminaire [1]: $175.00
(incluant les notes de cours, les deux buffets servis à l'Université Laval et l'autobus entre le Château Frontenac et l'Université).

Inscription après le 6 octobre: $200.00

SEMINAIRE [2]

L'INTENSIMETRIE ACOUSTIQUE ET SES APPLICATIONS

Coordonnateur: Jean Nicolas

Ce séminaire s'adresse à toutes les personnes intéressées par l'intensimétrie, ses théories et techniques et ses nouvelles applications. Il sera donné **en anglais** et se tiendra les 22 et 23 octobre de 9h30 à 17h00 à l'Université Laval. Plusieurs compagnies doivent fournir du matériel de démonstration et participer activement aux conférences. Suite à la présentation des applications par différents invités, il est prévu que la session se termine sur une table ronde qui confrontera les différentes expériences et approches.

PROGRAMME

Lundi 22 octobre:
- Introduction théorique (J. Nicolas, Université de Sherbrooke): définition, principes, calculs, précision, instrumentation
- Sondes intensimétriques (G. Krishnappa, N.R.C., Ottawa)
- Applications et démonstration (J. Pope, Bruël & Kjaer, USA)
- Mesure de la puissance acoustique, application aux machines à écrire (M.J. Crocker, Auburn University, USA)

Mardi 23 octobre:
- Holographie acoustique et antennes (R. Seznec, Metravib, France)
- Mesure du coefficient d'absorption (J.-F. Allard, Université du Mans, France)
- Analyse des pertes de transmission (J. Roland, C.S.T.B., France)
- Démonstration d'utilisation des antennes (O. Mourcia, Metravib, France)
- Intensimétrie et vibration (G. Rasmussen, Bruël & Kjaer, Danemark)

Frais d'inscription au Séminaire [2]: $325.00
(incluant les notes de cours, les deux buffets servis à l'Université Laval et l'autobus entre le Château Frontenac et l'Université).

Inscription après le 15 septembre: $375.00

COMITE ORGANISATEUR

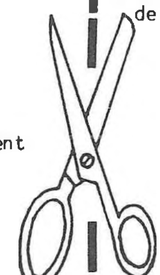
Jean-Gabriel Migneron (organisation générale)
Jean Nicolas (conférenciers)
Cameron Sherry (président A.C.A.)

SECRETARIAT

Line Pouliot (toute correspondance)
Centre de recherches en aménagement et en développement
1624 Pavillon Félix-Antoine-Savard, Université Laval
Québec, P.Q., G1K 7P4
Tél.: (418) 656-7558

INFORMATIONS

Organisation générale et exposition technique:	Jean-Gabriel Migneron (418) 656-7558 (418) 839-0101 (soir)
Conférences et Séminaire [2]	Jean Nicolas (819) 565-4479
Séminaire [1]:	Yvan Champoux (819) 565-4492



FORMULE D'INSCRIPTION
SEMAINE CANADIENNE D'ACOUSTIQUE
Québec 22 au 26 octobre 1984

NOM: ______________________________

COMPAGNIE OU ORGANISME: ______________________________

ADRESSE: ______________________________

____

CODE POSTAL: ______________ TELEPHONE: ______________

SIGNATURE: ______________________________

DATE: ______________

Prière de m'inscrire aux activités suivantes:

SEMINAIRE [1] (Acoustique générale et contrôle du bruit)*	$175.	☐
SEMINAIRE [2] (Intensimétrie et applications)**	$325.	☐
SYMPOSIUM (incluant les notes des conférences, deux repas et le banquet annuel)	$125.	☐
SYMPOSIUM (statut d'étudiant régulièrement inscrit)	$ 50.	☐
Inscription supplémentaire pour le banquet annuel	$ 30.	☐
Exemplaire supplémentaire des notes de conférences	$ 10.	☐
TOTAL:	____	

Je compte réserver une chambre au Château Frontenac (nuit simple: $63.)*** (les cartes de réservation de l'Hôtel sont jointes au présent envoi) ☐

Je compte venir accompagné(e)*** ☐

Les personnes qui le désirent peuvent s'assurer tout de suite de leur inscription en joignant un chèque à l'ordre de:
"Semaine Canadienne d'Acoustique - Québec 1984"
à l'attention de Jean-Gabriel Migneron
CRAD, 1624, pavillon Félix-Antoine-Savard
Université Laval
Québec, P.Q., G1K 7P4

(*) Après le 6 octobre, les frais d'inscription au Séminaire [1] seront portés à $200.

(**) Après le 15 septembre les frais d'inscription au Séminaire [2] seront portés à $375.

(***) Le prix spécial pour une occupation double est de $77. Après le 22 septembre, les réservations au prix spécial dépendront de la disponibilité de l'hôtel.

ACOUSTICS WEEK IN CANADA

October 22-26, 1984
Quebec City
(Château Frontenac Hotel)

PROGRAM

Monday October 22:

0830 Registration Seminars [1] and [2] (Laval University)
0930 Seminars begin
1130 Buffet (Laval University)
1930 C.S.A. Chairmen's Meeting (Château Frontenac)

Tuesday October 23:

0900 C.S.A. Main Committee (Château Frontenac)
0930 Seminars - Day 2 (Laval University)
1130 Buffet (Laval University)
1300 Seminars continue
1630 Round table on Acoustical Intensimetry (Laval University)
1930 CAC/ISO-T43/SC2 Committee (Château Frontenac)

Wednesday October 24:

0800 Symposium Registration (Château Frontenac)
0830 Working Group on Occupational Noise Exposure and Hearing Conservation begin
0900 Exhibition opens
0900 Sessions 1, 2 and 3 of Symposium (Château Frontenac)
1200 Buffet (Restaurant Le Champlain, included in registration fee)
1330 Sessions 4, 5 and 6 of Symposium
2000 C.A.A. Directors' Meeting (Château Frontenac)

Thursday October 25:

0900 Sessions 7 and 8 of Symposium
1200 Buffet (Restaurant Le Champlain, included in registration fee)
1330 Plenary session (Jacques-Cartier Hall)
1630 C.A.A. Annual General Meeting (Jacques-Cartier Hall)
1930 Annual Dinner (Château Frontenac Ball-room)

Friday October 26:

0900 Sessions 9, 10 and 11 of Symposium (Château Frontenac)
1700 Working Group on Occupational Noise Exposure and Hearing Conservation end
1700 Exhibition closes

1984 SYMPOSIUM

This year the Symposium will be held in Quebec City on October 24, 25 and 26.

Papers will be given from 0900 to 1630 in two or three parallel sessions and will deal with the following topics:

[A] Noise Identification Techniques (J. Nicolas)
[B] Noise Reduction (Y.Champoux)
[C] Prediction models and materials (G. Lemire)
[D] Acoustical Metrology (G. Wong)
[E] Noise and Hearing (R. Hétu)
[F] Physio and Psychological Acoustics (N. Lalande)
[G] Speech Analysis and Perception (M. Boudreault)
[H] Architectural Acoustics (J. Rennie)
[I] Barriers and Environmental Noise (M. Amram & G. Migneron)

In addition, the afternoon of October 25 will be devoted to a plenary session for all participants from 1330 to 1630.

As announced to the authors, the 2-page article that summarize their paper **are expected for September 7**, so that these can be distributed to participants before the beginning of the Symposium.

The annual dinner will take place in the Grand Ball-room of the Château Frontenac and will be accompanied by a concert of chamber music organized by the Quebec Conservatory. An exhibition of acoustical materials and measuring instruments will be held at the same time as the Symposium. Several companies are already registred for this exhibition.

Registration fees (including summaries of papers, coffee breaks, buffet dinners on October 24 and 25 and one dinner ticket for the CAA annual dinner on October 25) are $125.00.

SEMINAIRE [1]

GENERAL ACOUSTICS AND NOISE CONTROL

Seminar Leader: Yvan Champoux

This seminar is intended for professionals working in the fields of Hygiene, Engineering, Architecture and Urbanism (mainly in Québec). It will be given **in French** on October 22 and 23 from 0930 to 1700 at Laval University.

COURSE OUTLINE

Monday October 22:

- Introduction to Acoustics (Yvan Champoux)
- Norms, Effect of Noise, and Protection of Workers (Raymond Hétu)
- Architectural Acoustics (James Rennie)

Tuesday October 23:

- Noise Reduction (Jean Nicolas)
- Urban Acoustics (Jean-Gabriel Migneron)
- Measuring instruments and Acoustical materials (René Archambault et Yvan Champoux)

Course fee: $175.00
(including course notes, 2 buffet dinners at Laval University and transportation between the university and the Château Frontenac)

Fee for registration after October 6: $200.00

SEMINAR [2]

ACOUSTICAL INTENSIMETRY AND ITS APPLICATIONS

Seminar Leader: Jean Nicolas

This seminar is intended for those interested in intensimetry, both on the level of theory and technique and on that of new practical applications. It will be given **in English** October 22 and 23 from 0930 to 1700, at Laval University. Several companies will provide materials for demonstrations and participate in the seminar. After the presentation of practical applications, the seminar will end with a round table where the various experiments and approaches can be confronted.

COURSE OUTLINE

Monday October 22:

- Theoretical introduction (J. Nicolas, Sherbrooke University): definition, principles, calculation, precision, instrumentation
- Sound intensity probes (G. Krishnappa, N.R.C., Ottawa)
- Applications and demonstration (J. Pope, Bruël & Kjaer, USA)
- Sound power measurement application to type writers (M.J. Crocker, Auburn University, USA)

Tuesday October 23:

- Holography and antennas (R. Seznec, Metravib, France)
- Absorption coefficient measurement (J.-F. Allard, Le Mans University, France)
- Sound transmission loss via sound intensity (J. Roland, C.S.T.B., France)
- Demonstration on sound intensity and antennas (O. Mourcia, Metravib, France)
- Vibrational intensity and gated intensity (G. Rasmussen, Bruël & Kjaer, Denmark)

Course fee: $325.00
(includes course notes, 2 buffet dinners at Laval University and transportation between the university and the Château Frontenac)

Fee for registration after September 15: $375.00

ORGANIZING COMMITTEE

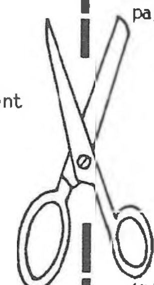
Jean-Gabriel Migneron (overall organization)
Jean Nicolas (lecturers)
Cameron Sherry (CAA president)

SECRETARY

Line Pouliot (all correspondence)
Centre de recherches en aménagement et en développement
1624 Pavillon Félix-Antoine-Savard, Université Laval
Québec, P.Q., G1K 7P4
Tel.: (418) 656-7558

INFORMATION

General and Exhibition:	Jean-Gabriel Migneron (418) 656-7558 (418) 839-0101 (evenings)
Lectures and Seminar [2]:	Jean Nicolas (819) 565-4479
Seminar [1]:	Yvan Champoux (819) 565-4492



REGISTRATION FORM
ACOUSTICS WEEK IN CANADA
Quebec City, October 22-26, 1984

NAME: ____________________

COMPANY OR ORGANIZATION: ____________________

ADDRESS: ____________________

____

POSTAL CODE: ____________ TELEPHONE: ____________

SIGNATURE: ____________________

DATE: ____________

Please register me for the following activities

SEMINAR [1] (Acoustics and Noise Control)*	$175.	☐
SEMINAR [2] (Intensimetry and its Applications)**	$325.	☐
SYMPOSIUM (including lecture notes, 2 meals and annual dinner)	$125.	☐
SYMPOSIUM (student registration)	$ 50.	☐
CAA Annual Dinner (extra tickets)	$ 30.	☐
Extra copy of lecture notes	$ 10.	☐
TOTAL:	____	

I plan to reserve a room at the Château Frontenac (single room: $63.)*** (reservation slips for the Château Frontenac are included) ☐

I will need accomodations for two ☐

Those who wish can register immediately by enclosing a cheque payable to:

"ACOUSTICS WEEK IN CANADA - QUEBEC CITY 1984"
and forwarding it to Jean-Gabriel Migneron
CRAD, 1624 Pavillon Félix-Antoine-Savard
Université Laval
Québec, P.Q., G1K 7P4

(*) After October 6, registration fees for the seminar [1] will be $200.00.

(**) After September 15, registration fees for the seminar [2] will be $375.00.

(***) The special rate for a double room is $77.00. After September 22, the special rate will be conditional on the availability of rooms.

SESSION (A) TECHNIQUES D'IDENTIFICATION DU BRUIT

Président de séance
J. Nicolas
G.A.U.S.
Génie mécanique
Université de Sherbrooke
Sherbrooke (Québec)
J1K 2R1

A1. "Gated Intensity Measurements", G. Rasmussen, Brüel & Kjaer, Naerum, Dannemark.

The use of gated intensity measurement is described and a few examples are given. The technic consists in measuring the intensity using a small time window during a cyclic event (diesel engine at any robiting machine). By moving that time window over the entire cycle it is possible to obtain a three D frequency spectrum describing one full cycle of the event.
This is a very powerfull tool to study noise emission of rotating or reciprocating machinery and for quality control of engine on a production line.

A2. "Computer Simulation of In Situ Sound Power Measurement Via Sound Intensity Measurement", G. Lemire, J. Nicolas, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.

The measurement of sound power in situ is one of the most important applications of sound intensity measurement. In theory, the sound power results simply from the integration of the normal intensity component over a surface enclosing the source. In practice, the integration is approximated by a discrete summation and sound intensity measurement itself relies on some approximations. Some questions are then rising: how many points of measurement?, which type of measurement surface?, effect of perturbating noise sources and/or reverberant field?, effects of the limitations of sound intensity measurement?
To study the implications we have implemented a computer program that simulates the sound power measurement of a source. Among the variable parameters there are the type and size of surface, the number of points, the number, type, strength and position of perturbating sources, the phase mismatch of the instrumentation, the microphone spacing and the frequency. Some results will be presented.

A3. "Spatial Transformations of Sound Fields", O. Roth, J. Hald, Brüel & Kjaer, Naerum, Dannemark.

In this paper we will demonstrate that with a system which contains a modified 1/3 octave real time intensity analyzer connected to a controller, it is possible to obtain complete information about the noise field. This is made possible by utilization of a combination of near-field holography and Helmholtz's integral equation.
We call this technique the "spatial transformation of noise fields".
With this versatile tool the engine designer can very early in the development stage obtain information about the noise produced in the far field. He can locate the sources on the engine, simulate an attenuation of one of the sources, and investigate the effect of this attenuation on the far field.
Example of practical measurements will be demonstrated as well as a discussion of problems and limitations.

A4. "Modal Analysis of Mechanical Systems by Acoustical Measurements", R.B. Bhat, Concordia University, Mechanical Eng., 1455 De Maisonneuve Ouest, Montréal, Qué., H3G 1M8.

Mechanical systems radiate sound when they execute vibratory motion. Sound radiated by the structure at any point is related to its velocity at that point. This fact has been used previously to estimate the vibratory response of the structure and to obtain its natural frequencies and mode shapes [1]. With the sophisticated digital analysis instrumentation available today, determination of modal parameters of a structure by acoustical measurements seems to be a promising technique.
In the present investigation, a simple cantilever beam is excited by impulse method using a commercially available modally tuned hammer and structural response is measured using a piezoelectric microphone. The excitation signal is measured with a transducer fitted to the impulse hammer. Both the force signal and the response signal from the microphone are fed into a two channel FFT analyzer. Transfer function in the frequency domain is used to obtain the natural frequencies and damping information. By obtaining such transfer functions at several points on the structure, and employing curve fitting techniques, the mode shapes of the structure are obtained. These informations are also obtained by measuring the structural response in the conventional way using a piezoelectric accelerometer. Comparative results by the two methods are presented.

A5. "Rayonnement acoustique des structures en vibration", J.B. Piaud, J. Nicolas, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.

Le but du travail consiste à aborder l'étude des structures vibrantes sous l'aspect énergétique et ondulatoire; énergétique: par la mesure de l'intensité vibrationnelle; ondulatoire: en cherchant à connaître dans une direction et en un point donnés l'onde incidente et l'onde réfléchie. L'étude se restreint tout d'abord aux ondes de flexion et aux poutres comme support de propagation. La mesure de ces paramètres sera effectuée à l'aide d'une sonde formée d'un doublet d'accéléromètres. Un analyseur deux canaux TFR B & K 2032 et un calculateur HP 9826 permettront l'analyse des signaux et leur traitement.
La mesure de l'intensité vibrationnelle permet de manière similaire à l'intensité acoustique là localisation des sources d'excitation de la structure.
La mesure des ondes incidente et réfléchie permet dans le cas de la poutre d'évaluer la radiation acoustique de cette dernière, avec un nombre restreint de mesures.

A6. "Modal Analysis of Aerodynamic Noise in Large Ducts", M.V. Eldada, T.M. Bengisu, C. Chamberland, Silentec, 785 Plymouth, Suite 304, Mont-Royal, Qué., H4P 1B2.

Blower low frequency noise propagates in large ducts in several modes. It is often necessary to determine the energy transported by each duct mode. This is the case in active noise control applications.
A computer program was implemented to perform modal analysis in ducts. It is based on the determination of the eigen values of the wave equation in ducts. The general solution allows to express an arbitrary complex pressure distribution in duct as a linear combination of an infinite number of eigen functions or duct modes. The orthogonality integral is performed and the fourier coeficients of the infinite series are obtained. From these coeficients, the acoustic energy distribution over the modes is determined.
An example is exposed. The acoustic pressure transfer function was measured in over a hundred positions over the cross section of a 18ft. diameter duct. This was performed with a two channal Fast Fourier Transform Analyser. The results were then fed to a computer loaded with the modal analysis program. The output was a list and illustration of the acoustic modes, frequencies and the eigen values or the normalised amplitudes of each mode in the frequencies of interest.

A7. "Diagnostic Methods to Determine Sources of Underwater Propeller Noise", L.J. Leggat, N.C. Sponagle, Defence Research Establishment, P.O. Box 1012, Dartmouth, N.S., B2Y 3Z7.

The primary course of underwater propeller noise from surface ships is cavitation which results from the low pressures developed on and near the propeller blades. It is generally understood that the noise producing mechanism is monopole in nature and results from the growth and collapse of the propeller cavitation voids.
Because a propeller develops different forms of cavitation, it is possible that the resulting noise may differ in intensity and spectral content. To investigate the source characteristics of propeller cavitation noise, methods have been developed to measure the distribution of acoustic sources in the near field of the cavitating propeller. The apparatus and experimental methods are described which allow noise source diagnostic investigations. Results from recent experiments are presented where different forms of cavitation were generated from experimental propellers. The results show trends of the relative source strength associated with the cavitation froms tested and the development of the noise producing region with increasing propeller power.

SESSION (B) REDUCTION DU BRUIT

Président de séance
Y. Champoux
G.A.U.S.
Génie mécanique
Université de Sherbrooke
Sherbrooke (Québec)
J1K 2R1

B1. "The Economics of Noise Abatement, W.V. Sydenborgh, 1243 Redband Cr., Oakville, Ont., L6H 1Y4.
An insight into the marketplace, its magnitude and potential benefits. What should the role of the C.A.A. be in this marketplace?

B2. "Noise Control in New Plant Design - A Progress Report", P. Nguyen, Noranda Research Centre, Pointe Claire, Qué., H9R 1G5.
Over the last ten years, concerted efforts have been made by Noranda Group compagnies to control or eliminate noise problems in existing operations. In the case of new plants, there is an opportunity to control noise at little or no additional cost by taking full advantage of available plant design and construction options and by purchasing "quieter" equipment.
With this objective in mind, Noranda Research Centre, in collaboration with Corporate Engineering, developed a comprehensive procedure for defining optimum noise controls in the design and construction stage. Key points are:
- noise level predictions;
- identification of potential noise problems;
- noise control cost estimation;
- definition of engineering noise controls;
- noise specifications for new equipment.

This presentation describes the results to date in applying this procedure during the engineering of a new mine and mill which is scheduled to start up at the end of 1984.

