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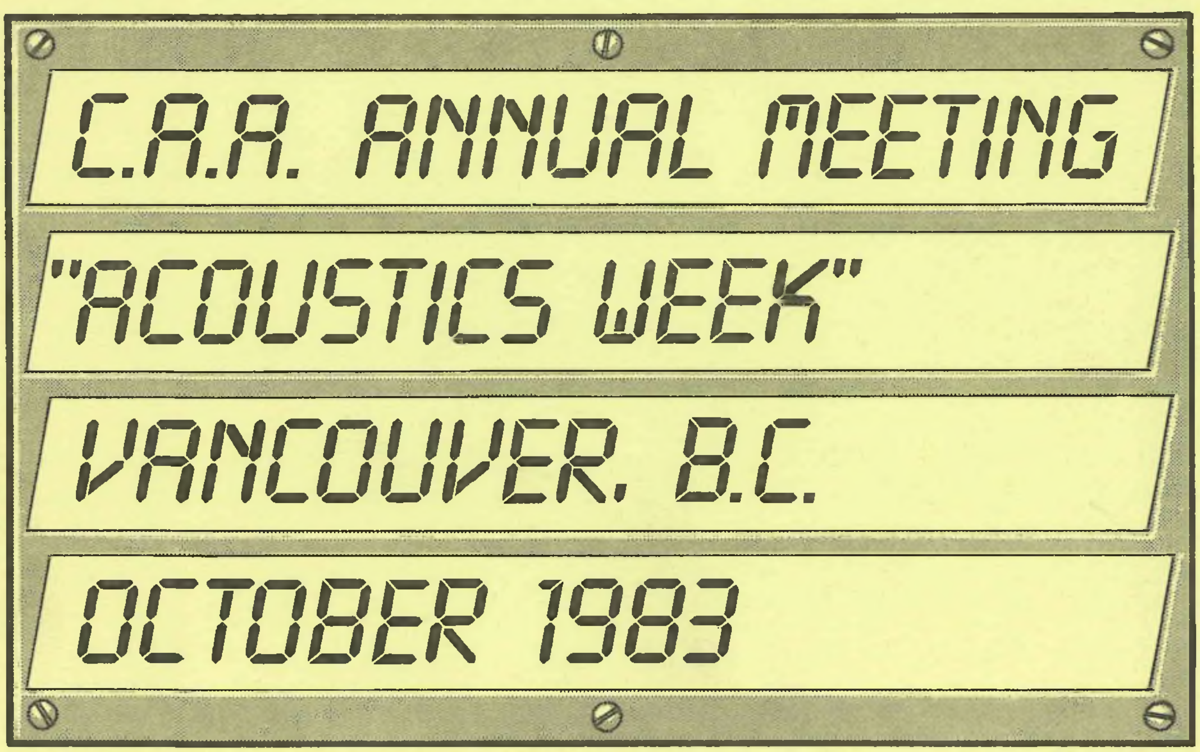

Simon Tuckett

canadian acoustics

acoustique canadienne

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Articles on 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

We hope to see many of our readers at the Canadian Acoustical Association Annual Symposium in Vancouver, October 20 and 21, 1983. Acoustics Seminars are planned October 17-19, and a meeting of the Canadian Standards Association Committee Z107 "Acoustics and Noise Control" is scheduled for October 19. Further details are contained in this issue.

The present editorial staff of CANADIAN ACOUSTICS would like to take this opportunity to thank all those that have helped improve the quality of this publication, and in particular our authors and reviewers that have steadily increased the quality and quantity of papers submitted. Thanks also to our subscribers and advertisers, for contributing the funds that enable us to operate.

The editor-in-chief and editor will be resigning their positions at the CAA Annual Meeting in Vancouver, having spent in total an enjoyable 5 years helping publish 20 issues of CANADIAN ACOUSTICS. We wish the new editorial staff every success. They have the excellent continuing support of Tim Kelsall, Advertising Editor; Mike Stinson, Printing and Distribution Editor and Simon Tuckett, Graphic Design. We ask that you give them your support too to help CANADIAN ACOUSTICS continue to improve.

CAA ANNOUNCEMENTS

CAA ANNUAL MEETING - Members of the CAA are advised that the 1983 annual general meeting will take place in Vancouver, B.C. The meeting is to be held at the Hotel Georgia, 801 West Georgia Street, Vancouver, Thursday, October 20, 1983 from 4-7 p.m.

CAA DIRECTORS' MEETING is to be held at the Hotel Georgia, Vancouver, Wednesday, October 19, 1983 at 8:00 p.m.

CAA NOMINATIONS - see page 63.
CAA MEMBERSHIP REPORT - see pages 6-7.

EDITORIAL

Le Symposium Annuel de l'ACA aura lieu à Vancouver, C.B., les 20 et 21 octobre prochains. Ce sera une semaine pleine d'activité: des présentations auront lieu du 17 au 18 et la réunion du comité de l'ACN sur l'Acoustique et le Contrôle du Bruit (Z107) aura lieu le 19. Vous trouverez les détails de ces activités dans ce numéro. On espère que vous y serez.

L'équipe de rédaction de l'Acoustique Canadienne voudrait porter ses remerciements à tous ceux qui ont participé à l'amélioration de la qualité de la publication, en particulier à nos auteurs et réviseurs. Des remerciements sont également dus à nos abonnés et aux compagnies publicitaires pour leur soutien financier.

L'éditeur-en-chef et l'éditeur résigneront de leurs fonctions pendant la réunion annuelle de l'ACA à Vancouver. Il y a déjà cinq ans qu'ils sont membres de l'équipe de rédaction. Ils souhaitent beaucoup de succès à la nouvelle équipe. Celle-ci profitera de la participation continue de Tim Kelsall - Publicité, de Michael Stinson - Impression et Distribution et de Simon Tuckett - Maquette. Nous invitons nos lecteurs à continuer d'apporter leur soutien à l'équipe de rédaction en vue de l'amélioration d'Acoustique Canadienne.

NEWS

12th ICA PLANNING GROUP and CAA MEMBERS AT 11th ICA MEETING

Canadian acousticians that attended the 11th Congress in Paris, France, are invited to join the 12th ICA 1986 Executive and the Toronto planning group at a meeting in Toronto to review their experiences for the benefit of planners who were unable to travel to Paris.

The meeting is scheduled to be held in the Manulife Centre, 51st Floor, Pink Boardroom, Toronto, on Sept. 15, 1983, with an Open Session, Info Exchange from 9:30 to 12:30 and a meeting of the 12th ICA Executive Committee from 13:30 to 17:30. For further information contact John Manuel at (416) 965-6191 or 922-7364 (res.).

I/INCE AND NOISE CONTROL RESEARCH

The International Institute of Noise Control Engineering (I/INCE) was founded in 1974 as an organization dedicated to the application of noise control technology for the benefit of the public. It provides leadership through the organization of international conferences and seminars on noise control engineering, especially the INTER-NOISE series of conferences.

I/INCE also seeks to develop interdisciplinary contacts between noise control engineering and other related fields of work and promotes international cooperation in research on noise control. As part of its responsibility to promote cooperation in research, I/INCE publishes a NEWSLETTER which contains many items of international interest. One of the objectives of this NEWSLETTER is to publish a survey of research in noise control in progress in laboratories throughout the world. These items will appear in a "Research column" in the NEWSLETTER.

Send items of interest to the I/INCE NEWSLETTER editor, Dr. A. Cops, at Celestijnenlaan 200D, B-3030 Heverlee, Belgium.

INTER-NOISE 84 TO BE HELD IN HAWAII

The Board of Directors of the Institute of Noise Control Engineering (INCE/USA) has announced that INTER-NOISE 84 will be held in Hawaii on December 3-5 next year. INTER-NOISE 84, the 13th International Conference on Noise Control Engineering, will be sponsored by the International Institute of Noise Control Engineering (I/INCE) and will be organized by INCE/USA in cooperation with INCE/Japan. More than 500 specialists in noise control are expected to participate at the 1984 meeting which will be devoted to the latest technical developments in this rapidly-expanding field of world-wide importance.

INTER-NOISE 84 will be the first international conference to be jointly organized by two member societies of International INCE. Honolulu was chosen as the site for INTER-NOISE 84 as it is approximately half-way between the West Coast of the U.S.A. and Japan. With the theme "International Cooperation for Noise Control," participation is expected from more than 20 countries in addition to large delegations from the U.S. and Japan.

The three-day conference will be held at the Hotel Ilikai, a complete resort hotel at the end of Waikiki Beach, just a few minutes from Honolulu International Airport with its excellent air connections around the world. The Ilikai was selected for the conference because it offers excellent meeting facilities for INTER-NOISE 84.

A Call for Papers for the conference will be issued next July. In the meantime, additional information may be obtained from the INTER-NOISE 84 Secretariat, P.O. Box 3469, Arlington Branch, Poughkeepsie, N.Y. 12603, USA.

NELSON ACOUSTICAL PAPER AWARDS

Nelson Industries, Inc. has announced the award winners in the 1983 Nelson Acoustical Paper Awards Program. First Prize of $2000.00 was awarded to K. Narayana Rao and M.L. Munjal of the Indian Institute of Science in Bangalore, India for their paper "A Generalized Decoupling Method for Analyzing Perforated Element

Mufflers". Second Prize of $1000.00 was awarded to Deane B. Jaeger of the Harley-Davidson Motor Company for his paper "An Exhaust System Investigation of a High Performance Air Cooled Engine". Honorable Mention Awards of $500.00 each were awarded to M.G. Prasad of the Stevens Institute of Technology and Malcolm J. Crocker of Purdue University for their paper "Acoustical Studies on a Multi-Cylinder Engine Exhaust Muffler System" and to J.L. Bento Coelho of the Instituo Superior Tecnico in Lisbon, Portugal for his paper "Modelling of Cavity Backed Perforate Liners in Flow Ducts."

The Nelson Acoustical Paper Awards Program is an open paper competition for outstanding original papers on mufflers, silencers, and related acoustical technology. Entries may be in the form of a research paper, engineering study, case history, or review paper. Judging is done by the Nelson Research Advisory Council composed of six university professors and professionals from industry with extensive research and educational experience. The selection of the award winners is based on technical excellence, clarity and completeness.

Additional information on the Nelson Acoustical Paper Awards Program may be obtained from Larry J. Eriksson, Corporate Research Department, Nelson Industries, Inc., P.O. Box 428, Stoughton, WI 53589, USA, telephone: (608) 873-4373.

CULTURAL CONSULTANT INVENTORY conducted by Ministry of Citizenship and Culture

The Planning and Project Management Section of the Ministry of Citizenship and Culture is presently compiling a list of firms that are available to act as consultants for the planning of cultural facilities.

This inventory will provide the Ministry clients with a list of consultants that will be made available to groups or individuals (i.e. regional municipalities, local governments, special interest community groups) who are considering a cultural facility of some kind and require a general list of consultants who might be available to help them.

Relevant Associations including the CAA have been notified by the Planning and Project Management Section of this Ministry to enable them to inform their members of the Consultant Inventory. Questionnaires will be available through a firms respective association or directly from the Ministry.

Inventory questionnaires can be requested from the Editor-in-Chief and should be returned by October 15 for a December publication. If you have any further questions regarding this consultants' inventory, please do not hesitate to contact Malcolm Lobban, Planning and Project Management Section of this Ministry, at 77 Bloor St.W., Toronto, Ontario, M7A 2R9, Telephone: (416) 965-0322/8438.

CANADIAN PULP & PAPER ASSOCIATION CALL FOR PAPERS FOR NOISE CONTROL SEMINAR

The Mechanical Engineering and Maintenance Committee of the Technical Section, Canadian Pulp and Paper Association, is organizing a Noise Control Seminar to be held at the Hotel Vancouver in Vancouver, B.C. from September 10-12, 1984.

The Program Chairman is Mr. Dennis Dmytrow of E.B. Eddy Forest Products Ltd.

At the present time, there is a great need for greater appreciation of the "whys" and "hows" of noise control in the Pulp and Paper Industry. Since the last Noise Control Seminar in 1976, there has been significant progress in the understanding and practical application of noise control. These will be addressed at this Seminar.

Papers are sought in the following subject areas: mill case studies; instrumentation in noise control; noise source diagnostic techniques; enclosures; production equipment selection; acoustical materials; mobile equipment; construction techniques to minimize noise; sawmill and woodroom noise; and principles in noise control. The emphasis should be on practical aspects and mill case studies.

Anyone wishing to make a presentation at the Seminar should send an abstract as soon as possible, but no later than February 2, 1984, to: Mr. Dennis Dmytrow, E.B. Eddy Forest Products Ltd., P.O. Box 600, Hull, Quebec, J8X 3Y7.

General inquiries on the Seminar should be addressed to: Mr. W. Robert Wood, Technical Section, CPPA, Sun Life Building, 23rd Floor, 1155 Metcalfe Street, Montreal, Quebec, H3B 2X9, Telephone: (514) 866-6621, Telex: 505-60690.

TRANSFER OF RESPONSIBILITIES FOR INTERNATIONAL NOISE STANDARDS IN U.S.A. TO NBS.

Although the domestic responsibilities of the Environmental Protection Agency's Office of Noise Abatement and Control have been transferred to state and local governments, certain international obligations will be continued by the Federal Government. The National Bureau of Standards (NBS) of the Department of Commerce will serve as a contact point for information on noise standards, both domestic and foreign, and will monitor the representation of U.S. interests in international standards activities.