B3. "Application de l'intensimétrie à la réduction du bruit dans une centrale hydro-électrique", B. Gosselin, Hamel, Beaulieu & Associés, place du Centre, 150, rue Marchand, suite 600, Drummondville, Qué., J2C 4N1.
Les techniques d'intensité acoustique permettent de réduire efficacement et économiquement le bruit en usine. Ces techniques ont été utilisées pour identifier les sources de bruit lors de la réalisation d'une étude de faisabilité dans une centrale hydro-électrique.
Tout d'abord, chaque type d'équipement susceptible d'émettre une importante quantité d'énergie acoustique a fait l'objet d'investigation. Ces investigations consistaient à mesurer la puissance acoustique avec un analyseur d'intensité acoustique relié à un ordinateur. Il a alors été possible d'éliminer les sources de bruit les moins importantes.
Pour les sources les plus importantes, la mesure de la puissance acoustique a permis d'établir clairement les objectifs de réduction du bruit pour se conformer aux règlements et critères existants. De plus, la cartographie de la répartition de la puissance acoustique pour chaque source s'est soldée par une meilleure identification des composantes bruyantes et par le fait même, par l'emploi de solution plus appropriée et moins onéreuse.

B4. "Réduction du bruit dans les filatures", R. Benoît, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.
Le filage à anneaux est un des procédé des plus bruyants du secteur des textiles primaires. Les études antérieures ont montré qu'il existe une très grande variété de modèles de métier à filer et une multitude de paramètres qui influencent les caractéristiques et le niveau du bruit. Quelques études ont mis en relief l'importance relative des diverses sources de bruit. L'interaction des broches avec différents types de rails qui constitue dans beaucoup de cas, la source majeure de bruit, n'a pas fait l'objet d'étude approfondie jusqu'à maintenant. Cette communication présente les objectifs de cette étude et la mise au point du banc d'essai très versatile et nécessaire à l'identification du problème de même qu'à l'optimisation des solutions. Les résultats montrent qu'il est possible de quantifier la puissance acoustique de broches et de rails. L'étude via les méthodes d'intensimétrie et de cohérence permet de caractériser l'interaction de ces sources et de mesurer l'effet du changement d'un modèle de broche par un autre, ou de modification à la structure du métier. Plusieurs modèles de broches et de rails sont étudiés à des vitesses de rotation et dans des conditions similaires à celles qui prévalent dans l'industrie. Le montage peut permettre de sélectionner une broche plus silencieuse et moins énergivore.

B5. "Réduction du bruit d'un aspirateur de tête de métier à filer", R. Benoît, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.
Un métier à filer comporte plusieurs sources de bruit. L'aspirateur de tête s'est avéré dans plusieurs cas une source majeure. L'installation d'un silencieux réactif, proposé par un fabricant à cause des contraintes d'espace pour l'installation ne réduisait pas le bruit suffisamment. Cette communication présente les résultats obtenus avec un silencieux de type dissipatif qui a pu être installé grâce à une légère modification du système, pour contourner les problèmes d'espace disponible sur la machine et d'évacuation de l'air. Le niveau de puissance acoustique est étudié en fonction de la charge du ventilateur. Une réduction supérieure à 10 dB(A) de la puissance acoustique a été obtenue sur un prototype, ce qui équivaut à l'élimination de cette source majeure. Le silencieux ne modifie pas de façon sensible les caractéristiques d'opération du ventilateur et l'installation respecte les contraintes de production de l'industrie.

B6. "Noise Attenuation with Exhaust after Treatment System on a Scooptram at Falconbridges' Strathcona Mine", M.U. Savich (Energy, Mines and Resources, Elliot Lake, Ont.) and J.K. Weglo (Director Environmental Control, Falconbridge, Ont.).
The measurement and evaluation of the noise emanating from an ST4A scooptram, in an underground stope under a simulated work cycle, and under three conditions of after-treatment systems is covered.
These were:
a) bare engine;
b) an in-line small filter, compared to a larger filter;
c) the larger filter with an in-line muffler in series with a fume diluter.

The results showed an attenuation of the scooptram at work of 8 to 15 dBA, 16 cm from the exhaust pipe of the machine, to 4.8 dBA at the operator's ear. Recommendations are made to increase the attenuation at the operator's ear by additional improvement in design of the fume diluter.

B7. "Automatic Close-Fit Acoustic Enclosures: a New Concept", T.M. Bengisu, M.V. Eldada, Silentec, 785 Plymouth, Suite 304, Mont-Royal, Qué., H4P 1B2.
Acoustic enclosures often interfere with equipment production and maintenance. This is especially true for manufacturing equipment requiring frequent access, physical as well as visual, by operators.
A new concept was developped to overcome this difficulty. The enclosure is made as small as possible. It is fitted as close as possible to the equipment. Only noisy components are enclosed. Employees effort or attention to operate the enclosure is almost eliminated. Where physical access to equipment is required, a large power window or door panel will open by a foot or photoelectric switch. It will close automatically.
In this presentation a prototype of automatic close-fit enclosure will be exposed. In-situ efficiency and operator's response will be discussed.

B8. "L'affaiblissement acoustique des rideaux de liquides", M. Bruneau, P. Dumas, P. Potiez, Université du Maine, Le Mans, France.
L'idée de rechercher les lois d'affaiblissement acoustique des lames liquides repose sur l'espoir de réaliser des capotages qui n'empêchent ni l'accès direct à l'intérieur des capots, ni le contrôle visuel d'un opérateur, qui épousent exactement, autant que faire se peut, les formes des pièces en transit par la zone bruyante (zone d'usinage, de coupe, ...) et qui isolent le voisinage des poussières émises dans la zone "active" en les entraînant dans l'écoulement.
Une étude expérimentale a montré que, en regard de la très faible épaisseur des chutes de liquides étudiées (de l'ordre du dizième de millimètre), l'affaiblissement acoustique est excellent: il croît généralement de 5 dB à 10 ou 15 dB avec la fréquence, entre 600 et 6000 Hz, et conserve à peu près la même valeur entre 6000 et 12000 Hz.
Une étude théorique, reposant sur la théorie des ondes de capillarité, a mis en évidence un double comportement de la lame, à savoir (en langage d'acousticien) un comportement du type plaque mince et un comportement du type membrane. Un calcul approché, qui tient en outre compte du profil d'épaisseur de la lame, a montré que le facteur d'inertie est finalement prépondérant.

B9. "Magnetic Vibration in a 3000HP Induction Motor", M.V. Eldada, T.M. Bengisu, Silentec, 785 Plymouth, Suite 304, Mont-Royal, Qué., H4P 1B2.

This is a case history of vibration diagnosis and reduction of a 3000HP four pole electric induction motor. The main concern was a steady increase of vibration with time, mainly at the frequencies of 1 x RPM, 4 X slip frequency and at the side bands of 1 x RPM.

Vibration tests were conducted in steady state, transient state (shutt down and run up) and as a function of temperature. These test were repeated before, during and after repairs.

The cause of vibration was found to be mechanical and magnetic unbalance. Both were of approximately the same magnitude.

The magnetic unbalance is due to broken, craked or loose rotor bar, or shorted rotor laminations. Furthermore, magnetic rotor defect was found to be a possible explanation for the vibration increase with time and with temperature.

Motor was repaired. Oversized journal bearings were replaced with ones with smaller clearances; it decreased considerably the existing unbalance vibrations, magnetic as well as mechanical. Furthermore, rotor balancing was performed; it decreased the residual unbalance forces. Typical vibration levels after repair have dropped from 4.5 mm/sec. to under 1 mm/sec. for 1 X RPM frequency component. This is acceptable.

However it was found that the repair did in effect mask the magnetic vibration component and that the defect is still present. It was recommended that motor vibration be closely monitored. Should it increase again, it would become necessary to make the expensive repair or replacement of the rotor of this $250,000 motor.

SESSION (C) ACOUSTIQUE PREVISIONNELLE ET MATERIAUX

Président de séance
G. Lemire
G.A.U.S.
Université de Sherbrooke
Sherbrooke (Québec)
J1K 2R1

C1. "Etude théorico-expérimentale d'un matériau absorbant poreux", J.L. Berry, J. Nicolas, A. L'Espérance, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.

L'utilisation des mousses d'argile à des fins acoustiques suscitent un intérêt grandissant compte tenu de leurs propriétés absorbantes et isolantes. Des essais réalisés au tube de Kundt ont permis de déterminer le coefficient d'absorption sous incidence normale d'échantillons dont l'imperméabilité, mesurée au préalable, varie entre 5 et 100 c.g.s., l'épaisseur entre 20 et 90 mm et la porosité entre 60% et 80%. Des recommandations relatives à l'optimisation de la structure (imperméabilité et porosité) en découlent. Parallèlement, une modélisation théorique du produit est envisagée à l'aide des modèles d'impédance de Delany & Bazley (généralement dédié aux matériaux fibreux) et d'Attenborough. Elle permet de tenir compte de l'épaisseur du produit et éventuellement de la présence d'un espace d'air en arrière pour simuler plus fidèlement les situations pratiques. Il est apparu que le modèle d'Attenborough se comparait favorablement à l'expérience dans la gamme d'imperméabilités optimales. Il est donc possible, compte tenu d'une application donnée du produit, de déterminer les paramètres conduisant au meilleur rapport coût/performance.

C2. "Coefficient d'absorption de panneaux de matériaux poreux", J.F. Allard, P. Delage, Université du Maine, Le Mans, France.

La propagation des ondes sonores dans les matériaux poreux ou fibreux à structure souple a été modélisée en utilisant la théorie de Biot afin de prévoir l'absorption acoustique de panneaux fixés sur une structure rigide en incidence normale.

Trois catégories de matériaux ont été étudiées, les laines de verre et de roche, des mousses plastiques à résistance spécifique au passage de l'air de l'ordre de quelques dizaines de g cm^{-3} s^{-1} et une mousse plastique à très forte résistance au passage de l'air.

Dans les 3 cas, la théorie de Biot permet de prévoir d'une façon très satisfaisante le comportement acoustique du matériau.

L'importance des vibrations de la structure dans le cas des mousses a pu être mise en évidence expérimentalement et peut être correctement prédite par la théorie de Biot.

C3. "Méthode de mesure de l'absorption acoustique sous incidence variable", J.M. Leclerc

Les différents procédés de mesure de l'absorption acoustique sous incidence variable peuvent être répartis en deux catégories: les uns utilisent des signaux continus et les autres font appel aux signaux impulsionnels. Les premiers sont limités en fréquence et en angle d'incidence, quel que soit leur degré de sophistication; les seconds, tout en éliminant partiellement ces inconvénients, pèchent par le contenu fréquentiel excessif des impulsions employées.

La méthode proposée consiste à envoyer, vers le matériau testé, des trains de sinusoïdes adéquatement modulés en amplitude, de manière à bénéficier des avantages des techniques impulsionnelles en conservant une sélectivité suffisante, et réglable, en fréquence.

Un convertisseur analogique/digital échantillonne le signal qui subit ensuite un traitement numérique par ordinateur afin d'extraire l'information désirée, c'est-à-dire la valeur des coefficients d'absorption. La mesure du déphasage introduit par le matériau, autrement-dit la phase de son impédance acoustique, est également possible, au prix d'une procédure malheureusement assez longue.

C4. "Modélisation de l'efficacité d'un écran dans un local industriel", A. L'Espérance, G. Lemire, J. Nicolas, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.

Des écrans, ou barrières acoustiques, peuvent être utilisés pour réduire le bruit lors de sa propagation. En champ libre, diverses théories permettent de déterminer l'atténuation obtenue suivant diverses configurations source-écran-receveur. L'efficacité théorique d'un écran sous des milieux réverbérants (locaux industriels) reste toutefois méconnue.

La méthode des sources-images ainsi que certains principes de la méthode des chemins acoustiques ont été utilisés pour développer une technique permettant de calculer les niveaux sonores dans un local avec écran. Mise sous informatique, l'approche utilisée a permis le calcul de l'efficacité théorique de l'écran, en fonction des paramètres géométriques (positions des sources, des receveurs, de l'écran, grandeurs du local, etc.) et des coefficients d'absorption des parois. Les influences des différents paramètres sont présentées et des recommandations générales sont proposées.

C5. "Modélisation de la propagation et mesure de la puissance acoustique d'une centrale thermique", J.G. Migneron, C.R.A.D., Université Laval et C. Archambault, Direction Environnement, Hydro-Québec.

Dans le but de prévoir l'impact acoustique d'une centrale thermique de pointe sur son environnement, un modèle de propagation a été établi à partir de mesures détaillées de puissance et de propagation relatives aux quatre premières tranches d'installation des turbines. Parallèleniveau de bruit total produit par une unité génératrice, au niveau des cheminées, des silencieux d'admission d'air et des transformateurs de sortie. L'intérêt de la recherche concerne essentiellement la procédure de mesure de la puissance acoustique totale d'un groupe générateur et la discrimination fine des différentes sources de bruit en présence, tant en termes de puissance partielle que de composition spectrale. Ensuite, la modélisation de la propagation, établie à partir de la puissance et de la directivité d'un groupe, reproduit de façon précise le mode d'impact de la centrale jusqu'à une distance de 2,000 pieds.

C6. "Wave Action: Its Applicability to Acoustics", M.E. McIntyre, Applied Maths, Cambridge, University, U.K. and R. Ramakrishnan, Vibron, 1720 Meyerside Drive, Mississauga, Ont., L5T 1A3.

Properties which are a measure of wave activity satisfying a conservation equation have been developed for a number of applications. A prime requirement of the wave quantities is that they can be evaluated from linearized theories.

One fundamental quantity that is derived for oscillatory disturbances is wave-action. The fundamental equation for wave-action and the related quantities are given in reference 1. The objective of the present work is its application to acoustic waves propagating through moving media.

The wave property is developed from wave-action such that it is linear as well as satisfies the conservation equation when viscosity and other irreversible processes are neglected. Suitable conservable quantities are well known in special cases (reference 2, 3, 4). Lighthill (5) has commented on the difficult nature of a quantity to be developed for general mean flow without high frequency (geometrical acoustics) approximation.

Recently the general property wave-action used in "classical field theory" has been successfully applied on waves in stratified, rotating fluids. An extension of the same property to the particular fields of acoustics in non-uniform flow was given in reference 6. The conservable quantities are first derived for a general inviscid non-uniform flow field. The acoustics of the gravest mode propagating in a duct with absorbent walls are evaluated. The acoustical properties are tested in the conservation equation through quantities developed from wave-action. The results show that for a number of frequencies the wave-properties (derived from a linearized theory) satisfy the conservation equation.

SESSION (D) METROLOGIE ACOUSTIQUE

Président de séance
G. Wong
Acoustics
N.R.C.
Ottawa (Ontario)
K1A 0R6

D1. "Critères et méthodes d'étalonnage pour les instruments et les capteurs de mesure", H. Scory, IRSST, 505 De Maisonneuve Ouest, Montréal, Qué., H3A 3C2.

Depuis plus de 3 ans que l'IRSST existe, le soutien analytique a mis au point un programme d'assurance qualité qui est appliqué annuellement à plusieurs centaines d'instruments de mesure du bruit utilisés par les hygiénistes industriels et les inspecteurs du gouvernement du Québec. La présentation décrira les méthodes d'étalonnage et d'essais qui ont été développées pour les différents types d'instrument, et mentionnera les critères minimaux de précision, actuellement exigés de l'instrumentation, en fournissant quelques uns des résultats obtenus.
Nous ferons part, également, des outils d'échantillonnage et d'analyse particuliers qui ont été élaborés, par l'IRSST, pour faciliter le travail effectué par les personnes s'intéressant à la protection de l'ouïe des travailleurs.

D2. "Application of Precision Acoustical Measuring Techniques", G.S.K. Wong, M36, Acoustics, C.N.R., Montreal Road, Ottawa, Ont., K1A 0R6.

Metrology is the science of measurement, and there is no boundary on the flow of knowledge between various disciplines of measurements. For example, some of the principles from mechanical dimensional metrology are very useful in electronic and acoustic metrology. The precision A.C. measuring system which has a resolution of better than 0.0001 dB, developed for the Canadian Primary Acoustical Standards, has applications in other branches of metrology.

D3. "Standards Using Two-Microphones Techniques", G. Rasmussen, Bruël & Kjaer, Naerum, Dannemark.

Methods for the measurement of intensity have been developed and implemented as routine during the late years. The use of standardized filter technique, standardized microphone calibration technique and traditional precisely calibrated reference sound sources enables comparison between the two-microphone technique and standardized measurement procedures. Especially the two-microphone technique offers use of standardized absolute calibration and a relative phase calibration. The two-microphone intensity methods bear the comparison between old and new technique very well. Experience enables us to set up rules for handling severe reactive environments using the advantages of the intensity technique:

- How agreement between calibration quality and reactivity of the sound field shall be documented.
- The technique necessary to cover a sufficient part of the emitted power from a complex source.
- The capability to discriminate against background noise in the measurement result.

The development of a proposal for "Determination of Sound Power of Sound Sources Using Sound Intensity Methods" includes practical experiences based on a number of measurements. It is possible to demonstrate reproducibility of intensity measurements to within ± 0,1 dB. Agreement with precision calibrated sources according to ISO 3741 and 3742 is better than 0,2 dB under varying environmental conditions.

D4. "Intensimétrie analogique en temps réel", C. Chamberland, F.W. Slingerland, Département de génie mécanique, Université Laval, Québec.

L'intensité acoustique est de plus en plus employée de nos jours pour résoudre les problèmes de bruit de l'industrie. La popularité de cette méthode est attribuable à la facilité avec laquelle il est possible de faire le diagnostique d'une source de bruit. Des appareils de haute gamme sont actuellement disponibles sur le marché mais ils sont adaptés pour le travail en laboratoire. Un intensimètre destiné à l'industrie devrait posséder les qualités suivantes: légèreté, petit volume, autonomie, précision, fiabilité et économie d'achat.
L'avènement ces dernières années, de composantes analogiques de haute qualité a permis aux auteurs de fabriquer un prototype d'intensimètre qui rencontre les qualités ci-dessus. Un choix judicieux des composantes permet de minimiser leurs nombres, de faciliter l'assemblage du circuit et d'augmenter la précision des lectures.
La réponse en fréquence de prototype est limitée dans les basses et dans les hautes fréquences. La limitation dans les basses fréquences dépend de l'erreur de phase qui existe dans les entrées de l'intensimètre. L'erreur dans les hautes fréquences est inhérente au principe de mesure qui estime le gradient de pression par différence finie. Il est possible d'estimer cette dernière erreur et de la corriger en filtrant le signal de sortie de l'intensimètre.
Les performances du prototype sont acceptables et suffisantes pour une utilisation industrielle. L'erreur de mesure sur l'intensité est inférieure à (± 2 dB), dans une gamme de fréquence de (100 - 15000 Hz). La gamme dynamique est comprise entre 70 et 140 dB.
Les applications possibles d'un tel appareil sont: diagnostic d'une source sonore; mesure in-situ de la puissance acoustique émise par une source; détection de fuites à travers une paroi; mesure du coefficient normal d'absorption d'un matériau. De plus, l'addition d'un filtre extérieur en bande d'octave permet de faire l'analyse spectrale d'une source sonore.
Le prototype fabriqué se révèle donc être un instrument bien adapté à l'intensimétrie industrielle. Il est probable qu'il remplacera les intensimètres de haute gamme qui sont plus appropriés pour les laboratoires, groupes de recherche et spécialistes en acoustique.

D5. "Test in-situ comparatif d'analyseurs d'intensité par FFT et par filtre", C. Sauvé, M.V. Eldada, C. Chamberland, C. Gélinas, Silentec, 785 Plymouth, Suite 304, Mont-Royal, Qué., H4P 1B2.

L'intensimétrie a été utilisé pour le diagnostic des sources de bruit d'un groupe de onze compresseurs réciproques de 600HP chaque. La puissance acoustique des composantes individuelles des compresseurs a été mesurée à l'aide de deux types d'intensimètres. Ces appareils sont l'analyseur FFT à deux voies, B & K type 2032 et l'analyseur d'intensité par filters numériques, B & K type 3360.
Dans ce papier, les résultats du diagnostic ainsi que leurs différences seront présentés. La précision et les limites pratiques de chaque instrument et technique sont discutées. Des conclusions préliminaires sont formulées.

D6. "Transmission Loss Measurements: Conventional Versus Intensity", R.E. Halliwell, A.C.C. Warnock, N.R.C., M27, Division of Building Research, Ottawa, Ont., K1A 0R6.

A two-room reverberation suite with rooms of different volume was used to compare transmission loss measurements made using conventional methods with those made using the intensity method. The rooms are connected by a "tunnel", 1.4 m long, in which the specimen was placed at five different locations. Conventional transmission loss measurements were made in both directions and intensity measurements made with the small room acting as the receiving room. To simulate the wide range of receiving rooms found in real buildings and to test the sensitivity of the intensity method to reactive fields, four different absorption conditions were presented in the small room for each of the wall positions. Neither method was found to vary appreciably with the amount of absorption, but both showed some dependence on the wall position. The intensity method was found to give a transmission loss much closer to the expected mass law dependence than did the conventional method.

D7. "Evaluation of Silencer Performance Through Sound Intensity Measurements", Xenia Vruvides, SNC, Environment Division.

When attempting to evaluate the in-situ performance of a silencer installed on a piece of equipment, conventional sound level measuring techniques are not practical if background noise levels are similar or greater than those expected at the silencer outlet. One possible technique is to determine the acoustic power radiated into and out of the silencer, incorporating a field-measured correction for the background sound intensity. The paper presents the adopted procedure for sound intensity measurements applied to a prototype silencer, the actual silencer performance, the observed limitations of this measuring technique, and its advantages over conventional measuring methods.

D8. "Contrôle numérique de signaux impulsifs émis par un haut-parleur", M. Sawan, J. Nicolas, G.A.U.S., Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.

Afin d'effectuer différents types de simulation en acoustique la génération de signaux temporels de courte durée est de plus en plus utilisée. Cependant quelque soit la qualité de la chaîne électro-acoustique utilisée le signal transitoire reçu est toujours déformé en amplitude et en phase. Afin d'obtenir des signaux temporels contrôlés, un signal numérique du type sin x/x est généré sur micro-ordinateur et converti en mode analogique et émis dans une chaîne électro-acoustique dont on calcule la fonction de transfert inverse. On montrera en outre la nécessité de l'utilisation de filtres digitaux récursifs et d'une parfaite synchronisation. L'audit entre le signal désiré et le signal contrôlé émis est excellent quelque soit la gamme de fréquence. Les perspectives d'application de cette méthode tant en psycho-acoustique qu'en acoustique architecturale seront discutées.

D9. "Utilisation du micro-ordinateur dans le domaine de l'acoustique: l'interface IEEE-488 (HP-IB) et un oscillateur software", Y. Champoux, GAUS, Génie mécanique, Université de Sherbrooke, Sherbrooke, Qué., J1K 2R1.

Dans le domaine de l'acoustique expérimentale, l'utilisation des micro-ordinateurs pour la collecte et le traitement des données est de plus en plus répandue. L'échange d'informations numériques sous forme digitale entre un appareil de mesure et un tel micro-ordinateur nécessite qu'il y ait compatibilité de langage de communication. En d'autres termes, les deux appareils doivent posséder la même interface. Le logiciel de base permettant la communication entre un micro-ordinateur SYM-1 et l'analyseur digital de bruit Bruël & Kjaer #2131 a été développé. Ce logiciel peut être adapté à peu près à n'importe quel micro-ordinateur, ce qui permet une utilisation plus rationnelle des équipements. Les principes de bases du fonctionnement de l'interface HP-IB seront exposés. Il sera démontré qu'un tel logiciel est relativement facile à réaliser. La qualification d'une chambre réverbérante permettant la mesure de la puissance acoustique de sources émettant des tons purs requiert l'utilisation d'un oscillateur et d'un compteur de fréquences. Ces instruments étant très spécialisés, le micro-ordinateur a été mis à profit et un oscillateur software "maison" a été développé. Les caractéristiques de cet oscillateur "bon marché" seront exposées.

SESSION (E) BRUIT ET AUDITION

Président de séance
R. Hétu
Ecole d'audiologie
Université de Montréal
Pavillon M.D'Youville
Montréal (Québec)

E1. "Draft Guideline for Regulatory Control of Occupational Noise Exposure and Hearing Conservation", D.A. Benwell, Radiation Protection Bureau, National Health and Welfare, Ottawa, Ont.

The Federal/Provincial Advisory Committee on Environmental and Occupational Health established a Working Group on Occupational Noise Exposure and Hearing Conservation in September 1982. The terms of reference were basically to prepare for publication a guideline for regulatory control of occupational noise exposure and hearing conservation with due regard for respective jurisdictions and responsibilities.
A draft report entitled "Guideline for Regulatory Control of Occupational Noise Exposure and Hearing Conservation" was prepared in April 1984 and circulated for comment. The final report is planned for publication in the spring of 1985.
The Guideline was prepared to assist Provinces to update their Regulations for Occupational Noise Exposure and Hearing Conservation. It may be adopted in its entirety, or may be modified to satisfy the specific requirements of each Province.
The Guideline is the result of the combined effort of a group of people with expertise in both occupational noise exposure control and in the associated regulations across Canada. Input and comments have been solicited from all the Provinces and from acoustics experts working in the area of occupational noise. One of the information bases used in the production of the report was a survey distributed by the Canadian Standards Association Committee of Acoustics and Noise Control Task Force on Occupational Noise to more than 150 representatives of government, regulators, employers, labour, consultants, universities and hospitals.
This paper describes the contents of the Guideline which include a statement of purpose, a framework for a regulation respecting noise exposure and hearing conservation, a rationale for the framework, and codes of practice for noise exposure control, audiometry and noise measurement. The Guideline is discussed in the context of orther activities to control occupational noise exposure in Canada.

E2. "La règlementation canadienne en matière de bruit émis par les jouets récréatifs et éducatifs", R. Hétu, S. Brochu, F. Lacombe, M. Poisson, Ecole d'orthophonie et d'audiologie, Université de Montréal, 2375 Chemin Côte Ste-Catherine, Montréal, Qué. H3T 1A8.

Quelle protection est assurée aux consommateurs canadiens en matière de bruit émis par les jouets d'enfants? D'une part, la Loi sur les produits dangeureux (Ch.3, art. 10), administrée par Consommation et Corporation Canada, comporte des dispositions explicites à ce sujet. D'autre part, les pistolets-jouets sont régis par la Loi sur les explosifs, appliquée par le Ministère fédéral de l'Energie, des Mines et des Ressources. Cependant, ces articles de loi apparaissent très peu satisfaisants pour trois raisons: a) la formulation des limites règlementaires du bruit émis par les jouets comporte de sérieuses ambiguités; b) il est improbable que les limites, même appliquées rigoureusement, assurent la protection de l'audition des utilisateurs de jouets bruyants; c) la procédure d'évaluation de la conformité des jouets en regard des règlements en vigueur n'a fait l'objet d'aucune normalisation. Ces problèmes seront discutés en fonction d'exemples concrets et des propositions en vue d'une amélioration seront présentées.

E3. "L'acuité auditive des étudiants de secteurs professionnel et non-professionnel", Louise Paré, France Filiatrault, Département de santé communautaire De Lanaudière, 585, boul. Manseau, Joliette, Qué., J6E 3E5.

L'hypothèse de l'étude est que les étudiants fréquentant certains ateliers professionnels sont suffisamment exposés au bruit au cours de leur apprentissage scolaire pour que leur acuité auditive diffère de celle des étudiants du secteur non-professionnel. Afin de vérifier cette hypothèse, les seuils auditifs de 821 étudiants furent évalués. Les individus présentant des problèmes auditifs causés par des facteurs autres que le bruit furent éliminés de l'échantillon. L'analyse a porté sur 286 étudiants du secteur professionnel et 375 étudiants du secteur général. L'âge de ces étudiants varie de 14 à 20 ans ($\bar{X}$: 17 ans). Chaque étudiant a passé un examen audiométrique par voie aérienne ainsi qu'un examen tympanométrique et a complété un questionnaire sur ses antécédants personnels, médicaux, professionnels et sur ses activités bruyantes. Des relevés sonométriques ont été effectués dans les ateliers fréquentés et les doses de bruit furent évaluées. Une description des seuils auditifs de 500Hz à 6000Hz est présentée de même qu'une comparaison entre les seuils auditifs à 4000Hz des deux groupes d'étudiants.

E4. "L'exposition pendant la grossesse à une dose de bruit jugée admissible au sens de la loi est-elle nocive pour l'organe de l'ouïe du foetus?", N.M. Lalande, R. Hétu, Ecole d'orthophonie et d'audiologie, Université de Montréal, 2375, Chemin Côte Ste-Catherine, Montréal, Qué., H3T 1A8.

Pour étudier ce facteur de risque, une étude épidémiologique de nature prospective historique a été menée. Ainsi, la sélection des enfants s'est faite suivant l'exposition ou non de leur mère pendant la grossesse à une dose de bruit voisine de 90 dBA-8h. Mais l'effet d'une telle exposition a été étudié rétrospectivement en ce sens que l'audition d'enfants âgés entre 4 et 10 ans a été évaluée. L'effectif total a donc été constitué d'enfants exposés in utéro à une dose quotidienne variant entre 65 et 95 dBA-8h et ce, pendant un minimum d'un mois mais pouvant aller jusqu'à 8 1/2 mois. La cueillette de données comportait trois volets distincts soit a) l'histoire auditive mère-enfant, tout comme l'histoire professionnelle de la mère pendant la grossesse, b) l'examen auditif mère-enfant et c) les relevés de bruit au(x) poste(s) de travail occupé(s) pendant la grossesse. Ces informations ont été recueillies grâce a) à un questionnaire-entrevue avec les mères, b) à un examen audiométrique et impédancemétrique en cabine insonore et c) à une enquête sonométrique des lieux de travail et/ou lorsque préférable à la consultation de relevés de bruit déjà existants. Les résultats préliminaires de cette étude seront présentés et discutés.

E5. "Risk Assessment of a Trade", A. Behar, Ontario Hydro, Pickering, Ontario, L1W 3C8.

When surveying noise exposure levels of large groups of workers (trades) using sampling techniques results are obtained as statistical estimates (means, std, deviations, etc.). This paper presents a method for determining if a trade is at risk by using the above estimates.
The first step of the procedure consists of deciding upon an acceptable risk of hearing loss. This is expressed as a percentile of workers that will suffer a given ("acceptable") occupational noise induced hearing loss at the end of their working life (usually after 45 years).
As a second step, formulas in the new ISO/DIS 1999 (1984) are used for the calculation of the noise exposure level that will cause the above percentile.
The trade is labelled as "at risk" if the level calculated in step 2 is exceeded by a percentile higher than this postulated in step 1.

E6. "Spectral Analysis of Industrial Noise, with Special Reference to Correlation Between Different Indices", Prem C. Pandey, H. Kunov, Sharon M. Abel, Institute of Biomedical Engineering and Department of Otolaryngology, University of Toronto, Ont.

Noise samples from worksites in six different types of Ontario Industries were recorded. These were analyzed in the laboratory and a number of spectral measurements and indices for the stationary noise samples were derived: sound pressure level, A-weighted sound level, speech interference level, octave, third-octave and decade band-levels. Statistical trends and general features of these measures for the different types of worksites will be presented. As our noise samples represent a typical cross-section, it is of special interest to study the correlation between the different indices. Even though all the correlation coefficients are significant at 1% level, there is a substantial variation in the values. Thus, we may say that A-weighted sound level is on the average, a better predictor of speech interference when compared with Sound Pressure Level. An equally good predictor is the mid-frequency decade band (0.2 - 2 kHz) level. However, for the ten octave-band levels, the differences in correlation coefficients for sound pressure level and A-weighted sound level are not significant (at 10% level). These and other results will be discussed.

E7. "Studying Hearing Loss: Design and Statistical Considerations", R. Phaneuf, R. Hétu, Ecole d'orthophonie et d'audiologie, Université de Montréal, Qué.

Conventional epidemiological considerations (the possibility of biases due to selection, confounding, misclassification, appropriateness of the analysis and design, and the power of the sample size) are required for sample based studies with the particular objective of examing the relationship between variables related to hearing loss. Examples derived from the literature are used as illustrations. The advantages and shortcomings of various epidemiological strategies (prospective studies and prevalence studies) are reviewed. The implications of using stringent exclusion criteria is considered with respect to the maintenance of validity. Emphasized is the rigor required to guard against audiometric measurement error. Statistical issues related to sample based studies using multivariant analysis are discribed with their implications including: effect modification, confounding, hetheroscedasticity. In conclusion, these issues must be considered whether it be a simple evaluation of a hearing conservation program, or the study of new associations.

E8. "Les conséquences indésirables de la fatigue auditive", R. Hétu, Ecole d'orthophonie et d'audiologie, Université de Montréal, Qué.

La fatigue auditive ou décalage temporaire des seuils d'audition (DTS) causée par l'exposition au bruit est généralement prise en considération uniquement comme précurseur d'une perte auditive permanente. Cependant, le DTS mérite d'être considéré en lui-même comme un phénomène indésirable par le fait de ses manifestations et de ses conséquences. En effet, le DTS résulte d'une perturbation physiologique du système auditif et pour cette raison, il est accompagné d'un certain nombre de déficits auditifs: perte de sensibilité, de discrimination, de sélectivité fréquentielle. Il en résulte des incapacités auditives telles que des difficultés à comprendre la parole dans un bruit de fond, à localiser la personne qui parle dans une conversation de groupe, à apprécier la musique ou à jouer un instrument de musique de façon satisfaisante. Ainsi, une exposition quotidienne au bruit qui cause des DTS plus ou moins importants est vraisemblablement à l'origine d'une situation paradoxale: les déficits et les incapacités auditives sont temporaires mais les désavantages qui en résultent peuvent être permanents. Cette problématique sera examinée en fonction de conditions d'expositions au bruit en milieu de travail et d'ambiances de récupération de la fatigue auditive en dehors des lieux de travail.

SESSION (F) PHYSIO ET PSYCHO ACOUSTIQUE

Présidente de séance
N. Lalonde
Ecole d'audiologie
Université de Montréal
Pavillon M.D'Youville
Montréal (Québec)

F1. "Audiometry and the Geometry of the Human Ear Canal", M.R. Stinson, Division of Physics, National Research Council, Ottawa, Ont.

Audiometry, the measurement of hearing thresholds, is an important clinical tool for the diagnosis of hearing impairment. In practice audiometric measurements are not made above 8 kHz, due to uncertainties in headphone - pinna coupling, ear canal geometry, and calibration procedures. However, hearing damage often appears initially at the higher frequencies, and an extension of current techniques to 20 kHz would be highly desirable. In this talk the limitations that are imposed by ear canal geometry on such an objective will be discussed. The variations in size and shape of ear canals between individuals become increasingly important as sound frequency increases: the pressure transfer function, from canal entrance to eardrum, can vary by as much as 25 dB between subjects above 10 kHz. Conventional audiometric techniques must be modified substantially if they are to be extended above 8 kHz.

F2. "Energy Detection in Normal and Hearing Impaired Listeners", B. Papsin, S.M. Abel, H. Kunov, Silverman Hearing Research Laboratory, Department of Otolaryngology, Mount Sinai Hospital, Toronto, Ont.

A study was conducted to explore variation in auditory temporal integration in listeners with normal hearing, and impairment due to middle ear dysfunction, cochlear hair cell damage, acoustic neuroma and lesion of the temporal cortex. Over a block of 50 two-interval forced-choice trials, subjects were required to determine which of two sequential intervals contained a 1/3 octave narrow-band noise signal centered at either 1 or 4 kHz. For each of eight signal durations (2.5, 5, 10, 20, 40, 80, 160, and 640 ms), the stimulus intensity was varied across blocks such that the proportion of correct responses, P(C), ranged from 0.50 (chance performance) to 1.00 (perfect detection). Major findings were: (1) the slope of the function relating threshold intensity and duration varied inversely with frequency, (2) the variability in the threshold intensity was greater for 4000 Hz than for 1000 Hz, (3) the magnitude of the slope of the temporal integration function was not significantly different in listeners with conductive loss relative to normal listeners, (4) the magnitude of slope of the temporal integration function was significantly less in cases of sensorineural loss and acoustic neuroma relative to normal listeners.

F3. "Determinants of Annoyance at Community Noise", F.L. Hall, S.M. Taylor, S.E. Birnie.

If annoyance at noise arises primarily because of interference caused by noise to activities such as speech and sleep, then sound levels from specific noisy events should be good indicators of annoyance. This paper reports the results of further analyses to test such a model of annoyance. The most important results are: (1) very similar functional forms are found for two different data sets; (2) the functions predicting activity interference from single event sound levels are similar for aircraft and road traffic events; and (3) the functions predicting annoyance from activity interference appear to be different for the two noise sources.

F4. "Measurement of, and Attitudinal Response of People to, Noise from High Voltage Transmission Lines and Transformer Stations", John E.K. Foreman, Faculty of Engineering Science, University of Western Ontario, London, Ont.

The Sound and Vibration Laboratory has been engaged in a project sponsored by the Canadian Electrical Association to undertake a program of long-term physical measurement and statistical analysis of audible noise (together with associated environmental conditions) which is a resulf of corona discharge from high voltage (550 and 735 kV) transmission lines under all conditions of weather. Noise at the property line from a 735 kV transformer station has also been studied. The project also entailed phychoacoustic testing of people to determine attitudinal response to this form of noise, as compared to other environmental noises, and to assess which measurement "weighting" of conventional sound measuring systems best correlates attitudinal responses with corona noise. This information is required in order to provide certain guidelines in the design and development of future high voltage transmission lines and in the monitoring and control of corona noise from these lines.

The field tests in Canada were conducted at selected test sites adjacent to Ontario Hydro and Hydro-Québec transmission lines and a Hydro-Québec substation. Portable trailers with instrumentation were developed for automatic long-term statistical data logging of corona noise and associated environmental (weather) data; the Laboratory also developed a microprocessor-based system for the automatic recording of corona sounds on studio-type, four-channel tape recorders.
The project involved playback of test tapes which had been prepared from the field noise measurements (and which included representative samples of other environmental noise). The facilities of the Laboratory, including a specially prepared listening room for subjective testing (which had been furnished and was acoustically calibrated and "shaped"), were used for the psychoacoustic testing.
A summary of the field instrumentation and laboratory testing procedures, together with the results of psychoacoustic testing, will be presented.

F5. "The Epidemiological Issues in Hearing Loss Among Adults", R. Phaneuf, R. Hétu, Ecole d'orthophonie et d'audiologie, Université de Montréal, Qué.

Clinicians have the difficult task of attributing a hearing loss to a particular cause, particularly in the absence of reliable serial audiometry, and adequate noise exposure data.
Furthermore, the occupational health professional must be alert for other causes of hearing loss (noise or age) particularly those diseases which require treatment. Accordingly, a comprehensive epidemiological review of hearing disorders focusing on conductive, sensorineural, and mixed hearing disorders disorders, is presented. The current state of knowledged of an age noise interaction as well as para-occupational risk factors for hearing loss, and diseases are emphasized.
By considering, the entire body of knowledge, it will be possible to make more confident statements about the probability that a particular occupational exposure was the cause of a particular hearing loss. The implications for compensation, rehabilitation service planning are discussed.

F6. "Preliminary Results for a Temporary Cochlear Implant", S.-M. Tse, S.M. Abel, H. Kunov, J. Nedzelski, Department of Otolaryngology and Institute of Biomedical Engineering, University of Toronto, Ont.

An experiment is in progress to determine the effectiveness of a temporary single channel electrode for auditory perception in bilaterally deaf adults. Pre-implant screening procedures include pure-tone and speech audiometry; subtests of the Minimal Auditory Capabilities (MAC), and the Iowa Cochlear Implant Batteries; and consonant discrimination with and with-out lipreading. Subjects are assessed unaided, as well as with high powered hearing and vibrotactile aids. Three individuals satisfying pre-established criteria for total deafness have been surgically implanted with a single ball electrode measuring approximately 2 mm in diameter. This was inserted through the external auditory canal and placed in contact with the round window membrane. Post-operative testing comprises psychophysical procedures to measure current thresholds and dynamic range for sine, square and biphasic pulse waveforms, frequency and gap discrimination. An analog version of fundamental frequency is presented to the electrode as a cue to speech perception. Speech testing allows assessment of improvements in tracking and discrimination of prelinguistic and supersegmental parameters. Preliminary results suggest that the temporary implant allows discrimination of pitch contours and voicing, improved speech tracking, and gap discrimination.

G1. "The emergence of Sensitivity to Doh, Me, Sol", A.J. Cohen, S.E. Trehub, L.A. Thorpe, B.A. Morrongiello, CRHD, Erindale Campus, University of Toronto, Mississauga, Ont. L5L 1C6.