The assumption of these responsibilities is consonant with the Trade Agreements Act of 1979, which assigns certain implementation responsibilities for the Agreement on Technical Barriers to Trade to the Department of Commerce. By serving as a focal point for information and as a monitor of U.S. representation, NBS will help to avoid or alleviate any technical barriers to trade which might otherwise result from differing noise standards. This will also enable NBS to be aware of all of the U.S. Government's activities related to international noise standards, and should result in more efficient utilization of resources while reducing duplication of effort. It is emphasized that NBS will not serve as a repository for information, nor provide representation at international meetings directly. Rather, NBS will refer inquiries to the appropriate source. U.S. representation will be provided by agencies with a technical interest or by Foreign Service personnel who will act as observers. Summary reports will be forwarded to NBS for further dissemination as appropriate.

Inquiries for information related to noise standards should be directed to: Mr. Walter Leight, Manager, Standards Code and Information, Office of Products Standards Policy, National Bureau of Standards, Technology Building, Room B166, Washington, D.C. 20234, telephone (301) 921-3272.

NEW B & K MICROPHONES FOR PROFESSIONAL STUDIO APPLICATIONS

A new series of precision microphones for broadcast and other professional studio applications has been introduced by Bruel Kjaer. The 4000-series units are all designed to render balanced, clean and sound with minimal tonal coloration.

The B & K types 4003 and 4006 are low-noise omnidirectional microphones, intended primarily for applications requiring very high-level handling capability plus extended frequency and phase responses. They feature very flat response (±2 dB) from 20 H_z to 20 kH_z, with a very smooth high-frequency roll-off.

The types 4004 and 4007 are high-intensity microphones with very flat on-axis frequency response up to 40 kH_z and low off-axis attenuation at high frequencies. Capable of handling levels up to 148 dB with less than 1% distortion, they are ideal for close miking of high intensity and short transient sounds, such as brass and percussion.

The microphones are all prepolarized condenser types with integral preamplifier. They are supplied with windscreen, individual calibration chart and input cable. Units are available for direct connection to standard 48-volt Phantom power supply or with optional B & K type 2812 two-channel high-output system. Address enquiries to: Bruel & Kjaer Canada Ltd., 90 Leacock Road, Pointe Claire, Quebec, H9R 1H1.

SPECIAL ADVISORY COMMITTEE APPOINTED IN ONTARIO TO STUDY NOISE

The Minister of Labour, Russell H. Ramsay, has appointed a Special Advisory Committee to study and report on certain issues pertaining to the formulation of a noise regulation under The Occupational Health and Safety Act.

The Ministry has not determined either the method for calculating the average level of exposure or what time frame or time frames should be used to calculate the average level of exposure for purposes of framing regulations in respect of engineering controls, mandatory hearing protection and mandatory hearing conservation programs. In addition the Ministry has not determined whether noise ceiling levels should be imposed taking into account the nature of the sound and the attenuation provided by hearing protection. The Committee has been appointed to evaluate the available scientific information in respect of these issues and to consult with interested parties in respect of the social and economic implications of the various alternatives. The specific terms of reference of the Committee can be obtained by contacting:

Special Advisory Committee on
Noise Regulation
400 University Avenue
4th Floor
Toronto, Ontario
c/o Kevin Burkett, Chairman

1983 CAA MEMBERSHIP REPORT

Earlier this year CAA implemented a new invoicing system for the collection of members and student fees, subscriptions and sustaining subscriptions. The early response by the dedicated CAA membership was excellent but a substantial group have yet to honour their 1983 obligation. The new invoice form encourages CAA members and supporters to make donations to the funding of the 12th International Congress on Acoustics which will be held in Canada in 1986. The "CAA Scholarship Prize in Acoustics" is another worthy project deserving of your financial support.

Outstanding membership dues must be received by the Executive Secretary before October 18, 1983 in order to preserve one's eligibility to participate in the 1983 business meetings of the Association in Vancouver, B.C. For those who have not yet made a voluntary donation towards the 1986 Congress or the Scholarship Fund, you are also reminded that 1983 donations must be received by the end of December 1983 to be eligible for income tax deduction. Every member is urged to donate $20 annually for four years or make one lump sum contribution of $75.

CAA LIST OF ELIGIBLE VOTING MEMBERS

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Tessier, J-S.
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Toole, F.E.
Toothman, E.H.
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White, B.F.
White, R.
Williams, A.S.
Wilson, K.
Wilson, S.S.
Wojcik, J.J.
Wong, G.S.K.
Zigelstein, S.

POSITION WANTED

Bradley Basnett is seeking a position in an acoustics related field. He holds an Acoustics Engineering Technician Diploma (Honours) from George Brown College in Toronto. Recent experience includes employment with the Noise Section of the Ontario Ministry of Environment on a construction site noise study. Potential employers may contact him at:

Bradley Basnett Tel:(416) 787-4616
402 Fairlawn Avenue
Toronto, M5M 1T8

12th ICA 1986 FUND AND CAA SCHOLARSHIP PRIZE FUND REPORT

LIST OF VOLUNTARY CONTRIBUTORS

Donations for 1983 tax year must be received before Dec.31

Abel,S	Foreman,J	Leggat,L	Shelton,B
Behar,A	Forshaw,S	Mackay,Jim	Simonsen,K
Benwell,D	Gaspar,R	Manuel,J	Slobodian,S
Birnie,S	Hall,F.L.	McKee,A	Stevenson,J
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		Sacks,M.	
		Shaw,E.A.G.	

CAA/ICA RECEPTION AT CANADIAN EMBASSY IN PARIS, FRANCE

A reception to honour present and past members of the International Commission on Acoustics was held at the Canadian Embassy in Paris courtesy of the Minister and Mrs Timothy A. Williams and their staff during the 11th Congress. Shown with Robert Beyer, Chairman of the Commission, are (L to R); Fred Hall, Raymond Hetu, Tony Embleton, Sharon Abel, Edgar Shaw and John Manuel.

Important Canadian Standards for CAA Members

Published CSA Standards		Price
Z107.4-1975	Pure Tone Audiometers for Limited Measurement of Hearing and for Screening (4a, 4e)	$ 4.75
Z107.21-M1977	Procedure for Measurement of the Maximum Exterior Sound Level of Pleasure Motor Boats	8.00
Z107.22-M1977	Procedure for Measurement of the Maximum Exterior Sound Level of Stationary Truck with Governed Diesel Engines	8.00
Z107.23-M1977	Procedure for Measurement of the Maximum Interior Sound Level in Trucks with Governed Diesel Engines	7.75
Z107.25-M1983	Procedure for Measurement of the Exhaust Sound Level of Stationary Motorcycles	8.75
Z107.51-M1980	Procedure for In-Situ Measurement of Noise from Industrial Equipment	11.00
Z107.52-M1983	Recommended Practice for the Prediction of Sound Pressure Levels in Large Rooms Containing Sound Sources	17.00
Z107.53-M1982	Procedure for Performing a Survey of Sound Due to Industrial, Institutional, or Commercial Activities	10.00
Z107.71-M1981	Measurement and Rating of the Noise Output of Consumer Appliances	20.00

Copies of these standards may be purchased from CSA in Toronto, Vancouver, Edmonton, Winnipeg or Montreal. The Toronto address is: Sales Group, Canadian Standards Association, 178 Rexdale Boulevard, Rexdale (Toronto), Ontario M9W 1R3.

There is a postage and handling charge of $1.00 in Canada, $2.50 U.S.A. and foreign, per order. A cheque is required with all orders under $75.00. VISA or MASTERCARD orders will be accepted by phone at (416) 744-4044.

1985 NATIONAL BUILDING CODE

The technical code changes proposed for inclusion in the 1985 NBC are now available for public review.

The acoustical requirements in the present version of the code are contained in Part 9. It requires, at present, that walls or floors separating homes should attain a sound transmission class of 45. There are no requirements for impact insulation. The proposed change is:

Delete and substitute:

9.11.1.1. Sound transmission class ratings for construction shall be determined in accordance with ASTM E90, "Laboratory Measurement of Airborne-Sound Transmission Loss of Building Partitions" or with ASTM E336, "Measurement of Airborne Sound Insulation in Buildings" or with ASTM E597, "Standard Practice for Determining a Single-Number Rating of Airbonre Sound Isolation for Use in Multiunit Building Specifications." (See Appendix A.)

Reason:

To reference as an option a new ASTM Standard which provides a quick and simple procedure to verify the actual sound isolation between rooms in a building. E90 and E336 are designed to evaluate a single element only such as a wall or floor whereas E597 accounts for all possible sound paths.

Also to reference explanatory material in the Appendix.

Comments will be accepted until 28 October 1983 and should be addressed to:

Secretary
Associate Committee on the National Building Code
National Research Council of Canada
Montreal Road
OTTAWA, Ontario
K1A 0R6

PENN STATE SHORT COURSE ON UNDERWATER ACOUSTICS AND SIGNAL PROCESSING

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The Canadian Acoustical Association
l'Association Canadienne de l'Acoustique

P.O. Box 3651, Station "C"
Ottawa, Ontario
K1Y 4J7

30 May 1983

CAA Members and Potential Members

Your directors and executive have been pondering over the request for a directory for the Canadian Acoustical Association. Unfortunately they have not as yet decided whether to have one made or not. For this reason I am asking you to comment on the subject by writing a note and sending it to my attention. This subject will be one of two items for discussion at our Vancouver meeting. One director and one of the executive are against the development of such a directory and three directors had no comment. The remaining ones in favour made the following statements.

1. NRC or the secretary and an ad-hoc committee should be responsible for the directory.
2. It should be a small booklet with the information divided into regions.
3. All in favour of a directory but one thought advertising should be allowed.
4. Those in favour thought that the individuals should decide whether or not they belonged in a given category. One director is of the opinion that there should be a category for those who have passed the INCE exam.
5. The decision of charging for the directory seems to be split down the middle.
6. The minimum information should be address and telephone numbers. Other information would relate to available facilities, qualifications, interests, source of income if over 25% in another field.

An example of the acoustical directory used in France is shown for your information.

Your President,

Cameron W. Sherry

Cameron W. Sherry

lc

he Canadian Acoustical Association
\ssociation Canadienne de l'Acoustique

). Box 3651, Station "C"
tawa, Ontario
Y 4J7

Le 30 mai 1983

Aux membres de l'ACA et aux membres virtuels

Vos directeurs et représentants ont examiné la question d'un répertoire de l'Association canadienne de l'acoustique. Malheureusement, ils n'ont toujours pas rendu leur décision. À cet effet, je vous prie de m'envoyer vos commentaires. Cette question sera l'un des deux points à l'ordre du jour de notre réunion de Vancouver. L'un des directeurs et l'un des représentants s'opposent à la création d'un tel répertoire et trois directeurs se sont abstenus de commentaire. Les autres en faveur du projet ont fait les observations suivantes :

1. La RCN ou le secrétaire et un comité spécial devraient se charger de compiler ce répertoire.
2. Il devrait être présenté sous forme de livret et l'information devrait être répartie en fonction des régions.
3. Tous les membres en faveur de l'élaboration du répertoire, à une exception près, sont d'avis que la publicité devrait être autorisée.
4. Les membres en faveur sont d'avis qu'il reviendrait aux individus de décider à quelle catégorie ils appartiennent. Un directeur est d'avis qu'il devrait y avoir une catégorie pour ceux qui ont réussi l'examen de l'INCE.
5. Les avis semblent partagés sur la décision de faire payer le répertoire.
6. Il faudrait qu'il contienne au moins les adresses et les numéros de téléphone. Les autres données utiles pourraient comprendre une courte description des installations, les compétences, les intérêts, la source de revenu si elle provient à 25 p. 100 ou plus d'un autre domaine.

Voici un exemple de répertoire du domaine de l'acoustique en usage en France.

Votre président,

Cameron W. Sherry

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Chaque nom est suivi de l'adresse à domicile (1ère colonne), des titres ou fonctions à l'adresse professionnelle (2ème colonne) et de la spécialité indiquée par les abréviations suivantes (3ème colonne) :

Code	Spécialités
AE	Acoustique aérodynamique
AR	Acoustique architecturale
BR	Bruit
EL	Electroacoustique (et Enregistrement)
IS	Infrasons
ME	Métrologie - Appareils de mesure
MO	Acoustique moléculaire
MU	Acoustique musicale
PA - CP	Parole (Communication parlée Analyse, synthèse, reconnaissance)
PH	Acoustique physique
PP	Acoustique physiologique et psychologique
SM	Acoustique sous-marine
TS	Traitement du signal
US	Ultrasons
VI	Vibrations

Each name is followed by the home address (1st column), the title or capacity at the business address (2nd column) and the specialization field using the following abbreviations (3rd column):

Code	Specialization Field
AE	Aerodynamic acoustics
AR	Architectural acoustics
BR	Noise
EL	Electro acoustics (and recording)
IS	Infrasound
ME	Metrology - Instrumentation
MO	Molecular acoustics
MU	Musical acoustics
PA - CP	Speech (Oral communication, analysis, synthesis, recognition)
PH	Physics of acoustics
PP	Physiological and psychological acoustics
SM	Underwater acoustics
TS	Signal processing
US	Ultrasound
VI	Vibration

6-kHz NOTCH IN NOISE-INDUCED HEARING LOSS

by

David Y. Chung, Ph.D.
Workers' Compensation Board of B.C.
Hearing Branch,
10551 Shellbridge Way,
Richmond, British Columbia, Canada
V6X 2X1

ABSTRACT

Audiograms from 49 711 workers exposed to industrial noise over 85 dB(A) and with no obvious ear pathology were analyzed by sex and age. It was found that the configuration of the mean audiograms shows a notch at 6 kHz instead of 4 kHz reported in previous studies. When the mean audiograms were corrected for presbycusis, the notch shifted from 6 kHz to 4 kHz only for the age groups over 45 years. The reasons for the difference between results of previous studies and this study are discussed.

SOMMAIRE

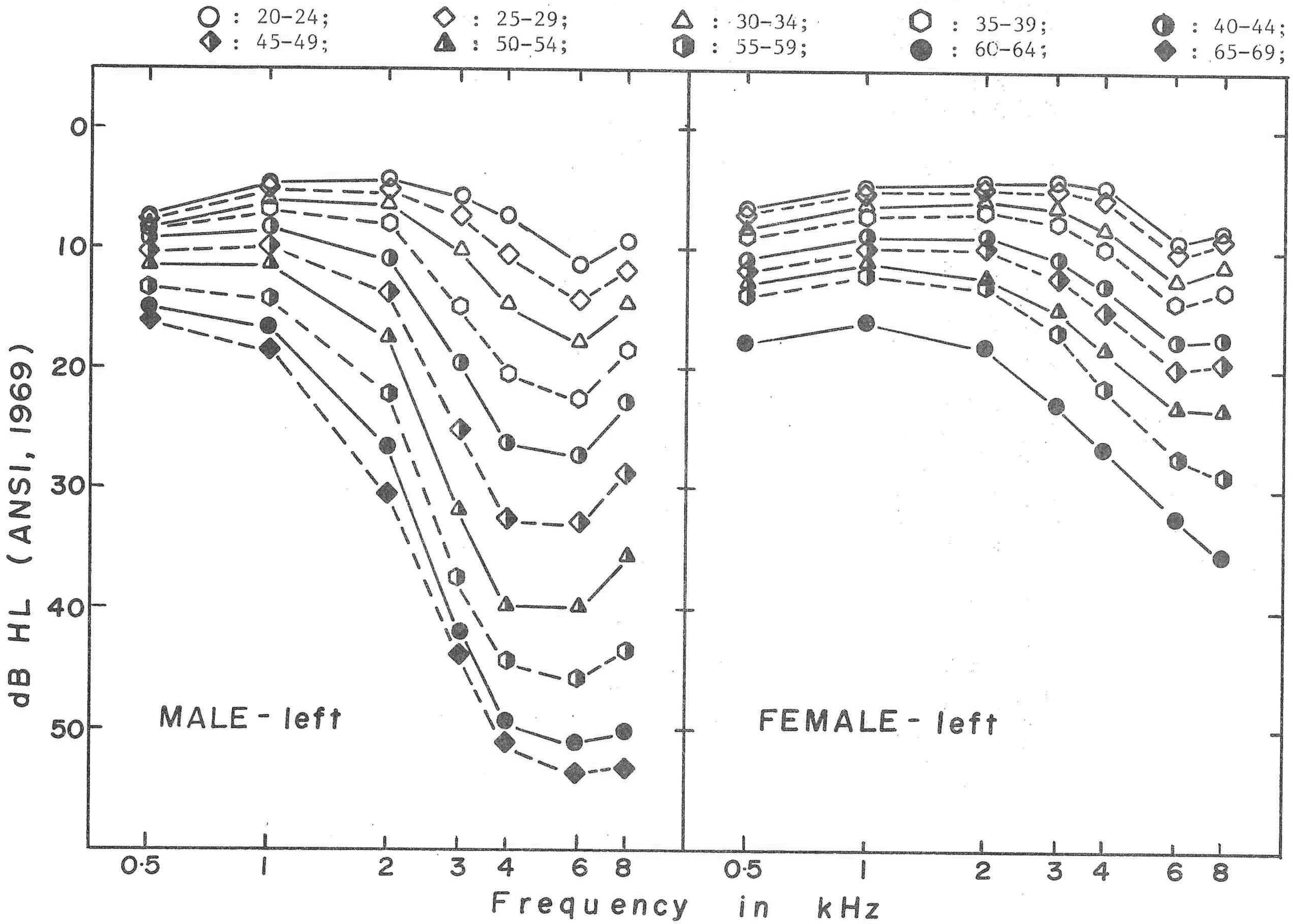
Les audiogrammes de 49 711 travailleurs qui étaient exposés aux bruits industriels de plus de 85 dB(A) étaient analysés par genre et par age. Cette population de travailleurs n'avait aucune patholgie de l'oreille évidente. Le résultat était que la configuration de la moyenne des audiogrammes indique un 'notch' à 6 kHz au lieu d'un à 4 kHz comme il y était rapporté par les récherches précédentes. Quand la moyenne des audiogrammes était corrigée pour 'le presbycusis', le 'notch' se déplaçait de 6 kHz à 4 kHz seulement pour les groupes de personnes âgées de plus de quarante-cinq ans. Les raisons pour la différence entre les résultats des récherches précédentes et de cette récherche sont examinées.

INTRODUCTION

In a previous paper (Chung et al., 1981) the hearing conservation program (HCP) administered by the Workers' Compensation Board of British Columbia (WCB) was described The WCB has copies of all audiograms of workers participating in the HCP of the WCB along with other information on medical history, shooting history, smoking history, and the use of hearing protectors. These data are recorded on an optical scan form (Appendix I) by technicians trained by the WCB and are stored on disc for record and for statistical analysis.

In this study we examined an industrial noise-exposed population in British Columbia by age and sex and discussed the possible use of these functions in a HCP. We also described the distribution of workers by hearing level and age for each test frequency.

Fig. 1. Mean audiograms of BC industrial workers by sex and by age group.



METHOD

Since only workers exposed to a time-weighted average (TWA) of 85 dB(A) or more for eight hours are required to be included in the HCP, all cases included in this study are believed to have a noise exposure of 85 dB(A) (TWA) for eight hours.

The type (manual vs automatic) and the make of audiometers used by different firms vary in BC. However, all facilities are inspected annually by industrial audiometric inspectors from the WCB to ascertain conformity to regulations. Audiometers and sound booths are checked as to whether they meet the CSA standard 107.4-1975 (1980 amendment).

Not all workers in our industrial audiometric data bank were used in the analyses. Only those who met the following criteria were selected. The selection criteria were: (1) answering "NO" to questions: Have you ever had A, B, C, D, E, F, G, and J, and Do you now have C and D, in the medical history (hearing) section in Appendix I; (2) between the age of 20 - 70 years. A total of 49 711 cases out of a total of 54 761 met the selection criteria.

The majority of the workers are exposed to a TWA (8 hours) from 85 to 100 dB(A). The type of noise varies with the industry. The industries that employ the largest number of noise-exposed workers in BC in decreasing order are: (1) sawmills, (2) steel fabrication and foundry, (3) logging, (4) pulp and paper, (5) heavy construction, (6) plywood, (7) shipbuilding, and (8) shake and shingle mills. Personal hearing protection has only been used extensively in BC for the past ten years.

RESULTS AND DISCUSSION

Mean audiograms by age and sex:

Fig.1 shows the mean audiograms by age and sex. The number of workers in each age group is shown in Table I.

Certain features can be recognized in Fig.1.

(1) As the age increases, the hearing threshold level also increases, particularly at the higher frequencies.

(2) The configuration of the mean audiograms shows a notch at 6 kHz instead of 4 kHz reported in previous studies (Burns, 1968; Robinson and Shipton, 1977) particularly in the younger age groups in which presbycusis is not a factor. However, when the audiograms are corrected for presbycusis (Robinson and Shipton, 1977) the notch shifts from 6 kHz to 4 kHz only for groups over age 45 years (Fig.2).

(3) Female workers as a group have far less hearing loss than male workers. A notch at 6 kHz is also apparent in the younger age groups but the notch disappears in the older groups.

The presence of a notch at 6 kHz in the younger population has been shown previously (Axelsson et al, 1981; Roberts and Huber, 1970; Gasaway, personal communication). In the present study we have also shown that such a 6 kHz notch is also present in both the young noise-exposed male and female workers. In examining the mean audiograms of the male workers, hearing loss would seem to commence at 6 kHz. Then damage at 4 kHz begins to catch up until presbycusis starts in the older groups and the hearing at 6 and 8 kHz begins to deteriorate more rapidly.

TABLE I Number of workers in each group.

Age in Years	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69
Number	8 630	8 445	7 526	5 790	4 621	4 459	4 211	3 359	2 301	369

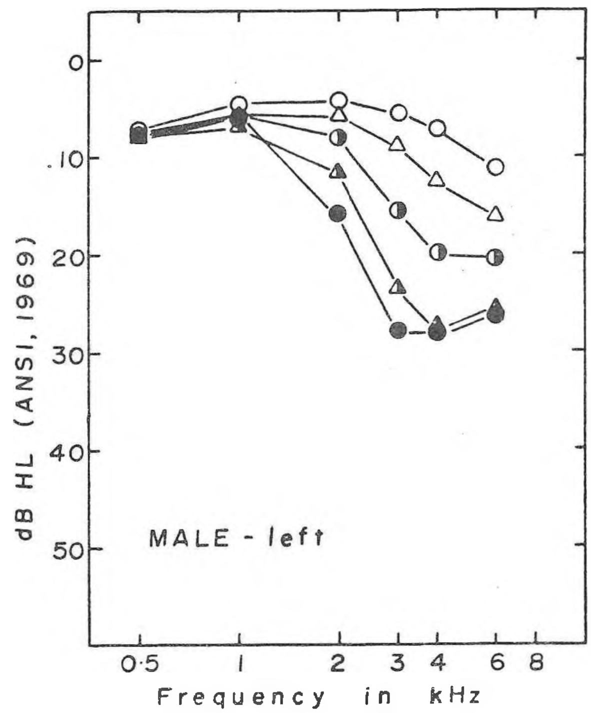
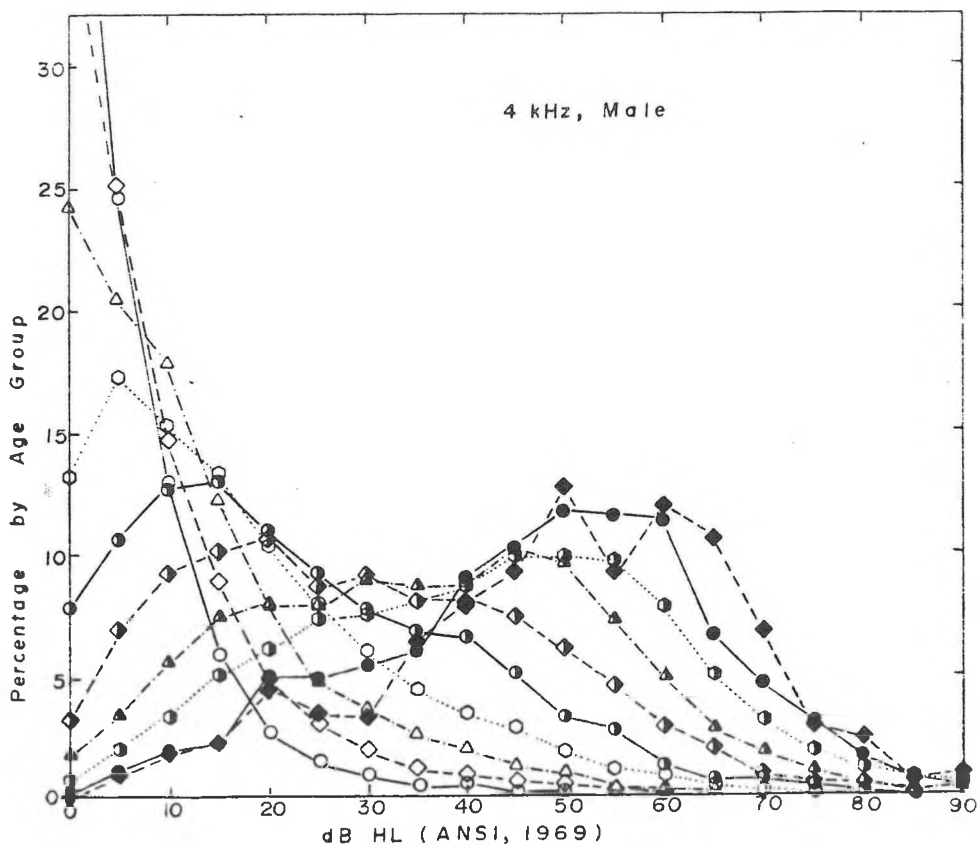


Fig. 2. Mean Audiograms of male BC industrial workers corrected for presbycusis. Refer to Fig.1 for symbol representation.

Fig. 3. The percentage of BC industrial workers in percentage by the degree of hearing loss at 4 kHz in each age group. Refer to Fig.1 for symbol representation.



The large disparity between the hearing levels of the male and female workers ›uld not necessarily be viewed as reflecting the sex difference in susceptibility noise damage. One important factor in the difference was the history of noise ›osure in the two groups. Male workers had much higher noise exposure during their :etime than female workers, both due to the job noise level and the amount of time noise.

Mean audiograms of this type are very useful in a HCP, as it can be used to ıpare HCP performance of different industries, firms, and occupations.

There are different ways of presenting the audiometric data other than the more ıventional one presented above. One is shown in Figs. 2 and 3 for frequencies ınd 6 kHz respectively. Each of the functions in the Figures represent an age group. :h data point represents the percentage of workers in that age group with hearing :eshold levels at that frequency.

The curves shown in Figs. 2 and 3 display great smoothness and orderliness with ɛ exception of the 65 - 69 year-old group, which had a sample size of only 369 ıble I).

The distribution of data points varies substantially from the low to the high ɛquencies. For the lower frequencies (0.5 and 1 kHz) the results, which are not ɛsented here, show that the majority of workers have hearing threshold level 25 dB HL (ANSI, 1969). For the higher frequencies, there is a shift of the peak ›ng the abscissa from low to high HL as age increases. This is particularly well ıonstrated in Fig.3 at 6 kHz.