The fourth, fifth, and sixth harmonics form what is known in music as the major triad. The relation is often referred to as doh, me, sol, corresponding to the names of the notes of the major scale. In multidimensional scaling studies, the major triad beginning on the tonic or first note of the scale is judged most stable of all chords of the scale (Krumhansl & Kessler, 1982). However, beyond its unique role in the musical scale, the major triad is granted great structural significance in music theory. Even young children recognize patterns ending in the major scale as "better" than those which do not (Krumhansl & Keil, 1982). At the level of the microstructure of musical pitch, the major triad relation, by virtue of its small integer frequency ratios, has privileged status with respect to periodicity theories of pitch processing, and indeed, infants of 7 months appear to categorize pitch similarly to adults (Clarkson & clifton, 1984). Although infants can be considered unfamiliar with Western-European music, they have the opportunity of encountering the major triad by virtue of its frequency ratios, in every complex tone. There is therefore a possibility that the major triad has a priority in auditory pattern recognition in infancy. This would account for the significance of the major triad as a basic element of musical grammar. Following a review of these issues, we describe research directed at revealing infants' greater sensitivity to a melodic pattern which exploits the major triadic pattern as compared to one which does not. Although a group of 20 infants of 11 months can discriminate e semitone difference (frequency ratio 1.06) in one note of a major triadic sequence in the conditioned headturn procedure, a comparable group of infants performs no worse on a similar melodic pattern which lacks the major triadic structure. From these data, it appears that heightened sensitivity to the melodic major triad is not present at this early age and emerges with either maturation and/or experience before early childhood.

G2. "Expected Vocabulary Capacity of Automatic Speech Recognizers", J.Z. Jacobson, L. Vigneault (Bureau of Management Consulting), N.J. Pullman (Queen's University) and M.M. Taylor (D.C.I.E.M.) Toronto, Ont.

One such question concerns the evaluation of discrete utterance recognizers. There are several available such automatic speech recognizers (ASTR's) available; there are thousands or more of potential applications. It is not feasible to evaluate every device separately for each potential application.
There may be a shortcut. Output from a discrete-utterance ASR may be retrieved in the form of distances from an utterance to the stored templates. We hope to discover the finite space which any given device operates in, and estimate its volume. After that, we hope to measure the smaller finite volume that one attempt to say a single word falls into. Then dividing the first volume by the second gives the "Effective Vocabulary Capacity", an estimator of the machine's largest possible vocabulary.
Many things are not known, however.
The dimensionality of the space is not given. The metric is not given either. There are several reasonable metrics that could be used. It is not trivial to decide which one applies in any one case. Some machines may operate in city-block distances while others attempt to output normal Euclidean distances and still others may may operate by the maximum distance along any dimension.
Further, whatever the metric that the machine may be intended to use, is it being applied perfectly? Perhaps not, and that implies that the underlying space may be curved. For that matter the space may be discontinuous or piecewise continuous.
Different ones of these questions are solved in different ways. Given a known metric, for example, there are techniques to partition rectangular distance matrices so that templates and utterances may be plotted in the same space. Alternatively, by forcing templates to become utterances, it may be possible to make at least some of both to occupy the same space. Other techniques apply when those conditions do not hold.

33. "Un avenir pour la détérioration méthodique de la parole de synthèse de haute qualité", L. Santerre, G. Basque, Université de Montréal, Montréal, Qué.

L'analyse-synthèse de la parole nous a fait faire de grands progrès dans la connaissance des traits perceptifs de la parole, à la suite de Delattre et al. dans les années 50. Mais la perception n'a pas encore pris la place primordiale qui lui revient dans la définition des indices acoustiques de la parole.

Les tests de perception, qui sont toujours à la base des expériences d'analyse-synthèse de la parole (ou de musique - Xavier Rodet à l'Ircam de Paris), sont encore en partie faussés par la pauvre qualité de la synthèse; seules des manipulations sur la synthèse aussi parfaite pour l'oreille que la parole naturelle peuvent permettre d'apprendre ce qu'est la parole humaine elle-même.

Des progrès viennent d'être faits dans la synthèse de la parole de haute qualité. Une équipe de l'Université de Montréal et un laboratoire du CNRS (le LIMSI à Orsay) réalisent maintenant de la parole de synthèse qu'il est difficile de distinguer de la parole naturelle.

L'intérêt de cette synthèse de qualité est multiple:

1. Des tests de perception peuvent être très rigoureusement contrôlés tout en ayant la qualité de la parole humaine authentique.
2. On pourra à l'avenir dégager les indices acoustiques de la parole. On ne les connaît pas ou si peu.
3. Quand on connaîtra mieux les indices acoustiques de la parole, on aura fait un grand pas dans la programmation de la synthèse par règles pour faire parler les ordinateurs "comme du monde", non plus comme des robots stéréotypés.
4. Les domaines de recherche restent considérables: ce sont la description des indices acoustiques de la parole, des caractéristiques individuelles, des champs de variations stylistiques, et des seuils de perception.
5. Enfin la synthèse fine permettra sans doute de faire des progrès plus rapides dans la reconnaissance automatique du langage, en aidant à la simulation de la perception du langage réel.

P.S. On présentera une illustration sonore.

SESSION (H) ACOUSTIQUE ARCHITECTURALE

Président de séance
J. Rennie
SNC
Division Environnement

H1. "Sound Transmission Loss Measurement by the Sound Intensity Technique", R.W. Guy, A. De Mey, Centre for Building Studies, Concordia University, Montréal, Qué.

The sound intensity technique is being implemented to measure sound transmission loss at the Centre for Building Studies acoustic test facility, and its validation will be discussed.

The potential of this technique is explored by tracing the sound power flow through panels with and without absorbent lined sills and reveals.

H2. "A Transmission Loss Microcomputer Data Base", R.W. Guy, A. Munn, Concordia University, Montréal, Qué.

A database system consisting of wall section descriptions along with their transmission loss spectra (as reported by other workers) and their sound transmission class (STC) has been established. The system has been specifically developed for microcomputer use and employs data originally collated for minicomputer application without significant loss of detail.

The system has facilities for managing the data (changes, additions, deletions, and data disc creation) along with a search facility which allows the user to find panels according to stipulated requirements of weight, thickness, material type, number of layers, or STC. Source reference and mounting conditions for given entry are contained within that entries descriptive title.

The system is currently implemented on an Apple II Plus microcomputer in MBASIC and thus is portable to other microcomputer types. The database presently contains one thousand panel entries which is about the storage capacity of a one sided floppy disc.

A series of interactive menus guides the user through the various sections of the system which include provision for typed or graphical output of selected entries. Guide booklets describing the system and its use have also been prepared.

H3. "Airborne and Structureborne Noise Intensity Measurement by Using a Cross Spectral Technique", A. Chawla, N. Popplewell, Mechanical Engineering Dept., University of Manitoba, Winnipeg, R3T 2N2.

An investigation has been initiated in conjunction with a local computer manufacturer to develop a measurement system capable of determining airborne and structureborne noise intensities. The basic methodology of this system is based on a cross spectral technique. Its accuracy was assessed by using a digital computer as the source of sound and vibration. The predominant frequency inherent to the computer's dynamics was about 55 Hz which is somewhat lower than that normally encountered in airborne and structureborne intensity meausrements. Problems associated with determining such low frequency sound sources and the corresponding structureborne vibration paths will be discussed fully. The first part of the paper will compare overall sound power measurements with conventionally measured data and will present the more easily obtained ranking of the various sources. The second part of the paper will identify important structureborne vibration paths by using a novel cross spectral technique using two accelerometers. Finally, the correlation between the airborne and structureborne intensity data will be presented with a discussion of the resulting practical implications.

H4. "Privacy in Open Plan Offices", P. Moquin, Public Works, College Plaza, 8215-112 Street, Edmonton, Alb., T6G 5A9.

Open-plan offices are enjoying a comeback so it was felt that an acoustical standard should be established. A review of the literature was done. Using simplified acoustical formulae, a computer simulation was developed for calculating privacy in screened workstations by varying various parameters. Using a fixed masking spectrum, the effect of ceiling absorption, screen height and screen transmission loss were investigated. Correlation between computer simulation and test data was also performed. This information permits the development of specifications for various levels of privacy typically required in a government facility.

H5. "Etude du comportement acoustique des systèmes de partitions mobiles", C. Yockell, J.-G. Migneron, C.R.A.D., Université Laval, Québec.

Le travail de recherche présenté se divise en trois grandes parties. La première de ces parties portera sur les résultats relatifs à l'isolement global procuré par les partitions et sur l'étude des corrélations entre les résultats obtenus pour les deux directions de propagation, ou bien leur moyenne, en fonction de chacune des méthodes de mesure utilisées. La seconde partie concernera plus particulièrement, la qualité des joints et des partitions en relation avec les pertes ponctuelles d'isolement. On y fera dans un premier temps l'analyse des comportements des différentes sortes de partitions en se basant sur les pertes moyennes de l'ensemble des joints et sur la dispersion; en second lieu, on y considérera la qualité acoustique des différents types de joints, afin d'en déterminer la contribution en termes de perte d'efficacité acoustique et d'en vérifier l'importance selon les modèles. Un rappel des différentes méthodes de mesure utilisées lors de l'appréciation des qualités d'isolement global des partitions, complètera cette partie analytique et permettra de vérifier, en se basant sur l'étude des corrélations entre les résultats moyens d'isolement global et les pertes d'isolement ponctuel des différents types de joints, laquelle de ces méthodes est susceptible de caractériser le plus simplement possible le comportement réel de ce type de partitions. Enfin, la troisième partie portera sur l'étude de la relation existant entre l'isolement global d'une partition et la pente isolement/fréquence. On y fera l'étude du comportement des partitions en fonction du déplacement des pentes de la courbe d'indice d'affaiblissement acoustique de 125 à 1000 Hz, de 1000 à 4000 Hz et globalement de 125 à 4000 Hz, et on analysera finalement l'intimité procurée en fonction de ces pentes globales.

SESSION (I) ECRAN ET BRUIT COMMUNAUTAIRES

Présidents de séance
M. Amram
Ecole Polytechnique
Montréal
J.-G. Migneron
Université Laval
Québec

H6. "Experimental Measurements on Room Acoustics: A Critical Review of Reverberation Time Theories", V.J. Chvojka, G. Ostiguy, L. Mongeau, Département de mécanique appliquée, Ecole Polytechnique, Université de Montréal, Montréal, Qué., H3C 3A7.

The purpose of this presentation is to determine whether one theory of sound decay in a room is of greater value than others in predicting the reverberation time.

As a first step to this approach, acoustical properties of several lecture rooms of various shapes were measured regarding the following aspects: A) verification of the reverberation field hypothesis broadly applied to rooms by decay comparison measured in different source-receiver positions B) differences of decay variations by using a directional stationnary source (loudspeaker) versus the omnidirectional impulse source C) influence on decay of the presence in the room of various furnitures and accessories.

In order to achieve the calculations of reverberation time, we first used the Sabine Absorption Coefficient of all materials in the rooms to calculate their mean absorption coefficient. Furthermore, we also employed the Normal and Statistical Coefficients.

To reach the best theoretical approach, our results were compared to several statistical and geometrical theories such as those of Sabine, Eyring, Millington, Kuttruff, Fitzroy and Pujolle.

Our conclusion, even with our limited data, is in accordance with the one of Lim & Lehmann that no unique theory is perfect but they all complete each other.

The next step of our project is the search for the most reliable absorption coefficient.

H7. "A Comparison of Three Theatres", J.S. Bradley, Noise and Vibration Section, Division of Building Research, NRC, Ottawa, Ont., K1A 0R6.

Acoustical measurements were made in three quite different theatres. Conventional acoustical measures such as background noise levels and reverberation times were obtained as well as speech intelligibility scores. In addition, newer acoustical measures such as early-to-late arriving sound ratios and early decay times were calculated. The measurements are used to compare the acoustical qualities of the three theatres, to identify particular weaknesses and to demonstrate the value of the newer acoustical measures.

H8. "L'acceptabilité de l'isolation acoustique, pour l'occupant, est fonction du niveau de bruit de fond des pièces", J. Rennie, SNC, Division Environnement,

Les mesures d'isolation effectuées dans des bureaux et des logements ont démontré que l'occupant détermine en grande partie l'acceptabilité de l'isolation acoustique d'après le niveau de bruit de fond d'une pièce.

Les niveaux de bruit de fond mesurés dans divers logements et bureaux sont bien inférieurs à ceux que l'on attend dans le design acoustique des lieux. Ce problème peut être réglé par une approche globale, dont on discute, au moment de la conception des espaces occupés.

I1. "Développement d'un modèle informatisé pour l'étude d'impact des autoroutes et le calcul des écrans acoustiques", J.-G. Migneron, A. Esteve, P. Jacques, C.R.A.D., Université Laval, Québec.

Il existe de nombreux modèles mathématiques, depuis les approches de JOHNSON et SAUNDERS ou de RATHE, pour décrire l'impact acoustique de la circulation automobile. Néanmoins, le passage de la théorie à l'informatique, de façon à la fois pratique et réaliste, pose de nombreux problèmes, à commencer par les paramètres de circulation qui doivent être pris en compte, tels que la vitesse, le débit, le pourcentage de poids lourds, le nombre de voies, l'état de la chaussée, la pente des voies de circulation, la forme et la localisation du corridor par rapport aux terrains avoisinants, etc. Le CRAD de l'Université Laval a bâti, pour ses propres besoins de recherche et d'expertise, un modèle informatique très souple, dont le développement se poursuit encore présentement. Les problèmes résolus jusqu'à ce jour concernent les systèmes de coordonnées pour les voies, les écrans et les résidences exposées au bruit, ainsi que la production d'iso-contours dans des plans verticaux selon des paramètres reconnus, tels Leq, Leq (24 h), L 50%, L 99%, etc. L'exposé portera sur l'adaptation du modèle à la réalité urbaine, telle que mesurée sur le site, ainsi que sur les problèmes posés par la modélisation informatique dans des cas particuliers comme celui des écrans multiples, des autoroutes en tranchée ou des autoroutes en viaduc.

I2. "Etude sur maquette des effets d'interférences obtenus avec un écran ajouré déphaseur; vérification théorique et applications possibles", L. Drouin, J.M. Rapin, M. Amram, Ecole Polytechnique de Montréal, Département de génie physique, Montréal, Qué.

Cette étude a pour objectif de montrer qu'il est possible, à l'aide d'un nouveau type d'écran acoustique ajouré, d'obtenir des effets d'interférences intéressants, entre les ondes sonores de basses fréquences diffractées par le sommet et les ondes réfractées, c'est-à-dire transmises par transparence à travers la structure avec un retard de phase.

Pour les mesures, nous avons utilisé le Centre des Maquettes du C.S.T.B. de Grenoble, laboratoire spécialement conçu et équipé pour la représentation des phénomènes acoustiques sur modèles réduits à petite échelle. La méthode expérimentale consiste à comparer le champ de pression acoustique mesuré en arrière de l'écran ajouré déphaseur (superposition des ondes diffractées et réfractées) avec la somme des champs de pression mesurés séparément en arrière d'un écran plein de même forme (ondes diffractées seules) et en arrière d'un écran ajouré "bafflé" en son sommet (ondes transmises seules).

Les résultats des mesures, confirmés par la théorie élaborée à l'Ecole Polytechnique de Montréal, montrent que l'on peut obtenir des interférences destructives importantes aux basses fréquences, localisées autour de la ligne d'ombre. Ce procédé est actuellement en cours d'application en vue d'améliorer l'efficacité aux basses fréquences des écrans conventionnels.

. "Absorptive Materials for Sound Barriers Along Highways", F.W. Jung, C. Blaney, Ministry of Transportation and Communications, Research and Development Branch, 1201 Wilson Av., Downsview, Ont., M3M 1J8.

In cooperation with industry, the Ontario Government has actively pursued a program of developing sound absorptive materials which can be used with exterior barrier walls. The most successful designs are a combination of well tuned "Helmholz Chambers", in the form of perforated (or slit) panels, and weatherproof fibrous materials behind the panels. Experimental results from standing wave tube and standard reverberation chamber tests are compared with one another and with theoretical calculations. In particular, the following problems will be addressed:

1. Can standing wave tube tests be used to predict the Noise Reduction Coefficient (NRC)?
2. What are the limitations of simple standing wave tube tests in predicting NRC?
3. How does the NRC change with changes in design dimensions (% of holes and volume behind perforations, thickness and location of specific fibrous materials)?
4. Information on durability through weathering tests.
5. Presentation of systems successfully developed.

Research in this area is still ongoing, and more results will be presented at a later date.

4. "Propagation du son en présence des surfaces enneigées", G.A. Daigle, NRC, Ottawa et J. Nicolas, J.-L. Berry, GAUS, Université de Sherbrooke, Sherbrooke, Qué., J1M 2R1.

La modélisation de la propagation du son en présence d'une surface homogène a été largement traitée dans la littérature mais le cas d'une surface d'épaisseur finie reposant sur un milieu réfléchissant, a suscité que peu d'intérêt. A ce propos, des mesures d'atténuation sonore en présence de couches de neige d'épaisseur variant entre 5 et 50 cm ont été entreprises. Des expériences ont également été réalisées en intérieur sur des mousses réticulées en épaisseur finie. Les résultats obtenus révèlent l'inadéquation du modèle théorique assumant un milieu d'épaisseur finie et une extension simple est suggérée pour tenir compte de la transmission d'ondes sphériques dans le milieu poreux. Le modèle ainsi obtenu se compare très favorablement avec les expériences réalisées en milieu semi-anéchoique, ainsi qu'à la grande variété de surfaces enneigées envisagées.

5. "Underwater Measurements of Impact Noises on Ice", P. de Heering, M. Desparois, P. Sutcliffe, Canadian Astronautics Ltd., 1050 Morrison Drive, Ottawa, Ont., K2H 8K7.

Under a contract with the Department of Fisheries and Oceans, the authors have measured by means of underwater hydrophones the noise spikes produced in the water under an ice layer when a bullet hits the ice. These experiments were conducted both on the fresh water ice of the Ottawa River (February 1984) and on the sea ice near Resolute Bay (may 1984) with .30 and .46 caliber bullets of various types. The presentation will illustrate and discuss the various effects observed.

6. "Emission Levels of Vehicules in Ontario", F.J. Jung, C.T. Blaney, Ministry of Transportation, 1201 Wilson Av., Downsview, Ont., M3M 1J8.

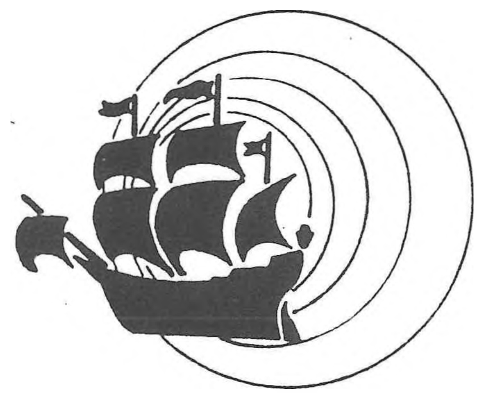
The FHWA-method of traffic noise prediction was set-up with a certain assumption on the average emission levels of the three categories of vehicles, cars, medium and heavy trucks. It was also recommended that each agency (State of Province) should investigate and check on emission levels of their vehicle fleets. Some agencies have carried out such investigations and have modified their input accordingly.
Ontario has embarked on a project to measure samples of vehicles and to use the results for recalibrating the emission level input equation of the FHWA-model. The report presents the results of such measurements, in terms of emission levels as a function of speed and frequency.

17. "Etude d'impact sur l'environnement sonore et vibratoire du métro de surface de Montréal", J.L. Allard, S.N.C., J.P. Panet, Ministère des transports, Montréal, Qué.

En prévision de l'implantation du métro de surface qui reliera Pointe-aux-Trembles au secteur ouest de l'Ile de Montréal, une étude d'impact sonore et vibratoire a été mise de l'avant afin d'analyser les répercussions d'un tel projet et d'identifier les mesures de mitigation réalisables pour ne pas dégrader la condition sonore actuelle.
L'étude d'avant projet répond aux directives du ministère de l'Environnement en ce qui concerne l'impact sonore causé auprès des riverains, fournit suffisamment de renseignements pour orienter ses concepteurs au point de vue de l'acoustique et traite de l'impact produit auprès des usagers et des employés du métro de surface.
Les sujets élaborés comprennent les normes à respecter, le climat sonore actuel et projeté, l'influence de la conception du matériel roulant sur la zone d'impact, l'étendue de la zone d'impact et vibratoire, les mesures de mitigation et impacts résiduels.

18. "Impact vibratoire relié au choix de la technologie de matériel roulant utilisé pour le métro souterrain à Montréal", J.L. Allard, J. Rennie, S.N.C.,

Etude préliminaire visant à préciser l'impact vibratoire engendré par l'implantation d'une ligne de métro souterrain du type fer sur fer.
Les sujets traités sont: Choix d'une norme acceptable pour les riverains du projet (bruit et vibrations), influence de la conception du matériel roulant sur l'étendue de la zone d'impact, propagation des vibrations dans le sol et dans les résidences, importance de l'impact produit et solutions retenues pour rendre acceptable le projet.