By comparing Figs. 2 and 3 it can be observed that it is at 6 kHz that hearing ırts to deteriorate first, and not at 4 kHz. At 6 kHz the function already peaks 5 dB HL for the 25 - 29 year-old group. The peak shifts to higher dB HL with age 6 kHz faster than the shifts at other frequencies.

The 6-kHz notch found in the mean audiograms of the large industrial noise-exposed ›ulation in BC is seemingly in disagreement with the classical finding that 4 kHz is ıtistically the frequency at which hearing is most susceptible to noise damage ›binson, 1976; Robinson and Shipton, 1977). However, this apparent discord can be ›lained by data from other studies.

Data from the U.S. National Health Survey (Roberts and Huber, 1970) have shown ıoticeable 6-kHz notch in the median audiogram for the sample of over 7000 children :ween 6 - 11 years of age. In the study the hearing thresholds are also represen- l in quartiles. It can be observed that the 6 kHz-notch increases its prominence the representation of the audiogram increases from the 25th quartile to the 75th ırtile. This suggests that the worse their hearing is, the greater the likelihood getting a 6-kHz notch.

In another study Passchier-Vermeer (1968) compiled data from various sources relating ıse-induced permanent threshold shift to noise exposure. Her data suggest that at lerate noise level (about 80 dB and below) hearing loss actually starts at 6 kHz. vever, at higher noise exposure levels, hearing loss at 4 kHz increases at a much ster rate.

The results of these two studies suggest that the 6-kHz notch is at least partly ɛ outcome of the calibration standard and that the notch seems to become more distinct persons with moderate noise exposure. The results of this study are consistent with such a notion. In the past 10 years, hearing protection has been used extensively in BC in industries where the unprotected TWA noise exposure level is over 85 dB(A). Therefore, the actual noise exposure of workers using hearing protection has been considerably reduced, possibly to 80 dB(A) or below. It is not surprising that the younger male and female groups have a notch of 6 kHz.

This is also consistent with Fig.1 in which the damage at 4 kHz begins to catch up with that at 6 kHz at a higher age group. This is likely the consequence of the fact that very few workers used hearing protectors 15 years or so ago. The high noi exposure then could have caused more damage at 4 kHz. It is entirely possible for a a younger worker who uses proper hearing protectors to have a notch which remains at 6 kHz. Therefore, one should not predict, although it is tempting, the future heari level of a younger worker on the basis of the audiological data from older workers.

Other studies which demonstrated a 6-kHz notch in the audiogram also involved populations with a moderate noise exposure and also the use of hearing protectors. There were 538 boys from trade schools (Axelsson et al, 1981) and the young U.S. Air Force Military Personnel (Gasaway, personal communication).

In many audiometric programs 8 kHz is not one of the test frequencies. In thos cases a 6-kHz notch is not seen. Particularly when this 6-kHz notch in the younger group occurs mostly between 10 - 20 dB HL it is often regarded as insignificant.

There is always the possibility, although unlikely, that the presence of the 6-kHz notch in the industrial population in BC is a consequence of the noise spectra that are peculiar to BC industries. However, in searching through our records of th industrial noise spectra no major occupations show exposure to noise with energy cor centrating above 4 kHz. Also the large number of workers and the variety of industı preclude the possibility of biased sampling.

CONCLUSION

There is evidence in this study which indicates that 6 kHz is the frequency fiı attacked by noise at moderate level. The 6-kHz notch often first occurs in young workers with moderate noise exposure. Even though the notch often occurs at a level below 20 dB HL in the younger population its significance should not be ignored. It serve as an early warning indicator of susceptibility to noise damage. In that resp testing at 8 kHz should be seriously considered in a HCP.

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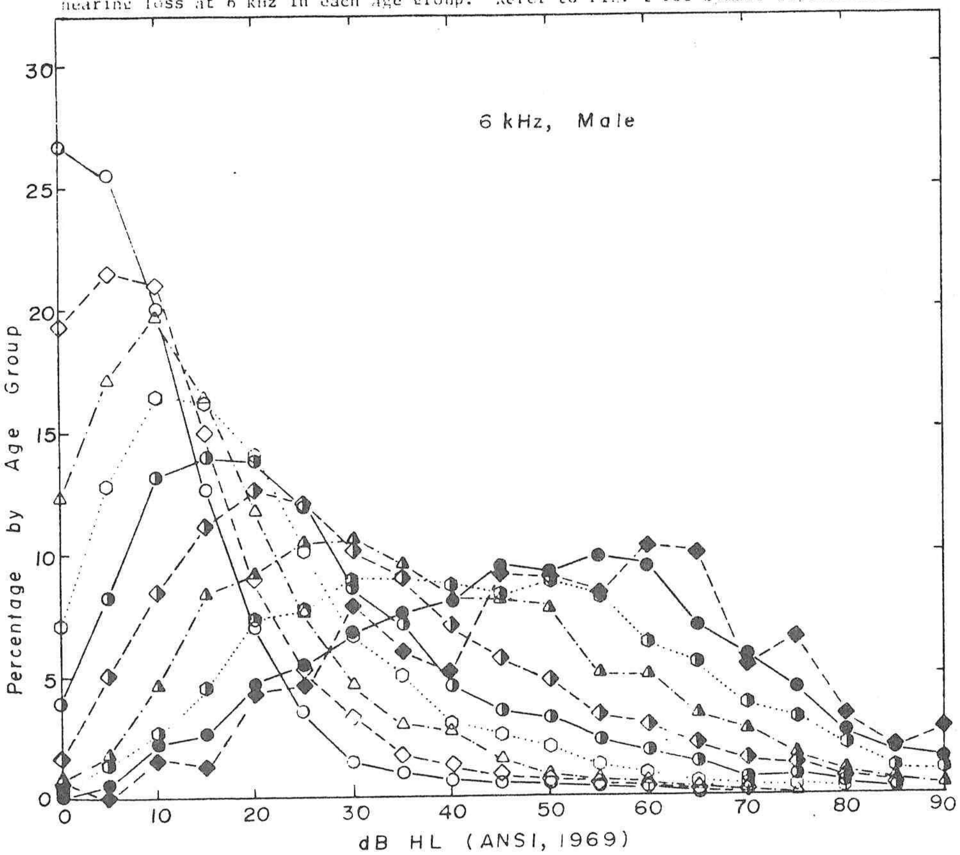
Fig. 4. The percentage of BC industrial workers in percentage by the degree of hearing loss at 6 kHz in each age group. Refer to Fig. 1 for symbol representation.



APPENDIX I

MEDICAL HISTORY (HEARING)

HAVE YOU EVER HAD:	NO	YES	LEFT	RIGHT
A) A hearing test by an ear specialist in the last 5 years	___	___		
B) A severe ear infection	___	___	___	___
C) Ear drainage or pain	___	___	___	___
D) Pressure in or around ears except altitude changes	___	___	___	___
E) Ear surgery	___	___	___	___
F) Dizziness or balance problems	___	___	___	___
G) A serious head injury	___	___	___	___
H) Exposure to loud blast or explosion	___	___	___	___
I) A hearing aid now or in the past	___	___	___	___
J) A relative with hearing loss before age 50	___	___	___	___

DO YOU NOW HAVE:				
A) Trouble understanding speech	___	___	___	___
B) Ringing in your ears	___	___	___	___
C) Changes in hearing from day to day	___	___	___	___
D) A ruptured ear drum	___	___	___	___

The following are 2 letters received by the editor regarding "Effect of mean flow and damping on the performance of reactive mufflers", P.T. Thawani and A.G. Doige, Canadian Acoustics, Vol. 11(1), pp.29-47, 1983, and are published unedited.

LETTER TO THE EDITOR

This letter is intended for two purposes, namely, to point out the misleading statement concerning equation (10) of [1] and to raise a question regarding equation (8.1) of [2].

Firstly, the statement about equation (10) of [1] is misleading in that it was mentioned there that it was the governing equation of wave propagation for the case of no flow and yet the constant $\alpha = [(c+U)/(c-U)]^2$ ... quoted was a function of mean flow U.

Secondly, it is interesting to note that a governing equation of wave propagation for the case with mean flow, equation (8.1) of [2] was not quoted and instead replaced by equation (10) of [1]. It is interesting because the writer of this letter was working in the same department as the authors of [1] and [2] was written in 1975.

C. W. S. To,
Department of Mechanical Engineering,
The University of Calgary,
Calgary, Alberta, Canada.
T2N 1N4

References

1. P. T. Thawani and A. G. Doige, 1983, CANADIAN ACOUSTICS, Vol. 11, No. 1, 29-47. Effect of mean flow and damping on the performance of reactive mufflers.

2. C. W. S. To, 1975, M.Sc. Thesis, The University of Calgary, Calgary, Canada. A transient testing technique for matrix parameters of acoustic parameters.

AUTHORS' REPLY

It should be understood by the reader that the mean flow velocity, U, is equal to zero in the case of 'no flow' as stated prior to equation (10) of [1]. The main purpose of this exercise was to arrive at a transfer matrix form shown in equation (11) of [1] for which U is obviously non-zero. Perhaps a footnote in reference to α stating that U=0 for equation (10) would have avoided the confusion. We regret if anyone was misled by this.

In response to Dr. To's second point, we would like to add that all the equations of wave propagation expressed in [1] were in terms of the acoustic pressure, p, and not the velocity potential, Ψ, as in equation (8·1) of [2]. Therefore, it was not felt necessary to quote equation (8·1) of [2]; instead, it was referenced by [3] and [4].

P. T. Thawani† and A. G. Doige
Dept. of Mechanical Engineering
The University of Calgary
Calgary, Alberta T2N 1N4
Canada

REFERENCES

1. P. T. Thawani and A. G. Doige, "Effect of Mean Flow and Damping on the Performance of Reactive Mufflers, Canadian Acoustics, Vol. 11, No. 1, 1983, pp. 29-47.

2. C. W. S. To, "A Transient Testing Technique for Matrix Parameters of Acoustic Systems," M.Sc. Thesis, 1975, The University of Calgary, Calgary, Alberta, Canada.

3. S. N. Rschevkin, A COURSE OF LECTURES ON THE THEORY OF SOUND, The MacMillan Company, New York (translation from Russian edition), 1963.

4. C. W. S. To and A. G. Doige, "A Transient Testing Technique for Matrix Parameters of Acoustic Systems; I. Theory and Principles," J. Sound Vib. 62 (2), pp. 207-222 (1979).

---

† Current address: Nelson Industries, Inc., Stoughton, WI 53589, U.S.A.

Letter to the Editor: - Correction to "Regulating Occupational exposure to noise - A review (Revised September 1982)." (Canadian Acoustics 11(3): 25-44, 1983).

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83 08 15

Deirdre A. Benwell
Editor-in-Chief
Canadian Acoustics
Radiation Protection Bureau
Environmental Health Centre
Tunney's Pasture
OTTAWA, Ontario
K1A OL2

Dear Deirdre:

This correspondence is reference Canadian Acoustics, July 1983, Volume 11 in which our out-dated Noise Regulation was cited. Enclosed is Alberta Regulation 314/81, the Province's current Occupational Noise Regulation. AR 314/81 was promulgated in September 1981 and conforms to Alberta's Occupational Health and Safety Act.

Among the highlights of this Regulation, as opposed to the old Division 29, are an impact noise table, a specified schedule of audiometry, review of abnormal and abnormal shift test results, hearing protection in accordance with CSA Z94.2-1974, and an annual activity report. This Regulation clearly outlines the responsibilities of both the employer and employee.

I have also taken the liberty of enclosing our latest Audiometric Technicians Training Manual. See you soon.

Sincerely,

John

John Throckmorton, M.S., CCC-A
Co-ordinator, Occupational Hearing Conservation
Medical Services Branch

Enclosure
JT/cmm

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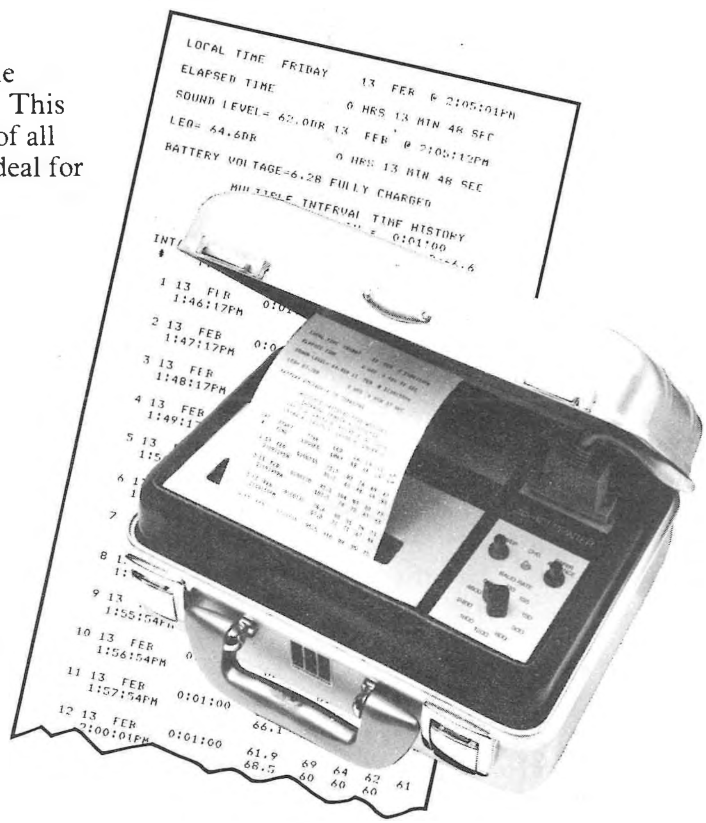

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Université Laval, Québec, GIK 7P4

SOMMAIRE

Les travaux présentés ici ont été initialement subventionnés par l'Hydro-Québec; ils constituent la deuxième partie d'une recherche relative au bruit des transformateurs et à son contrôle. Cet article fait donc suite à celui consacré dans le précédent numéro à la modélisation de l'impact acoustique des postes de transformation. Les matériaux testés ou mis au point en chambre réverbérante se divisent en trois grandes catégories, soit les éléments de maçonnerie avec résonateurs, les résonateurs avec cavité commune en acier et les membranes accordées. Dans les trois cas les dispositifs ont été optimisées pour le contrôle particulier du bruit des transformateurs, avec en complément un traitement de protection climatique et mécanique, de façon à répondre au mieux aux conditions réelles d'utilisation.