FISHERIES HYDROACOUSTICS AT THE PACIFIC BIOLOGICAL STATION IN NANAIMO B.C.

R. Kieser
Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

RESUME

Les méthodes hydroacoustiques constituent un outil important pour repérer et évaluer les poissons et le plancton. Divers appareils acoustiques puissants sont maintenant utilisés couramment par les pêcheurs, les gestionnaires et les scientifiques. Leur efficacité repose sur plusieurs principes fondamentaux qui rendent possible la télédétection de paramètres biologiques sous l'eau. Un certain nombre de techniques acoustiques sont utilisées régulièrement à la Station de biologie du Pacifique située à Nanaimo, et on en donne ici une brève description. On utilise, à titre d'exemples, un levé par intégration des échos de merlus du Pacifique et une expérience qui compare un dénombrement visuel et acoustique de saumons.

ABSTRACT

Hydroacoustic methods provide an important tool to detect and assess fishes and plankton. A variety of powerful acoustic devices are now in general use by fishermen, managers and scientists. Their success is based on several fundamental principles which make underwater remote sensing of biological parameters possible. A number of acoustic techniques, routinely used at the Pacific Biological Station in Nanaimo are briefly described. An echo integration survey of Pacific hake and an experiment that compares a visual and an acoustic count of salmon are used as illustrations.

Hydroacoustic methods play an important role in commercial fishing, fisheries management and fisheries research. The three endeavours rely on similar methods, but differ in the required accuracy, precision and timeliness of the results.

The most common acoustic device in fisheries is the vertically oriented sonar (echosounder), Fig 1. The usefulness of the echosounder and other hydroacoustic devices in fisheries is based on several phenomena:

1. Sound waves present the only form of energy that propagates in water with reasonable speed and relatively small attenuation and dispersion.
2. Fishes and plankton usually are the major scatterers in the water column.
3. Sufficiently reliable relations exist between the acoustic properties of fishes and some biological parameters of interest, e.g. fish target strength and fish weight or length.
4. Availabilty of hardware and trained personnel.

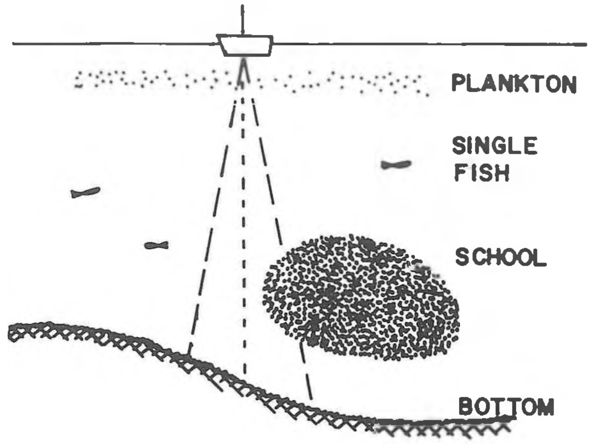


Figure 1. A vertically oriented sonar (echosounder), the most common acoustic device in fisheries.

It is important to note that alternate or conventional methods generally depend on direct visual observations or on some form of catching the fish. Visual observations are limited to clear water and short distances. Methods that rely on catching the fish are relatively labour intensive, slow and sample a small volume of water only. A typical trawl fishing operation is shown in Fig 2, it gives an impression of the coordinated and often large effort that is required.

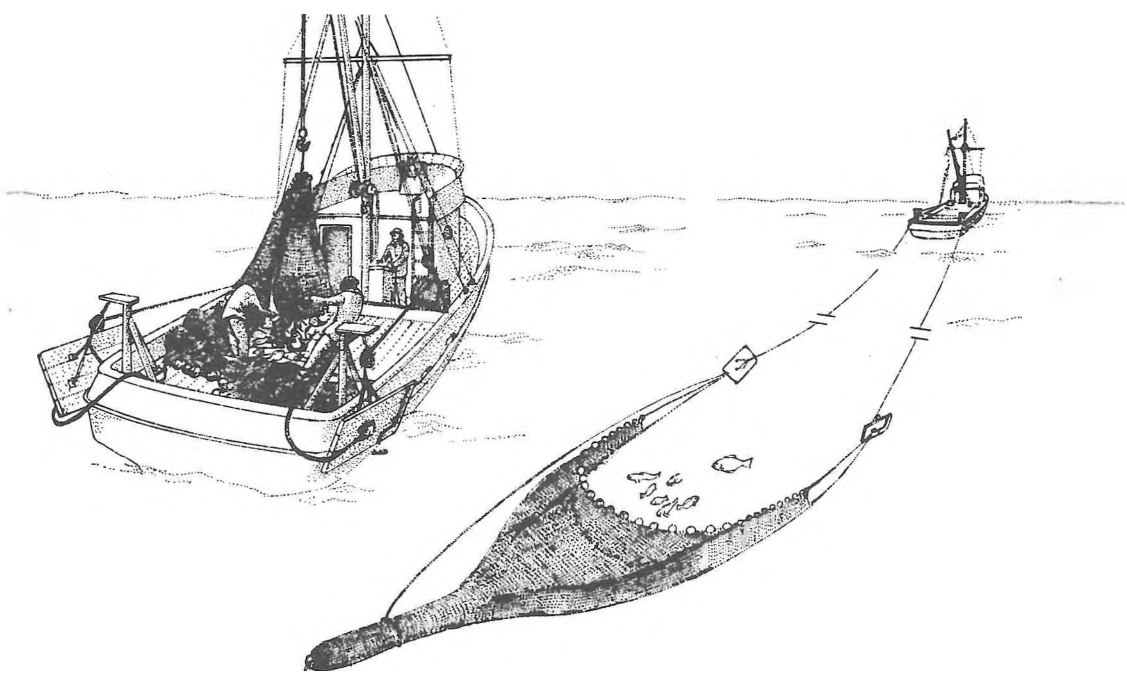


Fig. 2. A typical trawl fishing operation.

The following activities highlight the acoustic methods that are currently used at the Pacific Biological Station (PBS):

- Echo counting: This method determines fish number density from a visual count of the echo traces on the echogram, Fig 3. Alternately the resolved single fish echoes can be counted from an oscilloscope that is connected to the echosounder's receiver output, Fig 4.

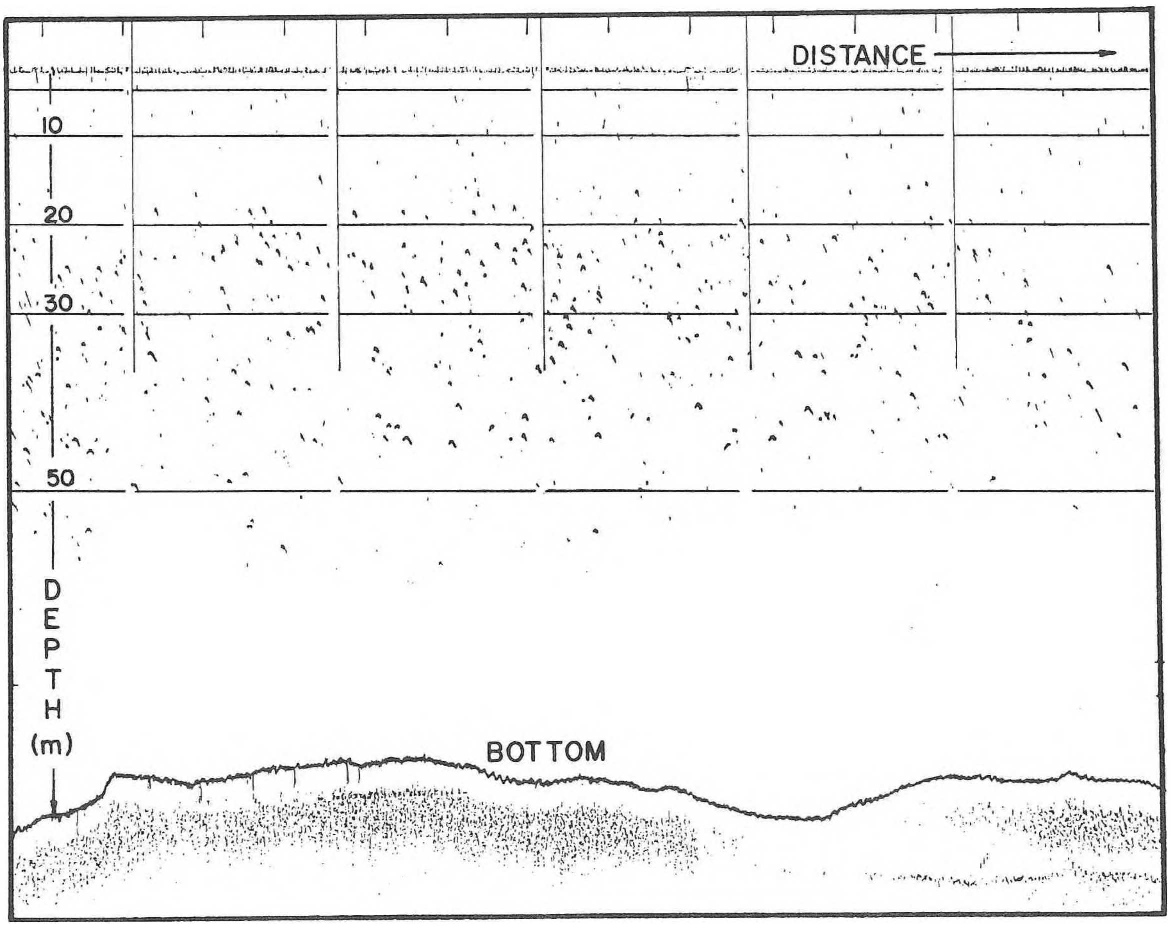


Fig. 3. The echogram gives a visual presentation of the echo returns as a function of depth and distance travelled. The depth below the transducer and the distance travelled are marked on the vertical and horizontal axis respectively. The bottom is shown as an irregular dark line. The single fish echo traces indicate a light layer of fish at about 30 m depth.

- Echo integration: This method determines fish biomass density from a measurement of the mean acoustic backscattering strength.
- Single beam target strength analysis is used to determine fish size.
- Acoustic fence: This device counts the number of fish that migrate up or down stream, Fig 5.

More sophisticated methods have been developed at the University of Washington, Seattle, Wa. and elsewhere. These include:

- Acoustic doppler measurements to detect fish movement and tail beat frequencies.
- Special beam forming and signal processing schemes to extract fish target strength.
- Swimbladder resonance measurements correlate with fish size.
- Multi-frequency measurements to provide an indication of the insonified fish species.

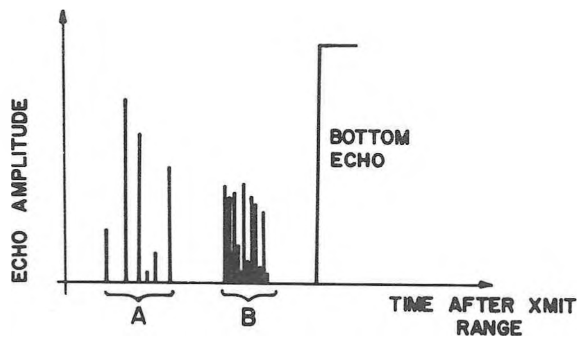


Fig. 4. Oscilloscope display of the echosounder receiver output. 'A' are resolved single fish echoes, 'B' are nonresolved echoes. The bottom echo saturates the receiver.

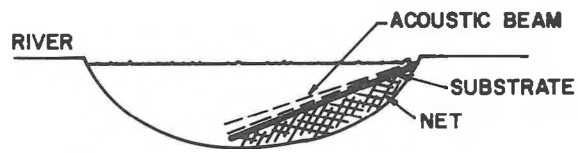


Fig. 5. The acoustic fence is deployed perpendicular to the shore. It crosses the migration path of the salmon, which often is near the shore rather than in the middle of the stream. The sketch shows the acoustic beam. Fish are guided through the beam by a net that is suspended from a pipe, just below the beam.

Generally acoustic methods provide a powerful tool for low resolution remote sensing of fishes and plankton. Ranges may be as large as many hundred meters for a 10 kHz Sonar which may have a range resolution of the order of one meter.

Increased resolution can be obtained at higher frequencies but the maximum range will be reduced.

Our work at PBS has focussed on improving acoustic estimation procedures and on demonstrating their usefulness to fisheries and fisheries management. To achieve these objectives we have pursued four major goals:

1. Set up a versatile, calibrated fisheries acoustic system.
2. Develop real time data analysis methods to obtain feedback during the experiment.
3. Develop hardware and software to record digitized echo returns and to analyse them on a central computer.
4. Identify fisheries situations where acoustic methods are appropriate and demonstrate their relevance.

At present our major effort is directed towards digital data analysis and experiments.

To illustrate our work I will describe an acoustic survey that was designed to determine the offshore hake biomass and its distribution and an experiment that compares acoustic estimates of the number of salmon in a lake with a visual weir count.

A TYPICAL OFFSHORE HAKE SURVEY

The successful estimation of a fish stock often depends on a detailed knowledge of the fish's life cycle. In many cases there is only a short time during which a particular fish stock can be acoustically assessed. At other times the fish's proximity to the surface or to the bottom or a mixing of species may make an estimate impossible.

Pacific hake occur on the west coast of North America from Santa Cruz, California, (36° 50'N) to Vancouver Island, British Columbia, (49° 00'N). Like many other species hake are best estimated in their spawning/feeding aggregations. These are pelagic and quite characteristic, thus signals are readily separated from surface and bottom echoes and can be distinguished from plankton, herring, rockfish and other species that may be present in the same area at the same time.

Hake is the target species for a large, international joint fishery that takes place annually off the west coast of Vancouver Island during July through September. (A similar joint fishery takes place off the coast of Washington.) Canadian trawlers and Polish and Russian factory vessels catch and process in excess of 30,000 tons of hake. Management of this fishery requires an estimate of the total resource, such an estimate can be obtained by echo integration.

The echo integration system was installed onboard the Canadian Research Vessel G.B. Reed. Its major components are shown in Fig 6. A single transducer is used to transmit a short pulse and to receive the echoes. It is mounted in a torpedo shaped towed body which is towed by an armoured cable that also provides the connection to the echo sounder. The echo sounder output is displayed on a chartrecorder and an oscilloscope and is recorded on analog tape as a backup. The same signal is also connected to the echo integrator which measures the average echo power for a specified number of depth slices. This measurement is proportional to the average volume backscattering strength. A printed output is available, it can be scaled to present fish biomass. These data are stored on 1/2 in. digital magnetic tape and are processed by the onboard computer to yield estimates of fish surface density and total biomass in the survey area.

The system is characterized by the following parameters: Frequency 38 kHz, pulse length .6 ms, pulse repetition 2 Hz and transducer full beamwidth between half-power points 10 degrees. The receiver has a 'time-varied gain' that compensates for the spreading and absorption losses that the acoustic pulse experiences in the water.

During late August and early September 1983 we have surveyed the shelf area off Vancouver Island that extends from the 48-th to the 49-th parallel and out to the 300 m depth contour. The survey encompassed ~8500 km^2 and was covered by a rectangular transect grid of ~1800 km length. The average spacing between the parallel transects was 4.7 km. The nominal survey speed was 17 km/hr.

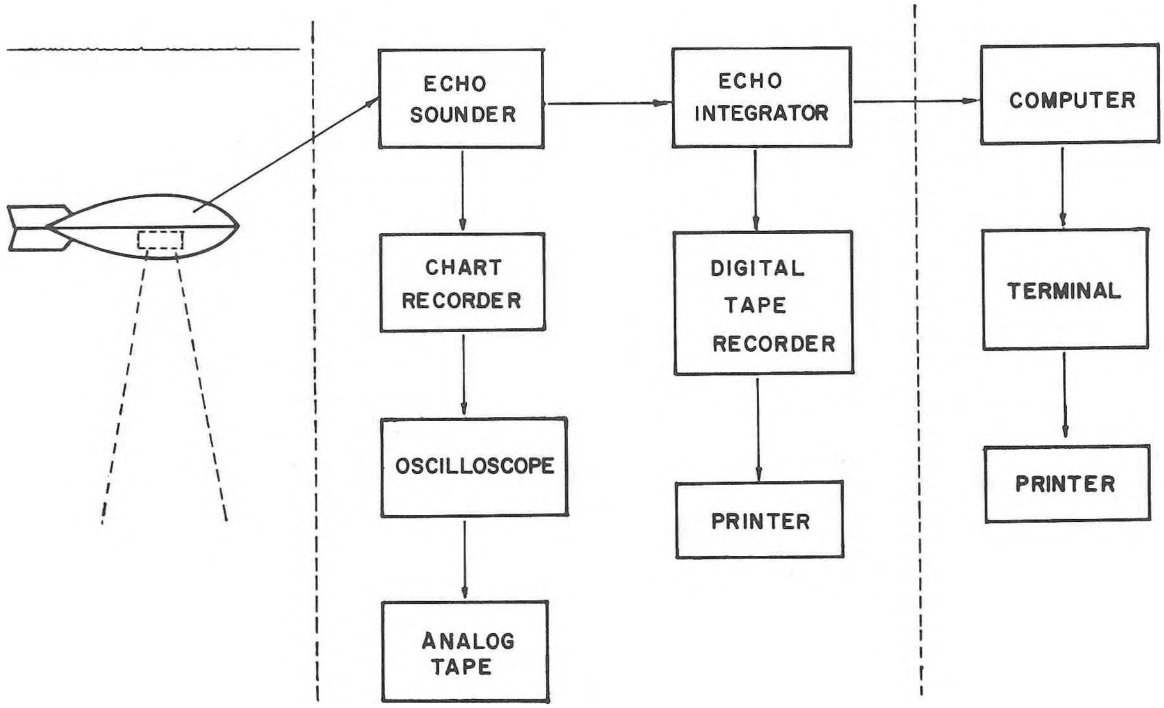


Fig. 6. The echo integration system. The transducer is mounted in a torpedo shaped body and towed from the stern of the vessel. The echogram, the oscilloscope and the printed output from the echo integrator provide immediate feedback on systems performance and fish densities. The computer is used to produce fish surface densities and biomass estimated.

The echo integrator output was processed to yield an estimate of the average fish surface density (kg/m2) every six minutes. This was plotted on a daily basis as a bar graph along the transects, Fig 7. A map of the biomass distribution in the area results when the transects and densities are plotted on a hydrographic chart, Fig 8.

The total fish biomass for all species in the survey area was estimated as 280,000 tons. The species composition has been obtained from a careful visual interpretation of the echograms and from the net catches that were made by a second vessel. Based on this additional information the total hake biomass was estimated as 140,000 tons.

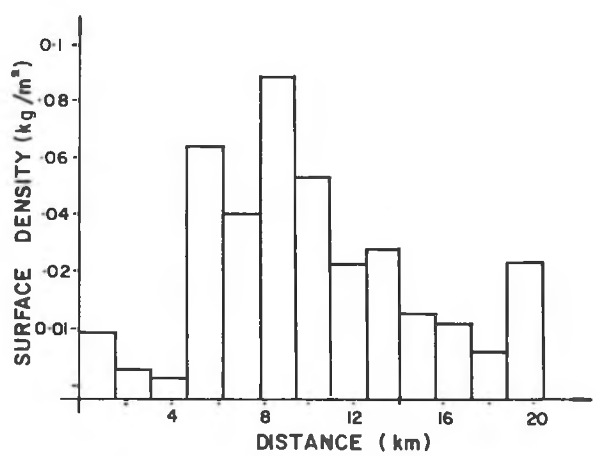


Fig. 7. A plot of surface density versus distance gives an impression of the fish distribution along the transect.

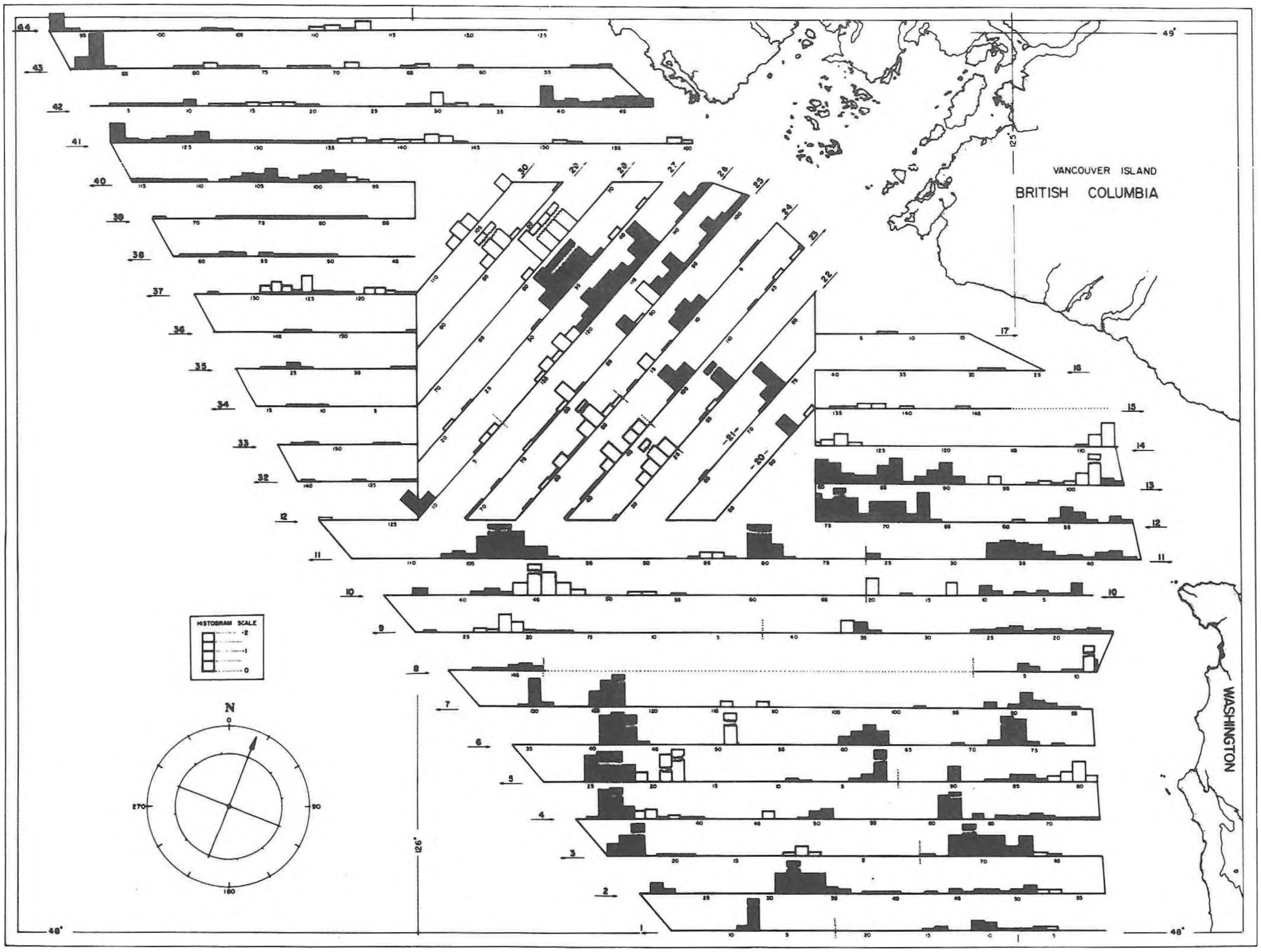


Fig. 8. The biomass distribution is shown by plotting the surface densities along the transects on a hydrographic chart. The scale used for the bars is shown above the compass rose, those that exceed .2 kg/m^2 are broken. Solid bars indicate hake, all other fishes are represented by open bars.

The accuracy of these estimates has been inferred from detailed considerations of the measurement process. An accuracy of 20% is expected for the measurement of the total acoustic backscattering strength from the insonified volume. Major sources of uncertainty occur when the measured backscattering strength is converted to a biomass estimate. Typical sources are: extrapolation from the insonified volume to the total volume of interest, fish target strength and species identification. The absolute acoustic biomass estimates may be accurate to within a factor of two, for this reason the better relative estimates are used whenever possible. It is important to note that comparable nonacoustic estimates have equal or larger errors.

The above estimates are valuable for the manager and biologist, and are used to manage the hake stock, to maximize the catch and to protect the fish stock from overfishing.

COMPARISON OF HYDROACOUSTIC ESTIMATES OF SALMON WITH A WEIR COUNT

Fisheries hydroacoustic methods are frequently employed but seldom verified. We have conducted an experiment that compares various acoustic estimates with each other and with an independent weir count, thus providing a direct indication of the accuracy of hydroacoustic estimation methods. The experiment was conducted in Long Lake near Smith Inlet B.C. A sockeye salmon run ascends the Docee River and reaches Long Lake during July. For many years a weir has been operated across the river to obtain a visual count of the total number of salmon that migrate into the lake. The salmon remain in the lake before they migrate into the tributaries where they spawn in the gravel beds. There is a period of several weeks when essentially all fish have been counted across the weir, yet none have appeared in the rivers that feed the lake. At this time the entire stock is in the lake. At night the fish are distributed in the water column and can be assessed acoustically. The acoustic gear was installed on a small skiff and eight surveys were carried out on four consecutive nights (July 31 - Aug 4, 1982).

Our comparative study has used the following methods to estimate the total fish population in the lake:

1. Weir count:
The fence was operated by fisheries management personnel who visually counted the number of salmon that migrated upstream into the lake.

2. Echo trace counting:
The single fish echo traces were counted from the echograms that were recorded during the surveys. A simple model was developed to estimate the number of fish per cubic meter from the trace count. An estimate of the total number of fish in the lake was derived.

3. Echo pulse counting:
The echo traces that were analysed above often include many successive echo returns. A pulse count is easily obtained from the digitized echo returns and can be converted to a fish number density. It yields a second estimate of the total number of fish in the lake.

4. Echo integration:
The same echo returns were used to measure the average volume backscattering strength for the depth interval of interest. This measurement provides an estimate of the fish biomass per cubic meter, which was extrapolated to obtain the total fish biomass in the lake. A fish target strength of -32 dB/kg was used for the analysis. The measured average fish weight of 2.9 kg was used to calculate the total number of fish in the lake.

The total number of salmon that was estimated by each of the four independent methods is given in the following table. The last row gives estimated accuracies for the population estimates that are based on detailed considerations of the measurement process.

Visual	Acoustic			
Weir count	Trace count	Pulse count	Integration 20logR	
200	120	121	197	10^3 # of fish
			571	10^3 kg of fish
±10%	±20%	±20%	±50%	Est. accuracy

Considering the expected accuracy of the various methods we have to conclude that the acoustic estimates agree with each other. There, however, is a discrepancy between the acoustic counting data and the visual fence count. Two possible reasons for the difference are: The fish might have avoided the noisy survey vessel or their distribution in the lake might have been less homogeneous than assumed. The data are insufficient to resolve the problem.

The different types of analyses presented above are frequently used by themselves but seldom on the same data set. A major point of this experiment was the comparison of the various methods with each other and with the independent estimate that was obtained from the weir count.

Recent developments in instrumentation and data processing have transformed fisheries acoustics into a field with new possibilities. Acoustic methods have reached a stage where they can compete with and supplement conventional fisheries sampling methods. Exciting new methods are now within reach of fisheries research which will lead to a better understanding of the fundamental acoustic processes and of fisheries biology itself.

ACKNOWLEDGEMENT

The hake survey and the salmon experiment were carried out by the hydroacoustics group at PBS under the direction of T. J. Mulligan. L. W. Barner and R. M. Hungar assisted in all phases of this work, their contribution is gratefully acknowledged.

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FIRMS FINDING APPLICATIONS FOR ACOUSTIC SURFACE WAVES*

By:
David Helwig

Surface acoustic wave devices that process electronic signals by turning them into sound are beginning to find their way into Canadian-built communications equipment. "It's a technology that's been around for a while, but its many potential applications are just beginning to be utilized in Canada," said Ezio Berolo, a project leader at the federal Government's Communications Research Centre in Ottawa. The centre has been designing the micro-electronic devices since 1975. "Back then, we had to catch up to the United States, the United Kingdom, and Japan. Now we are making significant contributions ourselves."

Surface acoustic wave technology involves converting electromagnetic waves to Rayleigh waves -- physical vibrations that ripple along the surface of an object. In effect, the speed of the waves is reduced from the speed of light to about 3,100 metres a second. "You can do things to the signal when it's slowed down that you couldn't possibly do when it's travelling at the speed of light. For example, you can perform complex mathematical functions, such as Fourier transformations," said Val O'Donovan, president of Com Dev Ltd. of Cambridge, Ont.

Mr. O'Donovan's company, which makes communications equipment used in commercial satellites, has been working with surface acoustic wave devices for three years, in conjunction witht the federal Department of Communications and the National Research Council. The world market for the devices is about $10-million a year, but is expected to grow to $1-billion by 1990, Mr. O'Donovan said. Com Dev has spent $2-million on research in the area, and is making a capital investment of $500,000 this year for equipment to make the devices. The company hopes the technology will enable it to broaden its product line to include two new fields: signal processing and radar systems.

Com Dev is developing equipment to process photographs transmitted by satellites, Mr. O'Donovan said. He hopes the application of surface acoustic wave devices will permit processing speeds to be increased by a factor of 10 over available equipment. The resulting pictures lack the quality obtainable from current equipment, but would be useful for screening large numbers of photographs, he said. Com Dev has received $300,000 in grants from the Department of National Defence to use the technology to develop radar systems with greater range of accuracy without increasing power requirements.

Bell-Northern Research Ltd., a unit of Bell Canada Enterprises Inc. of Montreal, has also received a defence grant to apply surface acoustic wave devices to processing of radar signals.

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RMS Industrial Controls Inc. of Port Coquitlam, B.C., a company involved in ultra-high frequency communications and microcomputer control systems, recently introduced its first radio transceiver module containing the technology. Peter Boorman, the company's vice-president, said a surface acoustic wave device was used to replace the transceivers' voltage control oscillator to reduce microphonics -- electronic noise caused by vibration. The technology also allows the radio to operate on 160 channels, and Mr. Boorman said RMS hopes to produce a radio that can be used on 2,000 channels. In addition, the company is looking at the possibility of mounting a surface acoustic wave device along with other components on thin film to produce a hand-held radio transceiver.

The largest application of the technology to date has been in frequency filters for television receivers. Colin Campbell, a professor of electrical and computer engineering at McMaster University in Hamilton, Ont., said about 12 million surface acoustic wave devices are used each year by television manufacturers in North America and Europe. "Virtually every domestic television receiver made in Japan now uses these devices," said Mr. Campbell, who has assisted both Com Dev and RMS in applying the technology. He is using it himself to develop a new resonator for television and precision radar applications. Surface acoustic wave technology enables the active part of some electronic filtering circuits to be reduced in size 100,000 times, he said. The circuits do not require hand tuning.

Velimir Ristic, a professor of electrical engineering at the University of Toronto, is using the devices in conjunction with integrated optics technology for potential applications in satellite communications and navigational systems in aircraft.

At McGill University in Montreal, Professor Eric Adler is seeking to develop a more complex surface acoustic wave device that can be mounted as part of an integrated circuit. Mr. Adler is trying to develop a device using Lamb waves -- sound waves that vibrate on a thin membrane instead of a thick surface. In addition, he is studying the possibility of using a surface acoustic wave device to deflect optical waves. Another McGill scientist, electrical engineering dean Gerald Farnell, is using acoustic waves to study the microscopic features of matter. The acoustic microscope, which is being developed in a joint effort by McGill, the National Research Council and the University of Sherbrooke, uses high-frequency ultrasound to produce images similar in quality to those produced by optical microscopes. Because it uses acoustic rather than light waves, the microscope can reveal details of an object's interior, a feature that could be used to detect faults in micro-electronic circuits.

THE TRANSMISSION OF SOUND THROUGH WALLS, WINDOWS, AND PANELS: A ONE DIMENSIONAL TEACHING MODEL

By:
R.W. Guy
Centre for Building Studies, Concordia University
Montreal, Quebec, Canada H3G 1M8

ABSTRACT

A One dimensional mathematical teaching model which incorporates many of the sound transmission characteristics found in real panels, has been developed.

The model enables the ready formulation of panel velocities and sound pressure level ratios for simple and multiple panel systems. The analysis is ideally suited for micro computer application.

SOMMAIRE

Un modèle mathématique à une dimension, incorporant plusieurs caractéristiques de transmission sonore propres à des panneaux réels a été développé pour des applications pédagogiques.

Le modèle permet de calculer les vélocités et le niveau de pression sonore pour des systèmes de panneaux simples et multiples. L'analyse s'adapte parfaitement à des applications sur micro-ordinateur.

LIST OF SYMBOLS

A	Constant of equations 5 and 6
B	Constant of equations 5 and 6
B	Plate bending stiffness defined after equation (36)
B'	Complex Plate stiffness
b	Panel length
C	Panel damping
c	Panel width
d	Depth or axial distance
E	Youngs Modulus
e	Exponential
F	Forces
h	Panel thickness
j	$\sqrt{-1}$
K	Panel spring stiffness constant
k	Wave number
M	Mass
P	Pressure
q	Modal integer
R	Real or resistive component
r	Modal integer
SPR	Sound pressure ratio
t	Time
t'	Thickness of absorbent material, employed at equation (30)
V	Velocity
X	Imaginary or reactive component
x	Spatial ordinate
Z	Impedance
Z'	Normalised impedance
α	Resistive component of complex propogation constant
β	Reactive component of complex propogation constant
η	Material internal damping factor
θ	Angle of incidence
Π	Successive products
ρ	Density
ψ	Velocity potential
ω	Angular frequency

Suffix

A	Designator employed after equation (20)
B	Designator employed after equation (20)
i	Variable integer relating to panel number
i'	Incident
L	Left of
m	Mechanical (in vacuo)
n	Relating to the last panel
o	Material or propogating medium property
p	Panel
q	Panel mode in y direction
R	Right of
r	Panel mode in Z direction
r'	Reflected
rr	Rereflected

1. INTRODUCTION

The teaching of sound transmission through windows, walls, and panels is typically achieved by presenting a series of simple models each of which attempts to describe a trend or phenomenon observed in practice.

Such models lead, for example to a qualitative understanding of the 'Stiffness Controled Region', the 'Damping Controled Region', the 'Mass Controled Region', the 'Coincidence Region, as applied to single leaf systems, and the 'Mass Spring Mass Resonance' encountered in double leaf systems

The models generally involve infinite panels and consider the influence of incidence angle upon various resonant frequencies, whilst in practice the most prominent resonance - 'Mass Spring', 'Coincidence', and 'Mass Spring Mass', have been found independent of angle; meanwhile the models do not readily consider the influence of 'Room Effects', 'Multiple Panels', 'Multiple Resonance', 'Absorbent layers', since their inclusion is usually accompanied by complicated analysis and interpretation, however each of these factors may drastically change the manifestation of a 'Region', or 'Resonance Conditions'. In consequence a need exists to expand the 'repertoire' of model types whilst avoiding the complexities of model formulation and analytical intractability.

In an attempt to satisfy these requirements an analytical structure and procedure based upon the work of Nestrov [1] is developed which the student may employ to generate formulations in a simple manner, for models ranging from the most rudimentary to complicated multi-faceted systems; the analytical procedure developed is capable of implementation on micro computer systems and applied in this way will assist in relieving problems associated with analytical intractability.

The present analysis is generally confined to one dimensional considerations particularly with respect to incident air born waves, thus complexity of analysis is eased, however the concept and influence of two dimensional panel vibration is introduced for illustrative purposes.

2. BASIC TERMS AND EXPRESSIONS

2.1 THE WAVE EQUATION

The one dimensional form of the acoustic wave equation may be written as, [2]:

$$\frac{d^2\psi}{dx^2} = \frac{1}{c_0^2}\frac{d^2\psi}{dt^2} \qquad (1)$$

where
ψ is the velocity potential
c_0 is the velocity of sound in the medium
x a spatial coordinate
t time

Confining attention to the steady state harmonic form, that is

$$\psi \propto e^{j\omega t}$$

where ω is the angular forcing frequency.
Equation (1) may now be rewritten as:-

$$d^2\psi/dx^2 + k^2\psi = 0 \qquad (2)$$

where k is the wave number ($k = \omega/c_0$).

The wave equation is here expressed in terms of the velocity potential 'ψ' to facilitate the derivation of expressions for pressure and particle velocity via the relationships:-

$$V = d\psi/dx \qquad (3)$$

where V is the acoustic particle velocity

and $P = -\rho\, d\psi/dt$

which, for the steady state harmonic case yields:-

$$P = -j\rho\omega\psi \qquad (4)$$

where P is the excess or acoustic pressure
ρ is the density of the propogating medium

Non trivial solutions of the wave equation may be expressed in several ways: one common form of solution to equation (2) being:-

$$\psi = A\,e^{j(\omega t - kx)} + B e^{j(\omega t + kx)} \qquad (5)$$

where A and B are the wave amplitudes of two distinct plane waves travelling in opposite direction. the wave amplitudes are determined by having equation (5) satisfy the prevalent boundary conditions.

An alternative form of solution to equation (2) may be written as:-

$$\psi = [A\cos(kx) + jB\sin(kx)]e^{j\omega t} \qquad (6)$$

where A and B are also determined from the applied boundary conditions.

The common time dependence $e^{j\omega t}$ will subsequently be ommitted for brevity.

2.2 IMPEDANCE

Specific Acoustic Impedance Z

Z is defined as the ratio of excess pressure 'P' at a point to the acoustic particle velocity 'V' at that point,

thus $Z(x) = P(x)/V(x)$ (7)

For example, in the case of a positive going plane wave as described by the first term on the right hand side of equation (5) one can, by utilising the relationships shown in equations (3) and (4), show that

$$Z_{(+)} = \rho c_o \qquad (8)$$

where the index (+) indicates a positive travelling wave.

Similarly, for the negative travelling wave described by the second term on the right hand side of equation (5),

$$Z_{(-)} = - \rho c_o \qquad (9)$$

where the index '(-)' indicates a negative travelling wave

Normalised Impedance Z'

Z' is defined as the ratio of the specific impedance to that of a standard impedance.

A common 'standard impedance' is the 'characteristic impedance' of air 'ρc_o'.

Mechanical Impedance Zm

Zm is defined here as the ratio of the vibratory force 'F' per unit area acting on a surface to the vibratory velocity 'V' of the surface caused by that force

thus. $Zm = F/V \qquad (10)$

In the case of a panel caused to vibrate by acoustic pressures acting on either side of it, one may write:-

$$Zp = (P_L - P_R)/Vp \qquad (11)$$

where Zp is the panel impedance
P_L is the pressure acting on the left side of the panel
P_R is the pressure acting on the right side of the panel
Vp is the panel velocity

3. BASIC MODEL AND ANALYSIS

The basic model consists of the i^{th} and (i+1) vibrating panel separated from each other by a distance d_i and forming part of 'n' vibrating panels in series as shown in Figure (1).

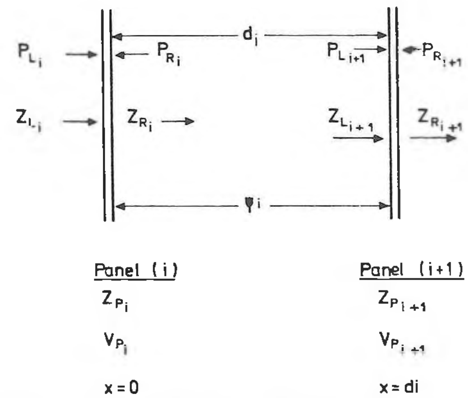

Figure 1 - Model describing parameters for the interspace between vibrating panels

With respect to Figure (1) the indices 'i' and 'i+1' denote 'with respect to given panel', and for each panel

	P_L	is the acoustic pressure developed on the left
	P_R	is the acoustic pressure developed on the right
	Z_L	is the total impedance of the system to the right of and including the given panel
	Z_R	is the total impedance of the system to the right of the given panel
	Z_P	is the panel's mechanical impedance
	V_P	is the panel's velocity
and	ψ	is the velocity potential between panels

3.1 THE ANALYSIS

Consider in the first instance the forces acting on the i+1 panel.
Recalling equation (11) and rewriting :-

$$V_{P_{i+1}} = (P_{L_{i+1}} - P_{R_{i+1}})/Z_{P_{i+1}} \quad (12)$$

Recalling also equation (7) and considering the right hand surface of the i+1 panel:-

$$P_{R_{i+1}} = V_{P_{i+1}} \cdot Z_{R_{i+1}} \quad (13)$$

Substituting equations (13) into equation (12) yields

$$P_{L_{i+1}} = V_{P_{i+1}} \cdot (Z_{P_{i+1}} + Z_{R_{i+1}})$$

or, again noting equation (7)

$$Z_{L_{i+1}} = Z_{P_{i+1}} + Z_{R_{i+1}} \quad (14)$$

Since no assumption has been made concerning the nature of $Z_{R_{i+1}}$ one may generalize the result shown in equation (14) by writing

$$Z_{L_i} = Z_{P_i} + Z_{R_i} \quad ;i=1,2,3\ \ldots n \tag{15}$$

Consider now the velocity potential developed between the i^{th} and (i+1) panels.