ABSTRACT

The research work presented in this article was originally subsidized by Hydro-Québec; it constitutes the second part of a project dealing with transformer noise and means of controlling it. The present article is thus a continuation of that published in the preceding issue in which a model of the noise impact of transformer stations was described. The materials tested fall into three broad categories: masonry units with resonators, steel resonators with common cavities and tuned membranes. In all three cases these devices were optimized for special use in controlling transformer noise. In addition, the devices were treated to protect them against mechanical failure and climate so as to ensure their effectiveness under real conditions.

INTRODUCTION

Les recherches présentées ici se poursuivent depuis 1980, initialement subventionnées par l'Hydro-Québec via la firme d'ingénieurs conseils L.G.L. de Montréal, elles sont actuellement soutenues par le ministère fédéral de l'Energie, des Mines et des Ressources. La première partie du projet, confié au Centre de recherches en aménagement et en développement et au Laboratoire d'acoustique de l'Ecole d'architecture, a déjà fait l'objet d'un premier article dans le numéro précédent; elle concernait la modélisation de l'impact acoustique des postes de transformation (1).

Parallèlement à l'élaboration du modèle, nous avons vérifié en chambre réverbérante les propriétés de certains matériaux et dispositifs susceptibles de présenter une forte absorption acoustique dans les bandes de fréquence produites par les transformateurs (120 Hz et ses harmoniques). Après avoir discuté sommairement de l'importance des traitements absorbants pour le contrôle du bruit des transformateurs et des conditions générales de mesure, nous exposerons les principaux résultats obtenus,tant pour des éléments de maçonnerie que pour des caissons préfabriqués en acier, munis d'une membrane ou de résonateurs à cavité commune.

1. INFLUENCE DE L'ABSORPTION ACOUSTIQUE SUR L'EFFICACITE DES DISPOSITIFS DE PROTECTION

Il apparaît, plutôt subjectivement, que le niveau de bruit résultant de la présence d'un mur écran absorbant sera plus faible que celui mesuré en présence d'un écran réfléchissant, et cela d'autant plus que cet écran réfléchissant sera susceptible de présenter des surfaces parallèles de part et d'autre du transformateur. Ce concept peut être sommairement vérifié sur le plan mathématique, à l'aide de la formule de SABINE et à l'aide des équations qui expriment la puissance acoustique telle que mesurée en champs diffus. En tenant compte de la conservation de l'énergie indépendamment de l'absorption du mur écran, il est possible d'écrire, dans le cas d'un mur en rond autour du transformateur (en considérant le sol comme parfaitement réfléchissant):

$$\overline{N}\text{ réfléchi} - \overline{N}\text{ absorb.} = 10 \log (2\,H\alpha/R + 1)$$

équation dans laquelle H est la hauteur du mur écran, R son rayon et α son coefficient d'absorption. Cette équation sommaire est intéressante, parce qu'elle montre que le niveau sonore, par rapport au niveau diffus à l'intérieur de l'écran, diminue avec l'absorption acoustique (de façon pratique de 0 à 4 dB). On pourra constater qu'il en est de même pour l'espace extérieur protégé par le mur écran, comme nous le montrerons par la suite.

De même, REIPLINGER (1972) (2) a mentionné l'élévation potentielle du niveau sonore à l'intérieur des enceintes totales constituées de matériaux peu absorbants. Cette élévation peut être évaluée à partir de l'équation:

$$\overline{N}\text{ réfléchi} - \overline{N}\text{ absorb.} = 10 \log \left[1 + 4(1 - \alpha)\, S_T/S_R\alpha \right]$$

dans laquelle S_T est la surface du transformateur, S_R la surface des murs intérieurs de la cellule et α leur coefficient d'abosrption moyen. Ainsi, pour un rapport des surfaces S_T et S_R d'environ 1/4, le niveau de bruit intérieur peut croître de 20 dB(A) avec un coefficient d'absorption égal à 0,01; d'où l'importance de disposer des matériaux absorbants adéquats dans les enceintes totales destinées aux transformateurs.

En conclusion, la présence d'un matériau absorbant approprié constitue un moyen simple pour gagner quelques décibels supplémentaires, notamment dans le cas d'une enceinte totale ou d'un écran continu bordant les quatre faces d'un même transformateur. Enfin, c'est là également un moyen susceptible d'éviter une élévation du niveau de bruit de quelques décibels, par suite de la présence d'un bâtiment ou de murs coupe-feu trop réfléchissants.

2. CONDITIONS GENERALES DES MESURES D'ABSORPTION

Les mesures d'absorption ont été réalisées dans la grande chambre réverbérant du Laboratoire d'acoustique (d'un volume total de 245 m^3), conformément aux recommandations de l'Organisation Internationale de Normalisation (ISO/R 354, 1963) (3), et suivant les directives de l'American Society for Testing and Materials (ASTM, C423-66, 1972) (4). Ces mesures ont porté sur des murs de maçonnerie et sur un système de caissons modulaires en acier garnis de différents types de matériaux absorbants.

De façon pratique, en tenant compte de leurs surfaces latérales, nos échantillons de maçonnerie avaient une surface totale voisine de 10,7 m^2, alors que les 4 caissons en acier utilisés présentaient chacun à leur partie supérieure une ouverture de 1,86 m^2, soit 7,4 m^2 de matériaux actifs. Nous avons systématiquement négligé, dans cette phase purement expérimentale, l'absorption des cadres et entourages des échantillons, la substitution de surface sur le plancher de la chambre et l'effet de l'humidité (surtout important au-dessus de 2 000 Hz). Toutes les mesure ont été faites au 1/3 d'octave, avec un minimum de 6 relevés par bande de fréquence (salle vide et avec échantillon).

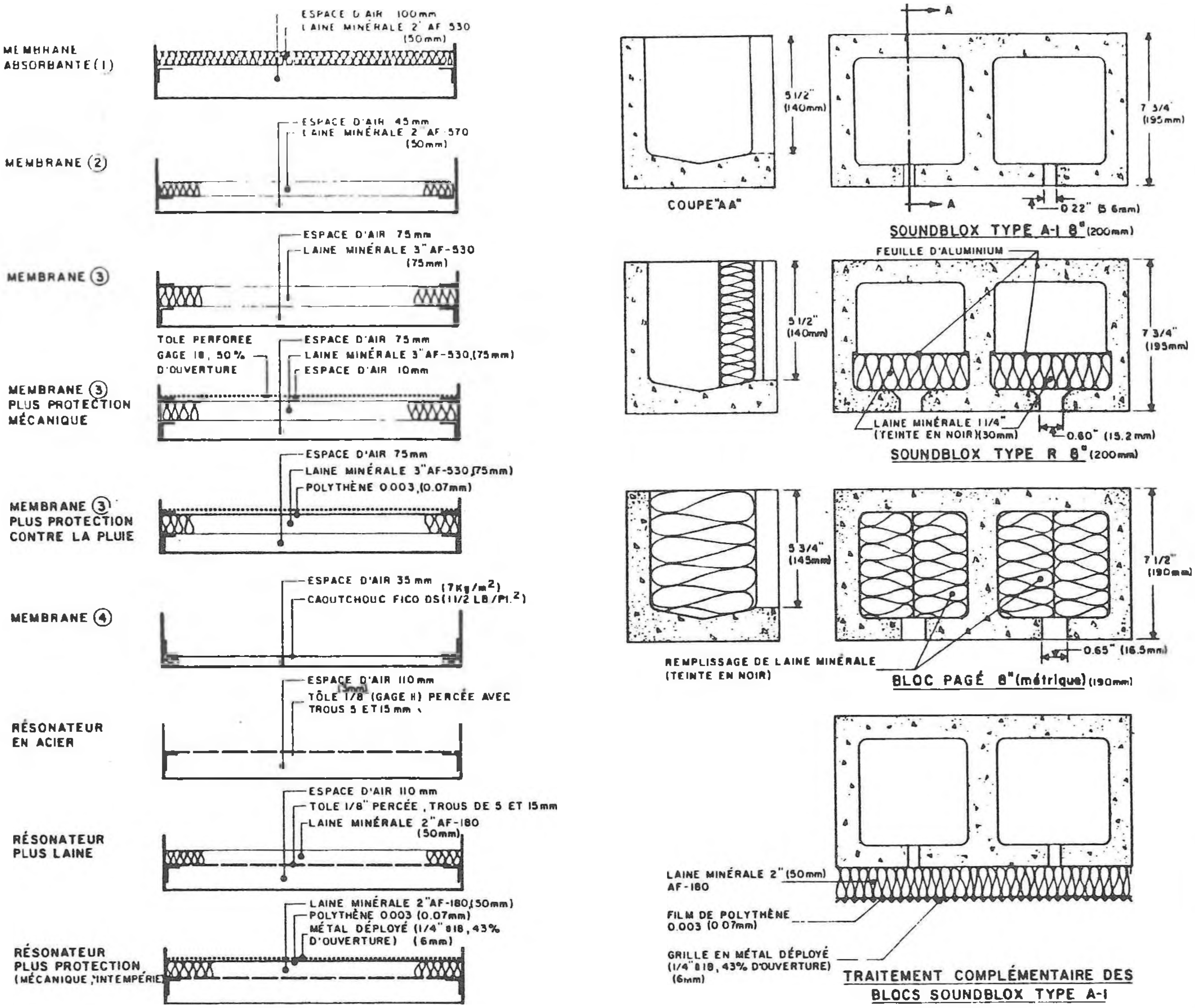
3. RESULTATS RELATIFS AUX ELEMENTS DE MACONNERIE

Nous avons testé trois sortes de blocs de béton acoustiques disponibles dans le commerce (0,20 m d'épaisseur à deux cavités). Leurs comportements ont été assez semblables soit une forte absorption à 125 Hz et ensuite une décroissance assez rapide vers les hautes fréquences, tempérée par la présence d'une garniture intérieure de laine minérale pour deux d'entre eux. De même, après de nombreux tests au tube à ondes stationnaires, nous avons essayé de percer des blocs de béton creux ordinaires (3 trous de 19 mm par cavité). Malheureusement ces blocs percés se sont révélés, en définitive, inférieurs aux blocs du commerce (absorption maximale de 0,46 à 200 Hz); d'autre part l'opération de perçage est fort longue donc coûteuse, c'est pourquoi nous avons préféré nous concentrer sur l'optimisation des produits existants, tel que montré sur la Figure no 1.

Ainsi nous avons recouvert les blocs acoustiques (à deux cavités et deux fentes de 5,6 mm) d'une laine minérale judicieusement choisie de façon à permettre à la fois la pénétration des basses fréquences et l'absorption des harmoniques jusqu'à 500 et même 1 000 Hz. Nous sommes finalement arrivés au choix d'une laine faible densité (29 kg/m^3). Les résultats de ce traitement complémentaire sont d'ailleurs reproduits avec ceux des blocs nus, sur la Figure no 2.

4. RESULTATS RELATIFS AUX CAISSONS EN ACIER AVEC TRAITEMENT ABSORBANT

Deux grands principes ont été mis en oeuvre pour la conception de ces caissons, soit les membranes accordées et les résonateurs avec cavité commune. En ce qui concerne les membranes, après plusieurs essais sur différents matériaux et indépendamment de la théorie appliquée pour les calculs préliminaires (PARKIN et HUMPHREYS, 1958) (5), il nous est apparu que la meilleure membrane devait être constituée d'une laine minérale épaisse (75 mm) à densité assez élevée (supérieure à 48 kg/m^3). Ce dispositif s'est d'ailleurs révélé dans la réalité peu coûteux et très efficace, bien qu'il puisse sembler assez fragile, sans une protection à la fois mécanique et climatique. Cet excellent résultat est à rapprocher de celui qui nous avions obtenu en 1976, lors de la mise au point de murs en maçonnerie (complétés par une membrane) pour le contrôle du bruit de la circulation automobile et notamment des basses fréquences issues des moteurs (6).



a) systèmes de panneaux modulaires en acier

b) éléments de maçonnerie

FIGURE NO 1 : *Principaux matériaux et dispositifs testés en chambre réverbérante pour l'absorption du bruit des transformateurs.*

Pour le choix d'un dispositif avec résonateurs, nous avons rejeté tout de suite le principe des volumes résonnants cloisonnés, parce que trop compliqués à construire. Nous avons concentré nos calculs, pour la paroi formant les collets des résonateurs, sur une tôle d'acier de 3,2 mm d'épaisseur, en prenant une disposition simple des perforations, suivant une grille orthogonale et avec un espacement de 76 mm. En fait, cet espacement des perforations est un paramètre important que nous avons dû optimaliser lors des calculs préliminaires, en gardant seulement comme variable le diamètre des perforations et le volume de la cavité, ceci conformément à l'approche de LIENARD et FRANCOIS (1972) (7). Après de nombreux tests préliminaires, réalisés notamment en sons purs de façon à accorder les cavités, nous nous sommes fixés sur un système à double perforation, accordé à la fois sur 120 et 240 Hz. Afin d'élargir le spectre d'absorption et améliorer le système, nous avons ajouté une laine minérale à faible densité