Recalling equation (6), one may write the velocity potential as

$$\psi_i = A_i \cos(kx) + jB_i \sin(kx) \text{ for } 0 \leqslant x \leqslant d_i \tag{16}$$

Noting the relationship between velocity potential and particle velocity shown in equation (3), one may form the boundary conditions:-

$$\left(\frac{d\psi}{dx}\right)_{x=0} = V_{P_i}, \text{ and } \left(\frac{d\psi}{dx}\right)_{x=d_i} = V_{P_{i+1}} \tag{17}$$

Applying the boundary conditions of equations (17) to equation (16) yields

$$\psi = V_{P_i} \cdot \frac{\cos\,(k[di-x])}{k\,\sin(kd_i)} - V_{P_{i+1}} \cdot \frac{\cos(kx)}{k\,\sin(kd_i)} \tag{18}$$

Applying the relationship of equation (4) to equation (18), one may form an expression for the pressure at any point 'x' between the panels as:-

$$P_{i(x)} = -V_{P_i} \cdot j\rho c_0 \cdot \frac{\cos(k[d_i-x])}{\sin(kd_i)} + V_{P_{i+1}} \cdot j\rho c_0 \cdot \frac{\cos(kx)}{\sin(kd_i)} \tag{19}$$

or, setting $x = d_i$ in equation (19)

$$P_i\ (x=d_i) = P_{L_{i+1}} = V_{P_i} \cdot Z_{B_i} - V_{P_{i+1}} \cdot Z_{A_i} \tag{20}$$

where $Z_{A_i} = -j\ \rho c_0 \cot(kd_i)$ and $Z_{B_i} = -j\ \rho c_0\ \mathrm{cosec}(kd_i)$

Now, $$V_{P_{i+1}} = P_{L_{i+1}} / Z_{L_{i+1}} \tag{21}$$

thus replacing $V_{P_{i+1}}$ in equation (20) by equation (21) one finds

$$P_{L_{i+1}} = V_{P_i} \cdot Z_{B_i} \cdot Z_{L_{i+1}} / (Z_{A_i} + Z_{L_{i+1}}) \tag{22}$$

or replacing $P_{L_{i+1}}$ from equation (22) into equation (21)

$$V_{P_{i+1}} = Z_{B_i} \cdot V_{P_i} / (Z_{A_i} + Z_{L_{i+1}}) \tag{23}$$

setting $x = 0$ in equation (19)

$$P_i\ (x=0) = P_{R_i} = Z_{A_i} \cdot V_{P_i} - Z_{B_i} \cdot V_{P_{i+1}} \tag{24}$$

Replacing $V_{P_{i+1}}$ from equation (23) in equation (24) yields

$$P_{R_i} = V_{P_i} \left[Z_{A_i} - Z_{B_i}^2/(Z_{A_i} + Z_{L_{i+1}}) \right] \tag{25}$$

and finally, forming the impedance Z_{R_i}, and rearranging, thus

$$Z_{R_i} = P_{R_i}/V_{P_i} = Z_{A_i} - Z_{B_i}^2/(Z_{A_i} + Z_{L_{i+1}}) \tag{26a}$$

where Z_{A_i} and Z_{B_i} are defined after equation (20).

Equation (26a) expresses the impedance relationship in a form suitable for deriving the recurring fraction one may develop to express the impedance of a multi layered system, Nestrov [1].

By re arranging trigonometric terms and utilising normalised impedance one may express equation (26a) as:-

$$Z'_{R_i} = (Z'_{L_{i+1}} \cdot \cos(k \cdot di) + j\sin(k \cdot di))/(\cos(k \cdot di) + jZ'_{L_{i+1}} \cdot \sin(k \cdot di)) \tag{26b}$$

where Z' represents the normalised impedance $Z/\rho c_0$

Equation (26b) may be recognised as a generalised input impedance, similar to the case of a pipe terminated by an impedance Z_L, Kinsler and Frey [2, Chapter 8.7]; also this mathematical form eliminates 'removable singularities' and thus is better suited for computational purposes.

In summary, the input impedance to the left of any panel surface may be expressed via equation (15) as the sum of the mechanical 'in vacuo' impedance of the panel and the prevailing impedance to the right of the panel surface; in addition, the impedance to the right of the panel surface may be expressed via equations (26) in terms of the input impedance to the next panel on the right and the characteristics defining their separation, namely the distance between panels and the characteristic impedance of the separating medium.

Thus, by progressing panel index 'i' and by successive cross substitution for Z_{R_i} or $Z_{L_{i+1}}$ between equations (15) and (26), one may develop comprehensive formulations for the impedance on either side of any panel within the vibrating system.
In may instances it will be found expedient to develop overall equations in reverse order, that is set the panel index to $i = n$ and determine Z_{R_n} from equation (26); substitute Z_{R_n} into equation (15) and determine Z_{L_n}; repeat the procedure successively for $i=n-1$, $n-2$, etc. until the whole system has been analysed. Naturally this procedure requires a knowledge of or assumption concerning the termination impedance $Z_{L_{n+1}}$ to begin and successive panel impedance terms Z_{p_i} to continue.

3.2 CAVITY TERMINATION IMPEDANCE - $Z_{L_{n+1}}$

The cavity's termination impedance '$Z_{L_{n+1}}$' will be found in practice to lie between conditions given by surface n+1 being non existant, and, being acoustically hard.

a) Surface n+1 does not exist (completely transmitting)

Under this condition, $Z_{L_{n+1}} = \rho c_o$ which upon substitution into equation (26a) yields

$$Z_{R_n} = \rho c_o \tag{27}$$

b) Surface n+1, acoustically hard (completely reflecting)

Since $V_{n+1} = 0$, $Z_{L_{n+1}} = \infty$ hence by substitution into equation (26a)

$$Z_{R_n} = Z_{A_n} = - j \rho c_o \cot (kd_n) \tag{28}$$

c) Surface n+1, reflecting and absorbing or transmitting

In general, $$Z_{L_{n+1}} = R_{n+1} + j X_{n+1} \tag{29}$$

where R_{n+1} is a resistive component

and X_{n+1} is a reactive component

For example, consider the case of an absorbent material lining an acoustically hard backing wall. The input impedance at the surface of the absorbent material may be written in a manner similar to equation (28), except that the characteristic impedance and wave number of the propogation medium will now be complex, Beranek [3, Chapter 10.4.4], that is,

$$Z_{L_{n+1}} = - jZ_o \cdot\cot(k_o\cdot t') \tag{30}$$

where

$$Z_o = R_o +jX_o \quad \text{(A complex characteristic impedance)} \tag{31}$$

$$k_o = \beta -j\alpha \quad \text{(A complex wave number)}$$

and t' is the thickness of the absorbent material (meters)
Equation (30) may now be rewritten in hyperbolic form as:-

$$Z_{L_{n+1}} = (R_o +jX_o) \cdot \coth ([\alpha +j\beta]t') \tag{32}$$

or by expanding the hyperbolic function with complex argument into its real and imaginary parts [4], that is

$$Z_{L_{n+1}} = (R_o +jX_o) [\sinh(2\alpha t')-j\sin(2\beta t')]/[\cosh(2\alpha t')-\cos(2\beta t')] \tag{33}$$

Equation (33) may now be expressed in its real and imaginary parts as:-

$$Z_{L_{n+1}} = R_{n+1} + jX_{n+1} \tag{34}$$

where $R_{n+1} = [R_0 \cdot \sinh(2\alpha t') + X_0 \cdot \sin(2\beta t')]/[\cosh(2\alpha t') - \cos(2\beta t')]$

and $X_{n+1} = [X_0 \cdot \sinh(2\alpha t') - R_0 \cdot \sin(2\beta t')]/[\cosh(2\alpha t') - \cos(2\beta t')]$

$Z_{L_{n+1}}$ may now be substituted directly into equation (26b) to determine Z_{R_n}.

Most cases of practical interest with respect to absorbents may be developed in a similar fashion.

3.3 PANEL IMPEDANCE

The panel's mechanical impedance 'Zp' may be presented in a number of ways depending upon the characteristic behaviour being demonstrated:-

i) Massive Wall

In the event that the wall mass control's the transmission of sound over the frequency range of interest:-

$$Z_p = j\omega M \tag{35}$$

where M is the panel mass per unit area

The impedance term of equation (35) will lead to an appreciation of the transmission loss characteristic refered to as the "Mass Law".

ii) Mass Control plus Coincidence Effect

The coincidence effect, first described by Cremer [5] and based upon a matching of airborn and panel travelling waves, leads to an impedance expression which may be written after Beranek [6, Chapter 13.7], as:-

$$Z_p = j\omega M.\cos(\theta) \left[1 - \frac{\omega^2 B'}{c_0 M} \sin(\theta)\right] \tag{36}$$

where: θ is the angle of incidence
B' is the complex plate bending stiffness $B(1+j\eta)$
B is the plate bending stiffness $(Eh^3/12)$
is the internal damping factor of the panel material as given from a complex Youngs modulus
E is Youngs Modulus of the panel material
and, h is the panel thickness

iii) Modified Coincidence Concept

It has been shown by Bhattacharya et al [7], that coincidence in a 'real' panel in the presence of a backing room is caused by a complicated matching of panel and room standing waves in the presence of strong coupling factor's, in consequence it is not angle of incidence dependent and it can occur at normal incidence ($\theta = 0$) excitation: it does however occur at the fundamental frequency predicted by equation (36), thus, for representative purposes only, one may re write the mass impedance term of equation (36) as:

$$Z = j\,\omega m[1 - (\omega/\omega_c)^2\,(1+j\eta)] \qquad (37)$$

where $\omega_c = c_o^2\,\sqrt{M/B}$ and is the fundamental coincidence frequency

iv) Sprung Wall

In an attempt to better represent the characteristics of a vibrating panel Foxwell and Franklin [8] employed a mechanical mass, spring, and damper model, for which:-

$$Z_p = C + j\,(\omega M - K/\omega) \quad \text{or} \quad Z_p = C + j\,\omega M\,[1-(\omega_p/\omega)^2] \qquad (38)$$

where C is the panel damping constant
K is the panel's spring stiffness constant

and $\omega_p = \sqrt{K/M}$, the panel's in vacuo mass spring resonance.

The impedance term of equation (38) will lead to an appreciation of transmission loss characteristics refered to as 'Stiffness Control', Damping Control', and 'Mass Control'.

v) Multiple Panel Resonance

Multiple 'Mass-Spring' resonance will be encountered in 'real' panels and their frequency will depend upon the panel characteristics such as size and boundary conditions. In general each resonance or 'eigen' frequency will have an associated impedance term and the sum of such terms will be similar to the addition of resistance in parallel; the impedance will also depend upon the spatial nature of the forcing function and upon the location considered on the panel surface which is generally evidenced by the panel velocity being coordinate dependent, thus for illustrative purposes it is necessary to consider an average impedance based upon surface averaged panel velocities and forces. The surface average impedance for the case of a simply supported panel subjected to normal incidence excitation may be written from reference [9, Appendix I], as:-

$$1/Z_p = 4.(2/\Pi)^4 \sum_{q=1}^{\infty} \sum_{r=1}^{\infty} 1/(qr)^2\, Z_{qr} \qquad (39)$$

where $Z_{qr} = j\,\omega M\,[1-(\omega_{qr}/\omega)^2]$ and is the qrth 'modal' impedance

$\omega_{qr} = \Pi^2\,(B'/M)^{\frac{1}{2}}\,[(q/b)^2 + (r/c)^2]$ and is the qrth panel 'eigen' frequency
b is the panel length
c is the panel breadth
q is a modal integer, q = 1,3,5 etc.
r is a modal integer, r = 1,3,5 etc.
Π 3.142 .... .

It may be noted that panel damping is now incorporated within the expression for 'eigen' frequency, by way of the internal damping factor occuring within the bending stiffness B'.

The series summation of equation (39) converges quite rapidly for terms involving eigen frequencies ω_{qr} greater than the excitation frequency ω, in addition one may note that the series summation $4 \times (2/\Pi)^4 \; \Sigma \; 1/(qr)^2 = 1$.
These features may be employed to yield computational economies.

3.4 PRESSURE AND PANEL VELOCITY

The velocity of any panel may be written in terms of pressure and impedance via the relationships shown in equations (7) and (11), that is:-

$$V_{P_i} = P_{L_i}/Z_{L_i} = P_{R_i}/Z_{R_i} = (P_{L_i} - P_{R_i})/Z_{P_i} \qquad (40)$$

Also, from equation (23)

$$V_{P_{i+1}} = V_{P_i} \cdot Z_{B_i}/(Z_{A_i} + Z_{L_{i+1}}) \quad , \; i = 1 \text{ to } n-1 \qquad (41)$$

Thus, equations (40) and (41) will allow any pressure ratio or ratio of pressure to panel velocity, to be determined.

Equation (19) may be employed to determine the pressure at any point between vibrating panels or between the last panel and the systems terminating impedance.

3.5 SOUND PRESSURE RATIO

As a measure of a panel system's performance, a sound pressure ratio (SPR) may be employed, that is :-

$$SPR = 20 \; \mathrm{Log}_{10} \; (|Pi'|/|P_{R_n}|) \qquad (42)$$

where $|Pi'|$ is the pressure amplitude of the incident pressure wave on the left hand side of the first panel.

and $|P_{R_n}|$ is the pressure amplitude on the right hand side of the n^{th} panel

The sound pressure ratio as defined in equation (42) is similar to the term 'Transmission Loss' based upon a ratio of incident intensity to transmitted intensity; this similarity becomes exact when the pressure wave on the transmitted side of the n^{th} panel is freely propogated; however the ratio of pressures employed here avoids complexities associated with the definition of intensity in the complicated sound fields caused by the presence of backing walls or rooms, whilst still providing a strong indicator of performance as might subjectively be judged.

For the present analysis, it is necessary to deduce a relationship between the incident pressure amplitude 'Pi' and the total pressure on the surface of incidence P_{L1}.

Proceeding in a manner shown by Richards and Mead [10], the total pressure on the incident surface may be written as:- $P_{L1} = Pi' + Pr' + Prr$

where Pi' = incident pressure wave
Pr' = reflected pressure wave
Prr = re-radiated pressure wave caused by panel vibration

Via equation (9), one may write the re radiated wave as:-

$Prr = -\rho c_0 \cdot V_{P1}$ and, given that $0 \leqslant Pr' \leqslant Pi'$,

as a first approximation $Pr' = Pi'$ thus $P_{L1} = 2p_i' - \rho c_0 \cdot V_{P1}$

or replacing P_{L1} by the product of panel velocity and input impedance, one may write:-

$$Pi' = V_{P1} \cdot (Z_{L1} + \rho c_0)/2 \quad (43)$$

4. APPLICATIONS

In order to illustrate the use of the forgoing analysis, three case studies will be considered.

1. Single leaf panel backed by a cavity
2. Double leaf panel
3. Multiple leaf panel

4.1 VIBRATING PANEL BACKED BY A CAVITY

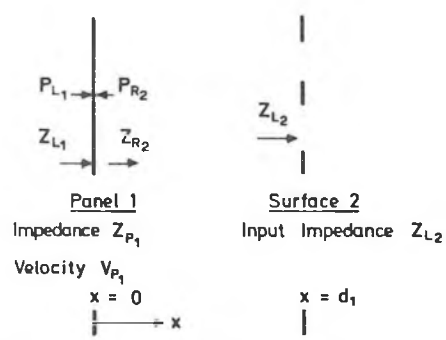

Figure 2 - Model describing parameters for a vibrating panel backed by a cavity.

The model of Figure (2) consists of a panel capable of vibration, backed by a cavity of depth d_1. The backing cavity is terminated by a surface having an as yet arbitary input impedance Z_{L2}.

Equations (15) and (26b) may be applied to determine the system's input impedance Z_{L1}, that is

$$Z_{L_1} = Z_{P_1} + Z_{R_1} \quad (44)$$

where $$Z_{R1} = \frac{Z_{L2}\cos(kd_1) + j\,\rho c_0 \sin(kd_1)}{\rho c_0 \cos(kd_1) + j\,Z_{L2}\sin(kd_1)} \tag{45}$$

The sound pressure ratio may be written from equation (42) as:-

$$SPR = 20.\log_{10}\left(|Pi'|/|P_{R1}|\right) \tag{46}$$

substituting for $P_{R1} = V_{p1} \cdot Z_{R1}$ from equation (40), and P_i from equation (43) into equation (46), and expressing impedance terms in their 'normalised' form, the sound pressure ratio may now be written as:

$$SPR = 20\log_{10}\left|(Z'_{p1} + Z'_{R1} + 1)/2\,Z'_{R1}\right| \tag{47}$$

Z'_{R1} will be derived from equation (45) upon consideration of the three choices for the normalised termination impedance Z'_{L2} deduced from equations (27), (28), and (29). For example consider the normalised form of equation (29), $Z'_{L2} = R_2 + j\,X_2$, (partially reflecting and absorbing) which upon subsituation into equation (45) yields

$$Z'_{R1} = \frac{R_2 \cdot \cos(kd_1) + j\,[\sin(kd_1) + X_2 \cdot \cos(kd_1)]}{[\cos(kd_1) - X_2 \cdot \sin(kd_1)] + j\,R_2 \cdot \sin(kd_1)} \tag{48}$$

where d_1 is the distance from the vibrating panel to the begining of the absorbing and reflecting layer.

If the normalised termination impedance Z'_{L2} is due to an absorbent material lining an acoustically hard backing wall, R_2 and X_2 above will be expressed by the normalised form of R and X defined after equation (34).

4.2 DOUBLE LEAF PANEL

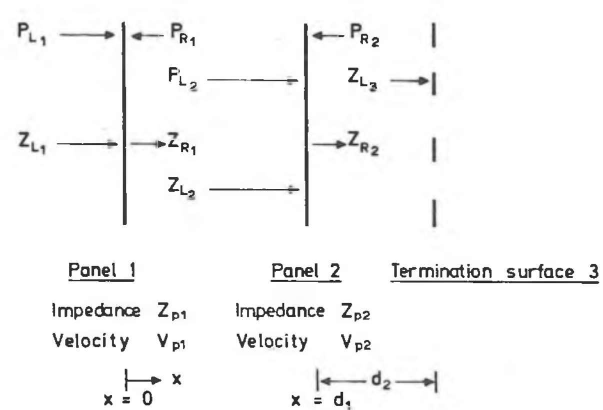

Figure 3 - Model describing parameters for a double leaf panel system.

The model of Figure (3) consists of two vibrating panels separated by an air gap of width d_1. To the right and at a distance of d_2 from the second panel, exists a termination surface having an arbitary input impedance Z_{L_3}:

The sound pressure ratio for the model of Figure (3) may be written from equation (42) as:-

$$SPR = 20 \log_{10} (|Pi'|/|P_{R_2}|) \tag{49}$$

where P_i is the incident pressure

and P_{R_2} is the pressure to the right of the second panel

The incident pressure P_i' may be written directly from equation (43) that

is $Pi' = V_{P_1} (Z_{L_1} + \rho c_0)/2$

whilst the pressure existing the right of the second panel may be written from equation (40) as:-

$$P_{R_2} = V_{P_2} \cdot Z_{R_2} \tag{50}$$

The second panel velocity V_{P_2} may be written in terms of the first panel velocity V_{P_1} via equation (23), and the impedance to the right of the second panel Z_{R_2} may be expressed in terms of the termination impedance Z_{L_3}, via equation (26a); thus:-

$$P_{R_2} = V_{P_1} [Z_{B_1}/(Z_{A_1}+Z_{L_2})][Z_{A_2}-Z_{B_2}^2/(Z_{A_2}+Z_{L_3})]$$

or, rearanging terms

$$P_{R_2} = V_{P_1} \{Z_{A_2}[Z_{B_1}/(Z_{A_1}+Z_{L_2})]-Z_{B_2}[Z_{B_1}/(Z_{A_1}+Z_{L_2})][Z_{B_2}/(Z_{A_2}+Z_{L_3})]\} \tag{51}$$

Equation (43) for P_i' and equation (51) for P_{R_2} may now be substituted into equation (49) to yield:-

$$SPR = 20 \log_{10} | (Z_{L_1} + \rho c_0)/2 Z_2 | \tag{52}$$

where

$$Z_{L_1} = Z_{P_1} + Z_{A_1} - Z_{B_1}^2/(Z_{A_1}+ Z_{P_2}+ Z_{A_2} - Z_{B_2}^2/[Z_{A_2}+ Z_{L_3}]) \tag{53}$$

and

$$Z_2 = Z_{A_2} [Z_{B_1}/(Z_{A_1}+ Z_{L_2})] - Z_{B_2}[Z_{B_1}/(Z_{A_1}+ Z_{L_2})][Z_{B_2}/(Z_{A_2} + Z_{L_3})]$$

The panel impedance terms Z_{P_1} and Z_{P_2} may be chosen from equations (35) to (38), whilst the termination impedance Z_{L_3} may be chosen from equations (27) to (29).

In general the evaluation of equation (52) and (53) must be undertaken by computational techniques, although it has been shown, Brüel [11, Chapter 5] London [12], that analytical interpretation is possible for certain simplified case studies. It may be noted that the angle of incidence dependence of the Mass-Spring-Mass Resonance as deduced by London [12] for the case of infinite panels, does not apply for the case of finite panels, Guy [13]. For finite panels, resonance occurs at about the fundamental predicted by London ($\theta=0$), but for all incident angles.

4.3 MULTIPLE PANELS

The sound pressure ratio for the general case of multiple panels may be written directly from equation (42):-

$$SPR = 20 \log_{10} \left(|P_i'| / |P_{R_n}| \right)$$

where P_i' is the incident pressure

and P_{R_n} is the pressure to the right of the n^{th} vibrating panel and its solution may be written in a manner similar to equation (52), that is:-

$$SPR = 20 \log_{10} \left| (Z_{L_1} + \rho c_0)/2\, Z_n \right| \qquad (54)$$

where

$$Z_{L_1} = Z_{P_1} + Z_{A_1} - Z_{B_1}^2 / [Z_{A_1} + Z_{P_2} + Z_{A_2} - Z_{B_2}^2 / [Z_{A_2} + \;\cdots\cdots$$
$$- Z_{B_{n-1}}^2 / [Z_{A_{n-1}} + Z_{P_n} + Z_{A_n} - Z_{B_n}^2 / [Z_{A_n} + Z_{L_{n+1}}]] \cdots\cdots]] \qquad (55)$$

$$\text{and } Z_n = Z_{A_n} \prod_{i=1}^{i=n-1} [Z_{B_i}/(Z_{A_i} + Z_{L_{i+1}})] - Z_{B_n} \prod_{i=1}^{i=n} [Z_{B_i}/(Z_{A_i} + Z_{L_{i+1}})] \qquad (56)$$

where $n > 1$
and Π infers successive products

Analysis of equations (54), (55) and (56) may now proceed via computational techniques.

5. DISCUSSION

The present discussion is based upon the results presented in Figures (4) to (8), with the objective of illustrating typical general analysis applications; the discussion is not exhaustive, nor do the figures display all possible trends, phenomenum, or phenomena interaction.

Results arising from the analytical procedure outlined in section 4.1 with respect to single leaf panels in the presence and absence of a backing room are shown in Figures (4), (5) and (6).

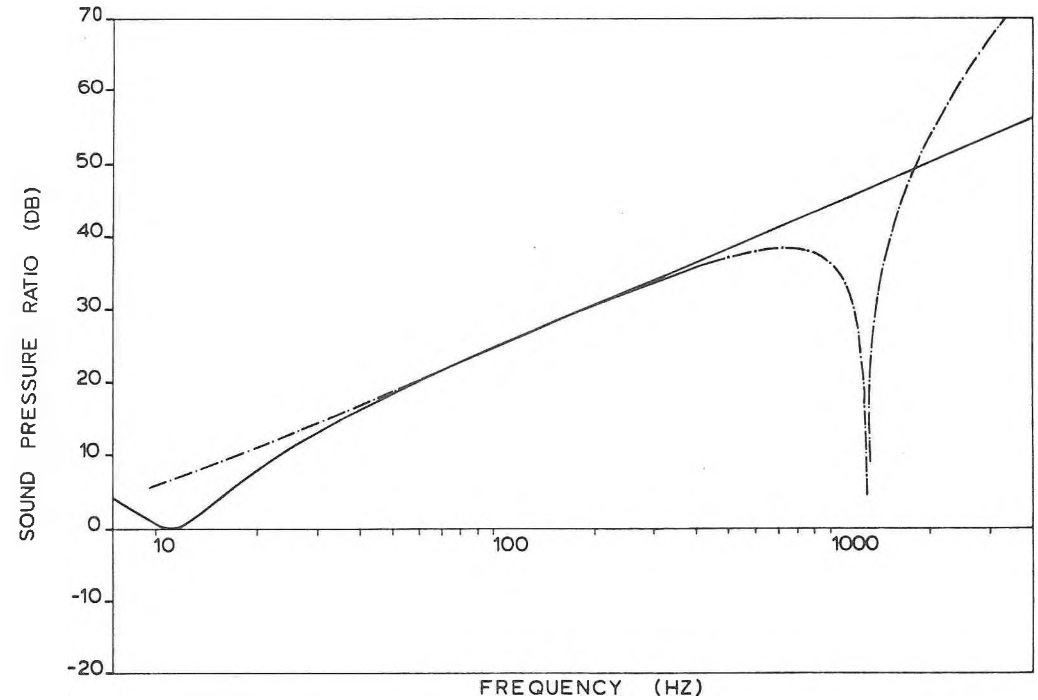

Figure 4 : Sound Pressure Ratio for a single leaf panel of glass.
Thickness 9.525mm, Density 2300 kg/m^3.
Perfect transmission to the right (Equation (27)).
—·—·— Modified Coincidence (Equation (37)).
Youngs Modulus 6.2×10^{10} N/m^2, Internal Damping $\eta = 0.002$.
——— Sprung Wall (Equation (38)).
Wall Stiffness Constant K = 108,000 N/m.

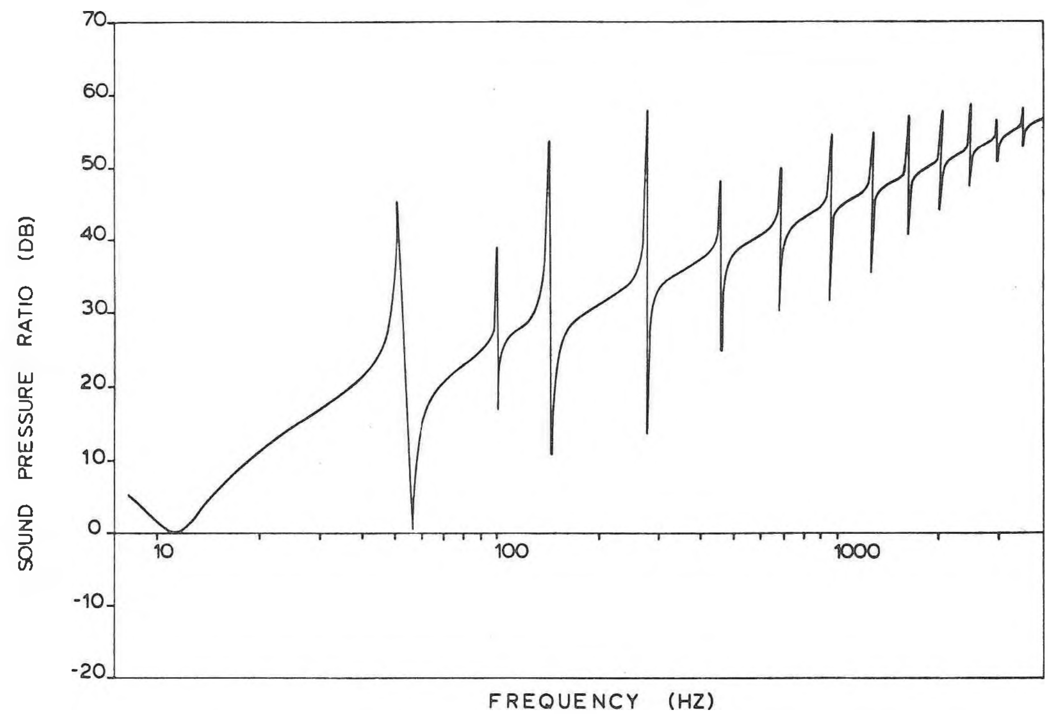

Figure 5 : Sound Pressure Ratio for a single leaf panel of glass.
Thickness 9.525mm, Density 2300 kg/m^3.
Perfect transmission to the right (Equation 27)
Multiple Resonance Panel (Equation 39).
Youngs Modulus 6.2×10^{10} N/m^2, Internal Damping $\eta = 0.002$.

Figure 4 shows the sound pressure ratio predicted for a 9.525 mm glass panel (typical of a shop window) based upon the modified coincidence equation (37), and the sprung wall equation (38). Such models are generally employed to illustrate classical control regions.

One may observe that the stiffness controled region occurs below the fundamental mass-spring resonance of 11 Hz and is therefore unlikely to be of significance for most practical purposes; the stiffness constant was chosen to yield the same fundamental resonance as predicted for a 2 x 2 metre panel (see Figure 5).

Figure (5) displays the transmission of sound when the glass panel exhibits the multiple resonance predicted for a 2 x 2 metre panel section, equation (39). The 'resonance region' can be seen over the whole frequency range thus an increase of panel damping would generally improve attenuation; it can also be seen that the sound pressure ratio tends to the 'mass law' prediction at higher frequencies although it should be noted that 'coincidence' has been ommitted from this display.

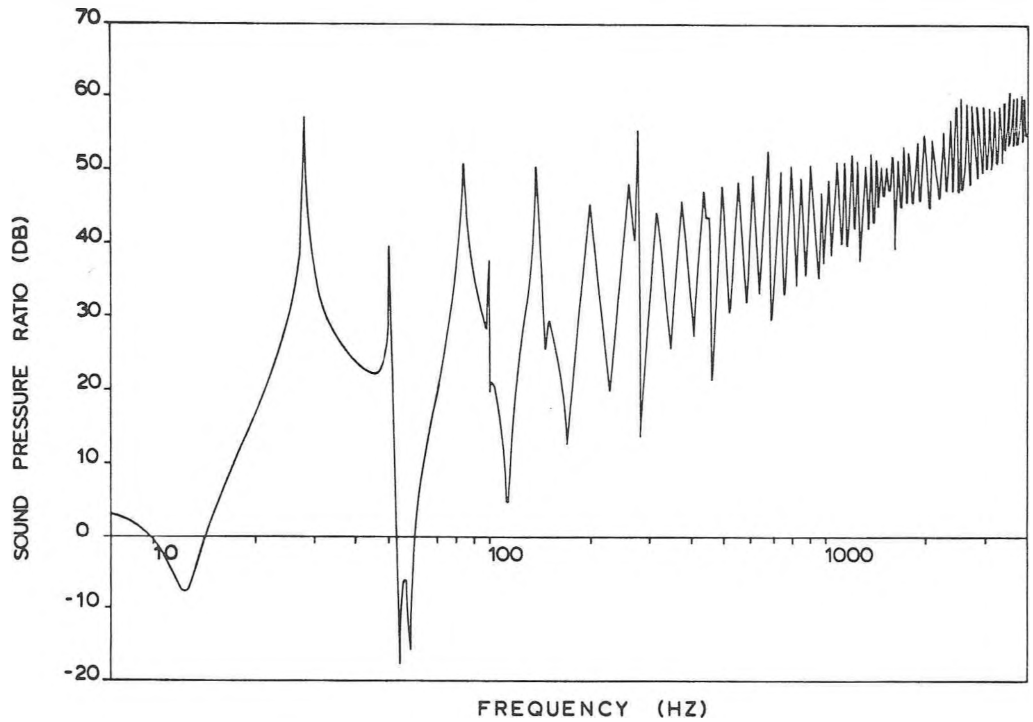

Figure 6 : Sound Pressure Ratio for a single leaf panel of glass.
Thickness 9.525mm, Density 2300 kg/m^3
Absorbent lined backing cavity (Equation 48), Distance 2900 mm.
Flow resistivity of Absorbent 20000 mks rayls/m, thickness 100 mm.
Multiple Resonance Panel (Equation 39).
Youngs Modulus 6.2×10^{10} N/m^2, Internal Damping $\eta = 0.002$.

Figure (6) displays the result of applying a 'damped' backing room to the multiple resonance panel of Figure (5). The overall cavity depth is three metres and the acoustically hard backing wall is lined with 100 mm of absorbent material having a flow resistivity of 20000 mks rayls/m. The occasions of resonance are significantly increased and the controling factors are the room depth and absorbent material; a tendency to the results of Figure (5) would be observed for increasing the room damping whilst marked increases in resonance excursions would be observed for decreasing room absorption. Resonance can be seen at lower frequencies, at which the sound pressure within the room is significantly higher than the incident pressure causing them!!

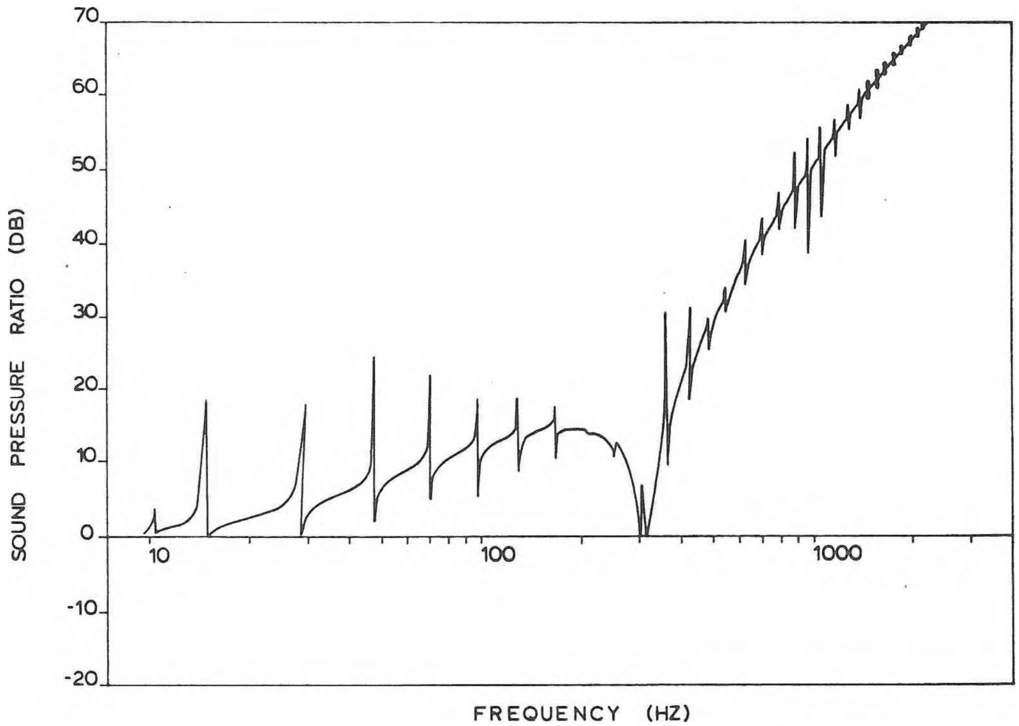

Figure 7 : Sound Pressure Ratio for a double leaf panel system of Aluminum.
Each leaf thickness 1mm, Density 2700 kg/m^3, Air Gap 25.4 mm.
Perfect Transmission to the right (Equation 27).
Multiple Resonance Panel (Equation 39).
Youngs Modulus 6.2×10^{10} N/m^2, Internal Damping $\eta = 0.0001$.

Figure (7) displays the sound pressure ratio for a double leaf panel determined in accordance with the procedure outline in section 4.2 and incorporating multiple panel resonance detailed in equation (39). The double panel is of two thin aluminum sheets, each 1 mm thick and separated by an air gap of 25.4 mm; the sheets are assumed to be square of 2x2 metres.

The mass-spring-mass resonance is clearly evident about 320 Hz, although a strong secondary resonance caused by the proximity of a panel eigen frequency can be seen about 310 Hz. The general trend is for the multiple panel resonance to be superimposed upon the curve dictated by two mass law panels separated by an air gap.

Figure (8) displays the sound pressure ratio determined for a three panel system (section 4.3) consisting of the double leaf aluminum system described for Figure 7 in association with a similar aluminum panel located one metre away, this being the typical air gap one might achieve by utilising the roof depth of an aluminum space frame. The advantage of a large air gap is that its associated mass-spring-mass resonance is located outside the frequency range of interest, such is the present case which exhibits this resonance about 40 Hz; the large air space has, however caused an air space resonance about 170 Hz thus potentially eliminating the earlier advantage. Some modification to the excursions of the 320 Hz resonance associated with the mass and smaller air gap may also be seen.

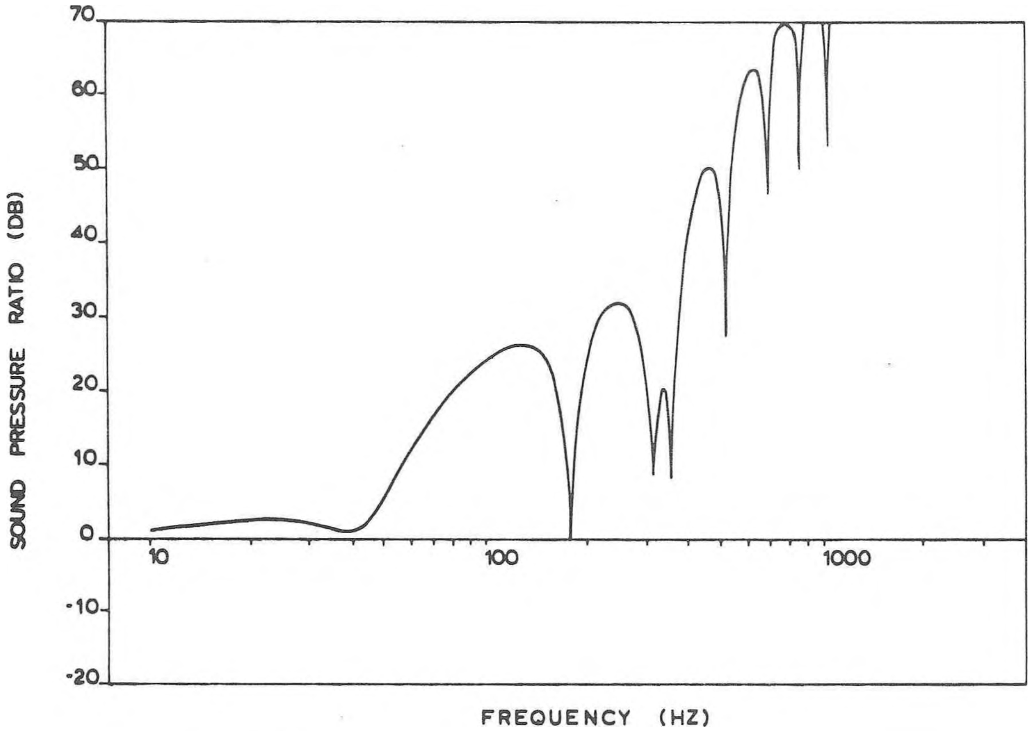

Figure 8 : Sound Pressure Ratio for a triple leaf panel system of Aluminum.
Each leaf thickness 1mm, Density 2700 kg/m^3, Air gap 25.4mm and 1000mm.
Perfect transmission to the right (Equation 27).
Mass Law Panels, (Equation 35).

The high transmission loss potential of this particular panel system may still be realised by locating absorbent material within the larger air gap; optimum absorbent material thickness, characteristic flow resistance, and location could be estimated by employing the general analysis.

All results presented in Figures 4 to 8 have been computed from the general analysis programmed in MICROSOFT BASIC on an Apple II plus microcomputer system. All computational times were 'reasonable' and as discussed are capable of visual qualative assessment.

6. CONCLUSION

A one dimensional analytical model capable of considering many features associated with vibrating panel systems has been developed and its use demonstrated by way of case studies.

It has been shown that formulations are readily generated and that they are based upon a recurring cycle involving a fixed menu of panel and termination impedance; this form of analysis is idealy suited for computation.

Graphical output from a programmed micro computer system has been shown capable of analytical interpretation, and computational times have been found 'acceptable'. Thus, the general analysis and procedure applied to a micro computer system will prove of use for instructional purposes and may also be of use for preliminary engineering design purposes.

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