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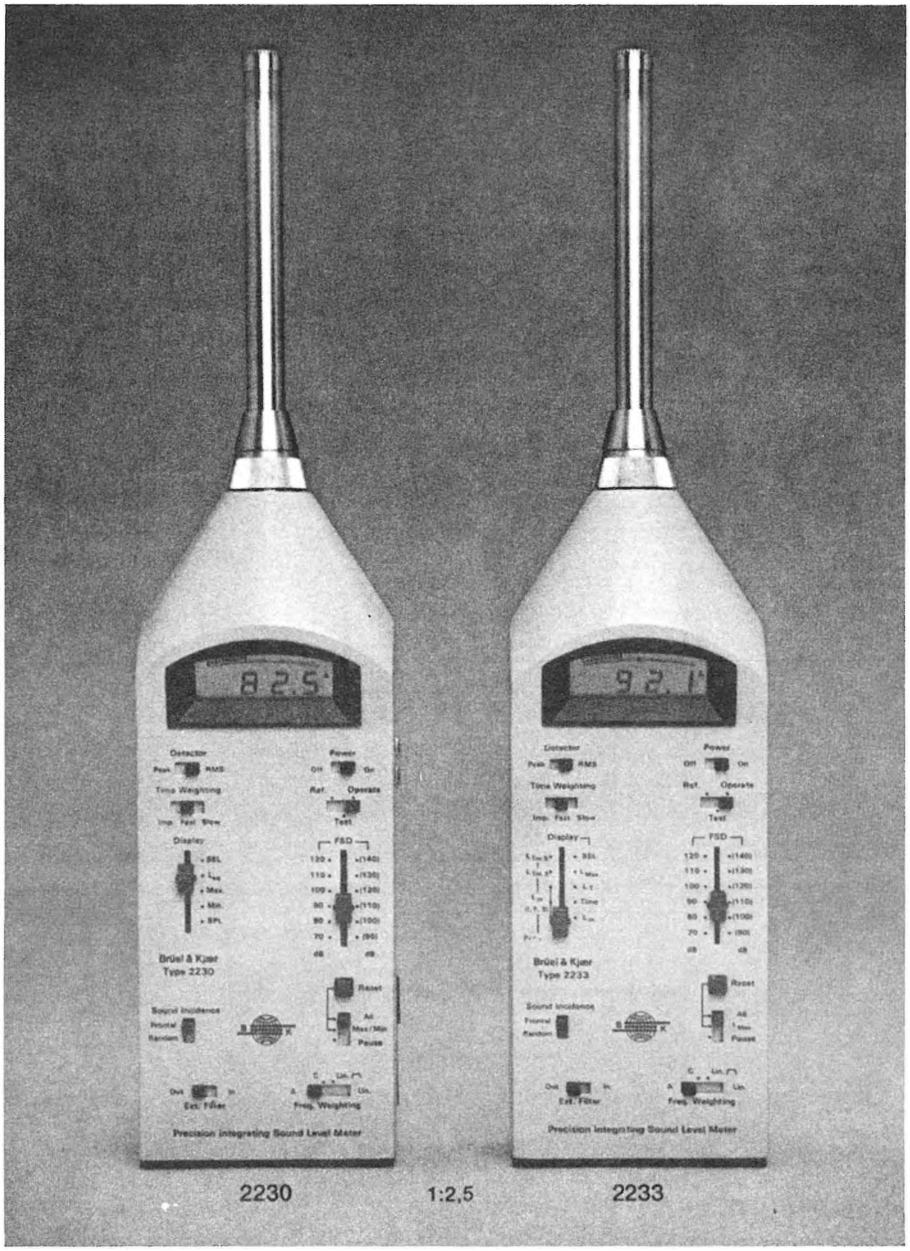

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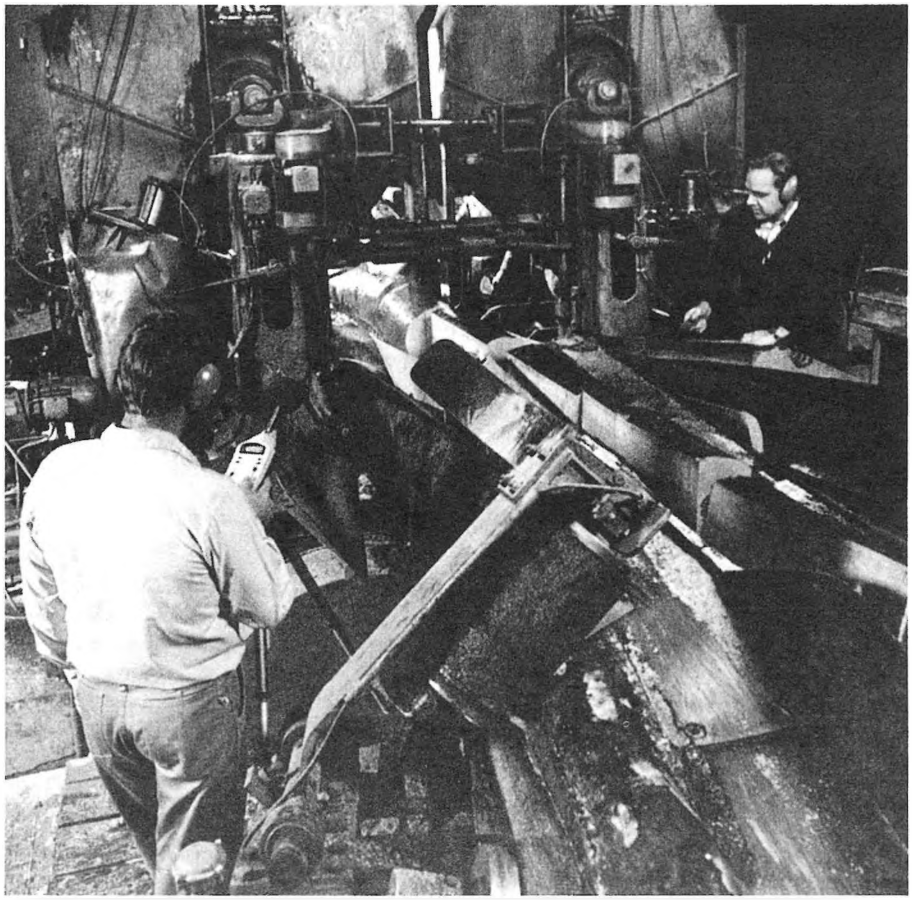

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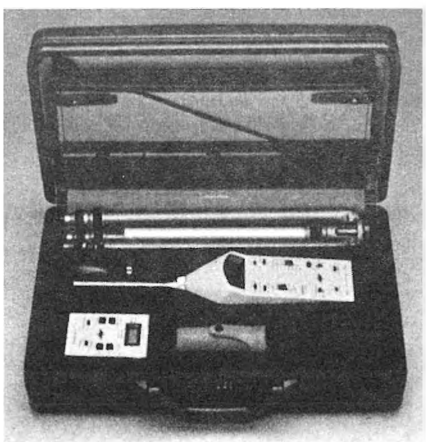

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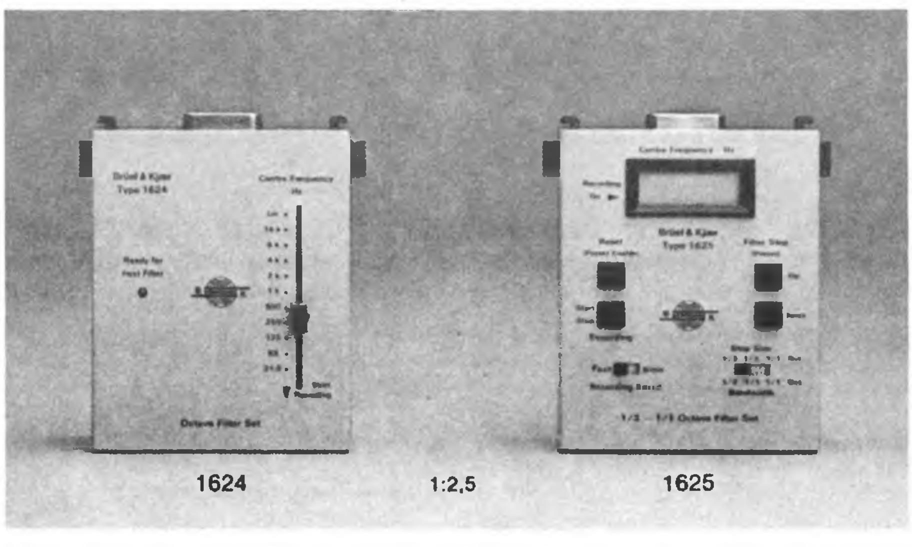

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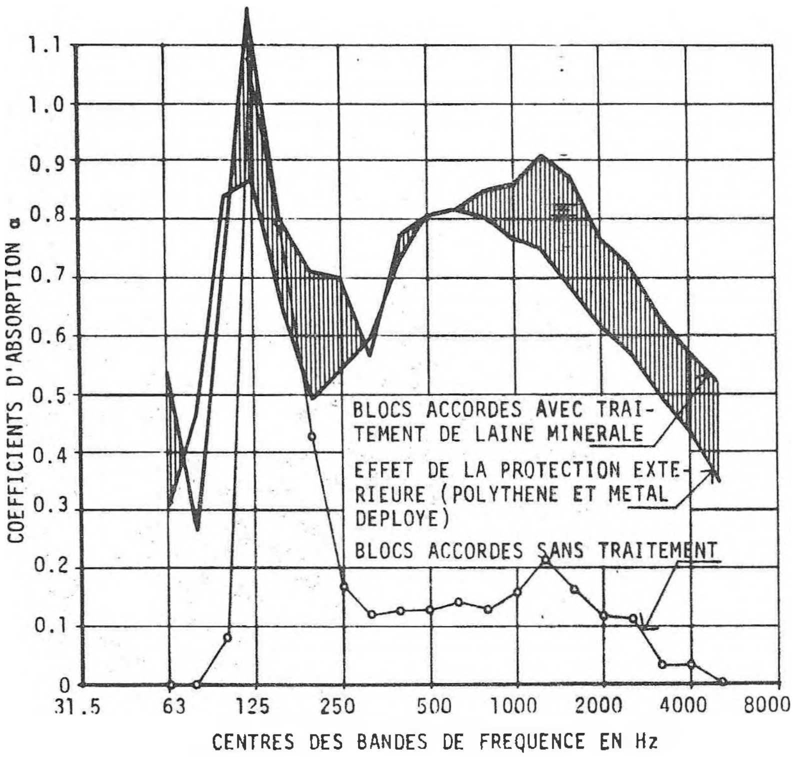

FIGURE NO 2 : *Principaux résultats obtenus en chambre réverbérante pour des murs absorbants en maçonnerie*

(29 kg/m^3) qui tout comme pour les blocs de béton creux, ne s'oppose pas à la pénétration des basses fréquences, tout en offrant une bonne absorption à partir de 500 Hz. D'ailleurs on commence un peu mieux à comprendre la nature du champ acoustique au voisinage de l'ouverture d'un résonateur, depuis l'existence des mesures intensimétriques (PETTERSEN et KRISTIANSEN, 1981)(8);ces études expliquent en partie l'efficacité de la disposition retenue. Les meilleurs résultats obtenus, tant pour les membranes que pour les résonateurs, sont reproduits sur la Figure no 3.

5. EFFET COMPLEMENTAIRE D'UN DISPOSITIF DE PROTECTION MECANIQUE ET CLIMATIQUE

Comme le montre les figures précédentes (notamment 1), pour la protection mécanique et la protection contre les intempéries du traitement acoustique, nous avons employé le même système pour les murs de maçonnerie et pour les résonateurs, soit une feuille de polythène de 7,5/100 mm et une grille extérieure de métal déployé à 42% d'ouverture. Les résultats acoustiques restent excellents, malgré une légère baisse de l'absorption au-dessus de 1 000 Hz, ce qui n'est pas important dans le cas du bruit des transformateurs. Pour les membranes absorbantes, le problème est plus complexe, puisqu'il faut laisser sa liberté au panneau en mouvement. La solution mise au point consiste en une feuille de polythène déposée directement sur la membrane de laine minérale et en une tôle perforée à 58% d'ouverture, installée à une distance d'environ 10 mm. Les résultats sont intéressants puisque le film de polythène ne réduit presque pas l'effet de la membrane dans la bande de 125 Hz. On peut d'ailleurs voir un exemple de cette disposition sur le Figure no 4 qui représente un mur écran, absorbant avec une membrane accordée installée sur un double "T" de béton.

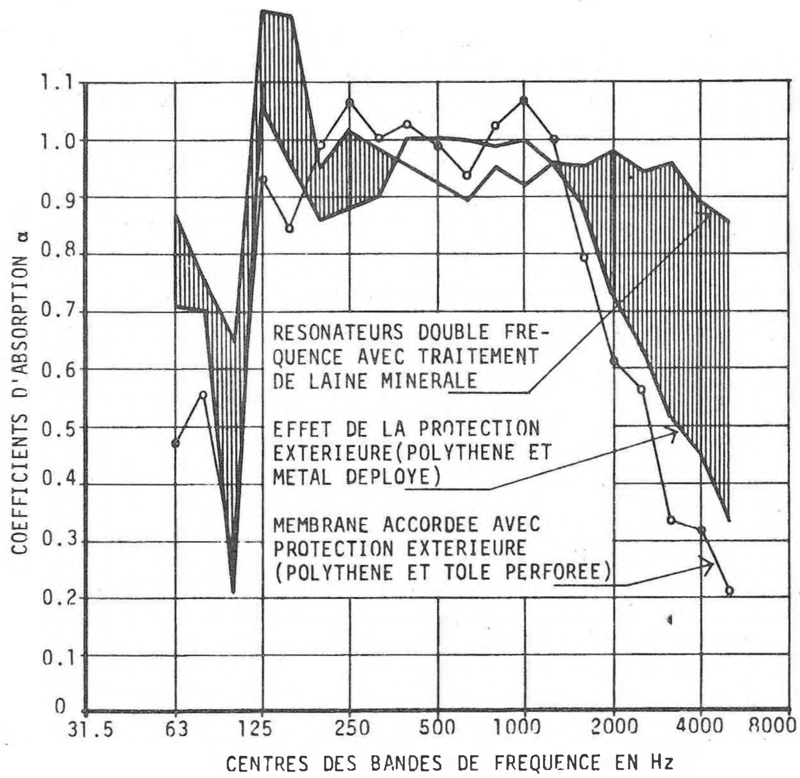

FIGURE NO **3** : *Principaux résultats obtenus en chambre réverbérante pour des murs écrans constitués de caissons modulaires en acier.*

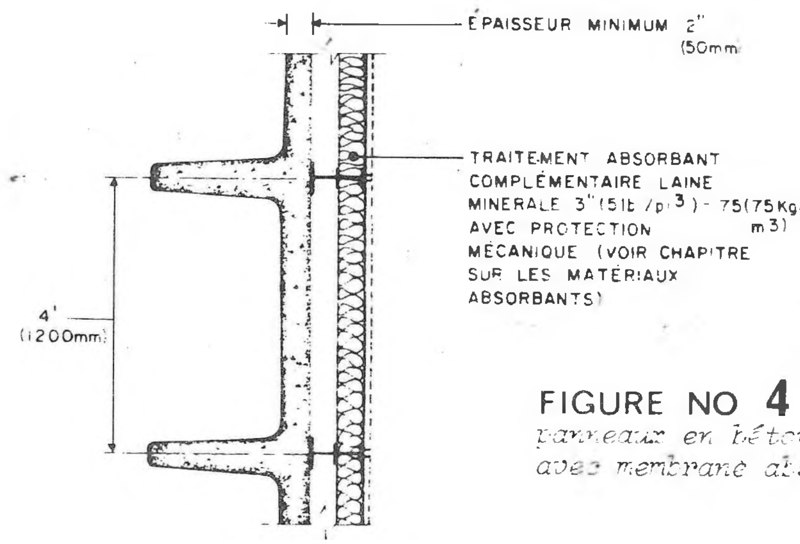

FIGURE NO **4** : *Exemple d'utilisation de panneaux en béton préfabriqués doubles "T" avec membrane absorbante.*

6. CONCLUSIONS RELATIVES AUX MATERIAUX ABSORBANTS ET AUX MURS ECRANS

Ces travaux montrent clairement qu'il est possible de construire des murs écrans autour des transformateurs électriques de puissance susceptibles de présenter à la fois une bonne durabilité et surtout une très forte absorption pour la fréquence de 120 Hz et ses harmoniques. A titre expérimental, nous avons eu l'occasion de construire en 1981 un mur linéaire de 4,6 m de hauteur et 22 m de longueur devant un transformateur de 315 Kv et 150 MVA; l'effet supplémentaire d'un absorbant du type membrane avec protection climatique a été de 4,5 dB(A) à 5 m de l'écran, 5,5 dB(A) à 10 m et encore 1,5 dB(A) à 100 m, ceci malgré l'ouverture du mur à ses extrémités et la présence d'une réflexion en arrière du transformateur. On peut donc constater l'importance de ce type de traitement, notamment pour les écrans à 3 ou 4 côtés.

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SUBJECTIVE RATING OF PARTY WALLS

by

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ABSTRACT

Results of a field survey of 98 subjects have been analysed and sound isolation measures have been compared to establish the influence of residential noise levels and non-acoustical factors on subjective judgements. A procedure is considered for estimating the properties of an ideal wall.

SOMMAIRE

Les résultats d'une étude in situ réalisée auprès de 98 ménages ont été analysés et des mesures d'isolation acoustique ont été comparées en vue de déterminer l'influence des niveaux de bruits et de facteurs non-acoustiques dans une habitation sur l'opinion subjective. Une méthode est envisagée pour évaluer les propriétés du mur idéal.

Standard procedures for measuring the transmission loss of party walls have existed for many years, but until quite recently no comprehensive field studies have attempted to relate adverse subjective responses to acoustical measures of sound insulation. Indeed, it has not been clear that it would be possible to establish strong correlations between acoustical measures such as STC and subjective responses. The present paper reports the results of a pilot survey consisting of interviews with 98 subjects and acoustical measurements of their 49 common walls. A more complete description is available.[1] In the absence of previous North American studies of this type the results of such a pilot study may be of general interest; it will be some time before complete results will be available from the more extensive studies now in progress.

PROCEDURE

After an introductory letter, subjects, if agreeable, were interviewed in their homes by trained personnel. The survey was presented as a building satisfaction survey, and initial questions made no mention of noise or acoustical problems. The responses to most subsequent questions were in the form of seven-point Likert-type scales. After each successful interview, permission to make acoustical measurements at a later date was requested. Finally, when interviewed subjects in adjacent homes both gave their consent, the acoustical measurements were made. These included the recording of A-weighted noise levels for one 24-hour period in each subject's living room. The transmission loss of each party wall was measured in 1/3 octave bands from 100 to 4000 Hz, in general following the approach of ASTM E336.[2] By tape recording test levels on each side of the wall, using a rotating microphone as well as sound decays in the receiving rooms, subjects were disturbed for less than half an hour. Acoustical data were processed by computer and several sound isolation measures were calculated.

Sound transmission loss in each 1/3 octave band is calculated as the difference in the space-averaged reverberant field sound levels in source and receiving rooms plus ten times the logarithmic ratio of the common wall area to the total receiving room sound absorption. From these individual transmission loss values an over-all Sound Transmission Class, STC, was calculated according to ASTM E413.[3] The Noise Isolation Class,[2] NIC, was calculated from the noise level differences between the two rooms. Also calculated were A-weighted level differences measured between the two rooms, referred to as DA when using a pink source spectrum and as DAS when using the source spectrum proposed by Schultz and incorporated in ASTM method E597.[4] An A-weighted sound transmission loss, STA, was calculated by summing the A-weighted transmission loss values as described in the equation below:

$$STA = 10 \log \left\{ \frac{1}{17} \sum_{i=1}^{17} 10^{(-TL_i + W_i)/10} \right\}$$

Values of the British Aggregate Adverse Deviation, AAD,[5] were also calculated. This measure is the sum of all deviations below a fixed two-segment reference contour and ignores bands where measured performance is above the reference contour. Statistical analyses of the combined data were carried out using the Statistical Package for Social Sciences.

SAMPLE CHARACTERISTICS

All subjects were residents of condominiums in the Ottawa area. Most were owners (91.8%) and lived (83.7%) in two-storey row-housing type developments. A satisfactory split between male (42.9%) and female (57.1%) respondents was obtained. In the summer of 1981, when data were gathered, the mean reported value of the homes was $41,433, the mean family income was $27,245, and the average subject was 37.4 years old, had 13.7 years of formal education, and had lived in his home for 45.6 months.

Measured STC values ranged from 39 to 60, with a mean of 51.2. Figure 1 shows the mean measured transmission loss characteristics of the 49 walls. Mean A-weighted L_{eq} values in the subjects' living rooms were 55.2 dBA for daytime (7 a.m. to 10 p.m.), 45.2 for night time (10 p.m. to 7 a.m.), and 53.0 dBA for the complete 24-hour period. Although a quite large range of measured party wall sound isolation values was obtained, the responses of this relatively small sample of subjects cannot be confidently generalized to large populations.

RELATIONS WITH ACOUSTICAL FACTORS

Figure 2 shows the results of correlations for four survey responses and various measures of party wall sound isolation. Among transmission loss type measures the British AAD tended to produce slightly higher correlations than the A-weighted STA, which in turn produced higher correlations than did STC values. The level difference measures DA, DAS, and NIC tended to produce lower correlations than the corresponding transmission loss measures. Although it is often suggested that actual differences in sound level would correlate best with subjective responses, the present results contradict this hypothesis. Level difference measures assess the steady-state

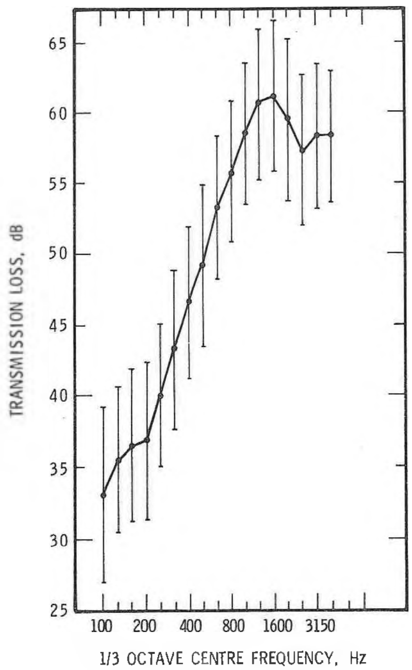

Figure 1. Mean, ± standard deviation transmission loss vs frequency

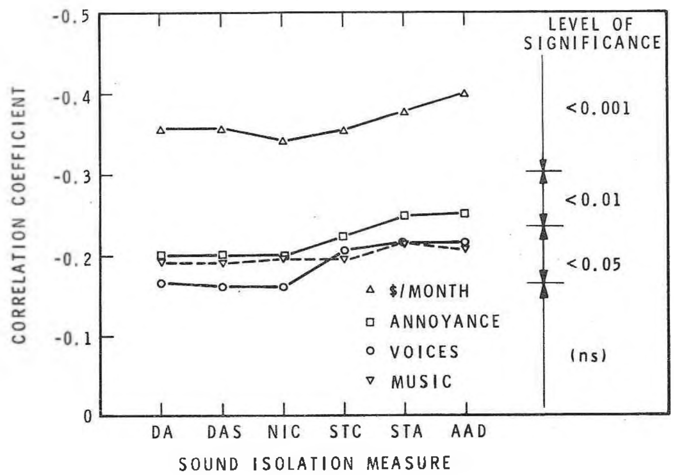

Figure 2. Correlations of four responses and six sound isolation measures

reverberant field sound levels in each room. It may be that the transient peak levels and the intervening common wall transmission loss are the more important parameters. This would explain the greater success of the transmission loss measures.

As in a recent study by Langdon,[6] more factual, less emotional responses correlated better with acoustical measures. In Fig. 1 it may be seen that the number of dollars per month that subjects are willing to spend to reduce annoying noises from neighbours correlates much more strongly with acoustical isolation measures (up to a correlation coefficient of 0.40) than do annoyance responses. In Langdon's study the highest correlations were obtained with responses to a question that simply asked subjects to rate the quality of their sound isolation. In the present study the interviewer came to believe that although some subjects acknowledge excessive noise intrusion, they are reluctant to say (in effect) that a particular neighbour is annoying. The situation is quite different from that for environmental noise surveys, such as those concerning traffic noise,[7] where subjects readily describe noise as annoying because there is usually no personal connection with the source of the noise.

Table 1 shows a selection of responses: some significantly relate only to measured STC values, others significantly relate only to L_{eq} values measured in the neighbour's home, and yet others significantly relate to both STC and L_{eq} values. Each annoyance response is thus related to a different set of predictor variables. The over-all annoyance measure was obtained as a result of a factor analysis of 22 annoyance and sleep disturbance responses. In traffic noise studies[8] this widely used technique produced composite response scales that were more reliable than single

Table 1

Correlations of Responses and STC, 24-hour L_{EQ}, and Combinations of STC and 24-hour L_{EQ}

Response	STC	L_{EQ}^{24}	$STC+L_{EQ}^{24}$
Satisfaction with Building	(ns)	-0.208	
Annoyance, Neighbours Either Side	(ns)	0.254	0.283
Annoyance, Neighbours' Voices	-0.210	0.213	0.316
Annoyance, Neighbours' Music	-0.196	(ns)	0.346
Annoyance, Neighbours' Children's Sounds	(ns)	0.331	0.333
Over-all Annoyance	-0.222	0.245	0.350

Table 2

Multiple Correlations with 24-hour L_{EQ} and Three Different Transmission Loss Measures

Type of Annoyance	$STC+L_{EQ}^{24}$	$STA+L_{EQ}^{24}$	$AAD+L_{EQ}^{24}$
Neighbours' Voices	0.316	0.316	0.312
Neighbours' Music	0.246	0.260	0.252
Neighbours' Children	0.333	0.334	0.332
Over-All Annoyance	0.350	0.359	0.358

item responses. In the present study the resulting composite annoyance scale (overall annoyance) was less successful in increasing correlations with STC values. The present responses, each having somewhat different characteristics, were unlike those observed in traffic noise surveys where many annoyance responses seem to be somewhat similar parallel measures.

The results of multiple correlations of several responses and combinations of acoustical measures are given in Table 2. It may be seen that all three transmission loss measures produced very similar correlation coefficients when combined with the neighbour's L_{eq}. Tables 1 and 2 show that it is not only the properties of the common wall but also the amount of noise the neighbour creates that influence negative responses. Neither the noise level measured in the subject's own home nor the difference in L_{eq} values between two homes was significantly related to annoyance responses. Thus, it is not possible to conclude that one's own noise produces a masking effect that reduces annoyance with neighbours' noises.

COMPARISONS WITH OTHER STUDIES

While the present work was being carried out, the results of two similar but larger studies were published.[6,9] By converting the Dutch and British sound isolation measurements to approximate STC values, comparisons were made with the present work. Figure 3 compares the percentage of subjects "moderately or more annoyed" from the present study with subjects "bothered quite a lot" or "very much" from Langdon's study and subjects bothered ("Hinder") from the Dutch study. Although the Dutch study showed reasonable agreement with the present results, Langdon's results suggested greater annoyance for lower STC values. This may be due in part to the difficulty of making even approximate conversions from AAD values to STC values. Accordingly, Langdon's results were compared with the present results in terms of measured AAD values for both surveys, as shown in Fig. 4. Here, the agreement is improved and the three studies seem to indicate reasonably similar trends, although there were differences in the questions asked.

NON-ACOUSTICAL FACTORS

Multiple regression analyses were performed to determine which non-acoustical variables were significant predictors of subjective responses. The two acoustical variables, STC and the neighbour's 24-hour L_{eq}, were forced in first, then non-acoustical predictors were added in a step-wise manner according to the amount of unexplained variance for which each accounted. Although the significant predictor variables varied for each response, several non-acoustical variables were consistently related strongly to annoyance responses. Negative responses increased with: length of occupancy, reported value of the home, number of daytime periods home per week, and Spielberger's measure of stress.[10] Increased feelings - of satisfaction with their building, of considerate neighbours, and of help from building officials - led to decreased annoyance in a number of responses.

The fact that annoyance increased with length of occupancy contradicts the concept of noise-sensitive people moving away from noisy homes. This and the influence of the number of daytime hours at home per week suggest that increased exposure to annoying neighbour noises leads to increased annoyance. Although more considerate neighbours would be expected to lead to reduced annoyance, it was also noted that perceived considerateness was significantly related to the measured STC of the party wall, suggesting that the acoustical quality of the wall influences the

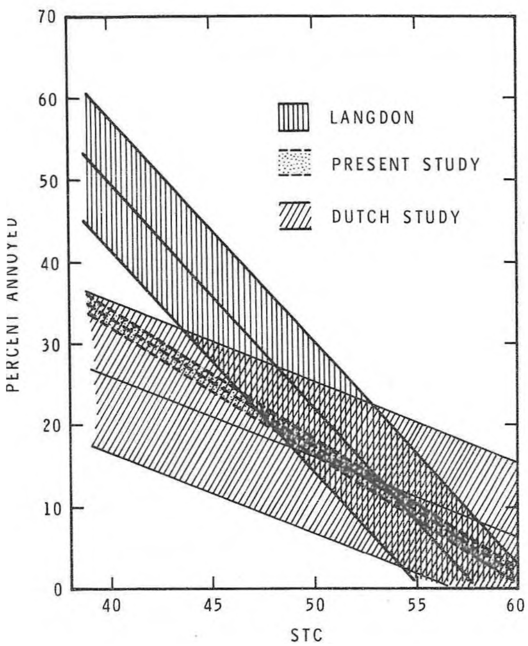

Figure 3. Comparison of mean ±1 standard deviation of percentage annoyed vs STC for three studies

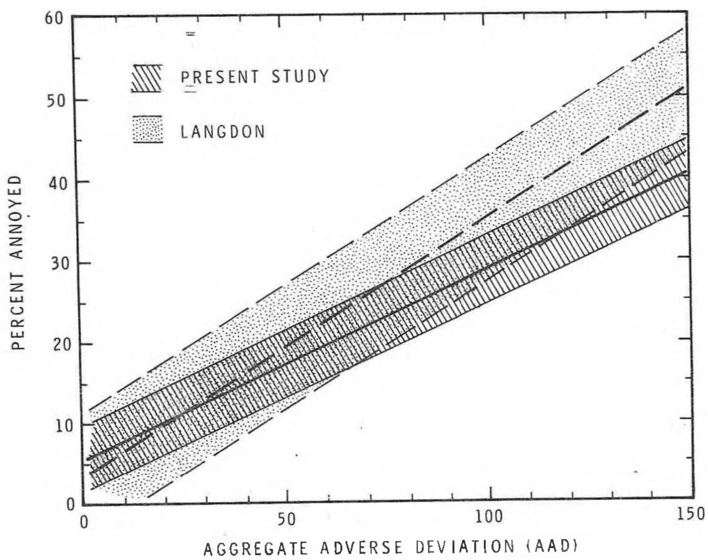

Figure 4. Comparison of mean ±1 standard deviation of percentage annoyed vs AAD for two studies

perceived considerateness. One might expect in the present context that inconsiderate neighbours would have noisier homes; the L_{eq} of the neighbour's home was not, however, significantly related to how considerate each was thought to be. This is strong evidence that in this study at least the inadequacy of the party wall was a source of social disruption in that neighbours were thought to be inconsiderate when it was really the party wall that was at fault.

The cost of improved party-wall sound isolation is frequently given as a reason for not building better walls. Although cost analyses relating wall costs to STC values have not been performed, the present results indicate clearly that subjects are prepared to pay for improved sound isolation. Figure 5 plots the reported dollars per month that subjects were prepared to spend to reduce annoying neighbour noises as a function of measured STC of the wall. As in all individual subject responses of this type, the scatter is quite large, but in this case there is a highly significant trend. The mean result shows a decrease from about $9 per month (1981 dollars) at STC 45 to essentially zero at STC 60. This suggests that an STC of about 60 is nearly ideal.

AN IDEAL WALL

Further analysis of the data produced another tentative suggestion for what is required of an ideal party wall. Correlations of responses and individual 1/3 octave transmission loss values reveal that significant correlation coefficients are generally found only in the approximate region of 100 to 1000 Hz. Correlations were strongest from 125 to 400 Hz, as shown in Fig. 6, for the dollars per month response.

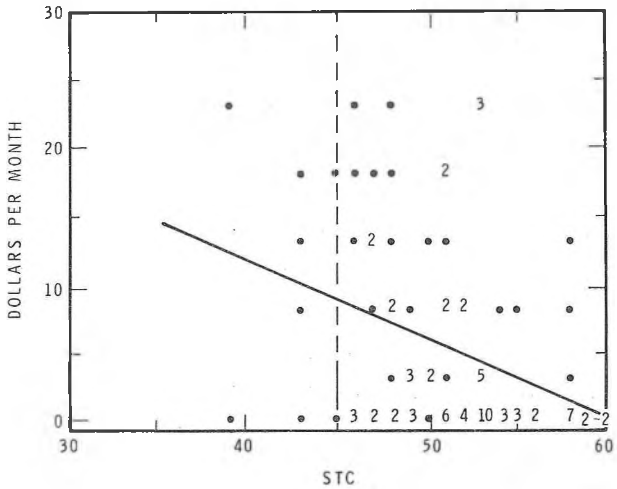

Figure 5. Regression of dollars per month vs STC values

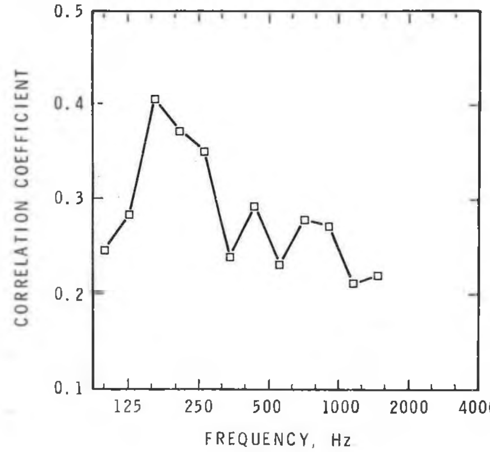

Figure 6. Correlations between dollars/month response and 1/3 octave TL values

The reason for this appears to be that it is only in this 100 to 1000 Hz frequency region that, on average, subjects will hear their neighbours.

Figure 1 shows that the mean measured transmission loss increases with frequency in the 1000 Hz region. One can assume that at 1250 Hz the mean transmission loss has reached an approximately ideal value; above this point responses were generally not related significantly to 1/3 octave transmission loss values, presumably because subjects could not hear their neighbours. This leads to the conclusion that at 1250 Hz a transmission loss of 60 dB can be considered ideal. Above this frequency a conservative estimate is that 60 dB transmission loss is required in all bands. The mean measured values were lower than this in most bands.

Determining an ideal wall transmission loss at lower frequencies requires a maximum typical source room spectrum and a threshold of detectability in the receiving room. The difference between the two would lead to the necessary transmission loss values for an ideal wall in the frequency region up to 1000 Hz. The 10 phon equal-loudness contour[11] was taken as the threshold of detectability in the receiving room. Although normal background sound levels would exceed this level, such noises are usually variable in nature and the 10 phon contour would be a better estimate of the threshold above which, over long time periods, intruding noises could be detected. Knowing that at 1250 Hz an ideal transmission loss of 60 dB is required, one can calculate a maximum typical source room level of 73 dB. This is composed of a 10 dB threshold of detectability (from the 10 phon contour), a 60 dB transmission loss, and an average 10 log (S/A) of 3 dB. If a reasonable maximum typical source spectrum shape is assumed, the maximum source room levels in the other bands can be determined. The maximum typical source spectrum was assumed to be pink because this is generally thought to be typical of music, and measurements of appliance noise[12] indicate that equal maximum levels are possible in all of these bands from a combination of appliances. Thus, the maximum typical source room levels are 73 dB in the bands from 100 to 1250 Hz. If one subtracts the 3 dB average 10 log (S/A) correction, then the difference between these levels and the 10 phon threshold gives the transmission loss values required of an ideal wall. If a higher hreshold of detectability had been selected, the various levels would be higher but he calculated ideal wall TL values would be quite similar.

The resulting ideal wall transmission loss characteristic is plotted in Fig. 7 nd compared with the STC contour. If, instead of assuming that a 60 dB transmission oss is required in all bands above 1000 Hz, one assumes a source spectrum that drops ff at 6 dB per octave above 1600 Hz, the plotted points in Fig. 7 result. The two pproaches give very similar high frequency results. Below 800 Hz the calculated deal wall closely follows the STC contour. The ideal wall characteristics orrespond to an over-all STC of 59, which is close to the STC 60 value obtained for n ideal wall (Fig. 5). Such a wall would be ideal in that responses would no longer e significantly related to measures of party wall sound isolation, and in a ractical sense subjects would no longer hear intruding neighbour noises.

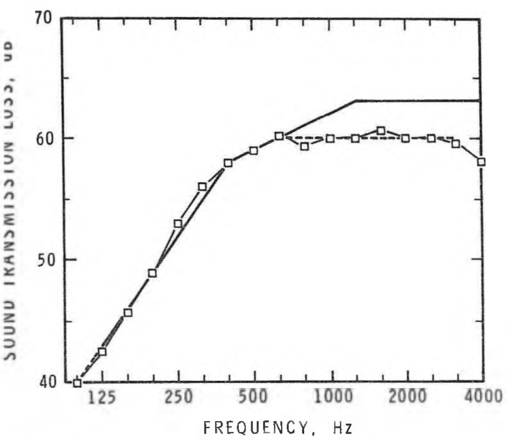

Figure 7. Calculated ideal wall transmission loss characteristic (points), STC contour (solid line), and modified STC countour (dashed line)

An alternative approach that led to some agreement with these results was also considered. Regression analyses were performed with the dollars per month response as the dependent variable and the 1/3 octave transmission loss values as predictors. It was thus possible to calculate the transmission loss in each band for which the mean trend indicated that subjects were prepared to pay zero dollars per month to reduce annoying neighbour noises. This approach produced remarkable agreement with the results of Fig. 7 for the few bands where the correlation coefficients shown in Fig. 6 were highest. Thus, it seemed to substantiate the calculated ideal wall characteristics within the limits of the present data.

One is tempted to suggest modifications to improve the STC contour shown by the dashed contour in Fig. 7: change the frequency range one band lower to include bands from 100 to 3150 Hz, and lower the high frequency plateau by 3 dB. Lowering the over-all range covered by one band would also bring it into agreement with the ISO rating scheme.[12] Such suggestions are only very tentative and will be explored more thoroughly when data from the complete main survey become available.

CONCLUSIONS

This pilot survey shows that subjective responses to noise from neighbours can be related in a statistically significant manner to both measures of party wall sound isolation and noise levels in the neighbour's home. Future studies should elicit more factual, less emotional responses (e.g., how frequently subjects hear their neighbours) that correlate more strongly with acoustical measures. Transmission-loss type measures tend to be superior to the corresponding noise level difference type measures, and noise levels in a subject's own home were not found to reduce annoyance by masking neighbours' noises. Inadequate party wall sound isolation is clearly recognized by residents as a degradation of the quality of their homes, and may be a source of social disruption in multiple residence buildings. It is demonstrated that the results of this type of survey can be used to derive the characteristics of an ideal party wall.

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THE EFFECTS OF INFRASOUND ON HUMAN HEALTH

by

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Abstract

Infrasound is defined as sound with a frequency less than 20 Hz. It is produced by both natural and man-made sources, although very high levels of infrasound must be artificially produced. A number of early papers suggested that infrasound may produce very serious adverse effects on human functioning such as the impairment of task performance, including driving. This paper assesses the literature published since those early reports. Auditory, physiological, and performance effects are discussed. The more recent studies show much less severe effects than those suggested in the first studies. Methodological considerations indicate that the recent studies are much more reliable than the earliest reports.

Sommaire

Le son à des fréquences moins de 20 Hz est appelé infrason. Il peut être émis par des sources aussi bien naturelles qu'artificielles, mais à des niveaux très élevés il doit être d'origine artificielle. Quelques recherches antérieures ont indiqué que l'infrason peut provoquer des effets néfastes sur le fonctionnement de l'être humain, comme l'accomplissement d'une tâche, y inclus conduire un véhicule. Cet article fait la critique de la littérature publiée depuis ces recherches antérieures. Des effets auditifs, physiologiques et des effets sur l'accomplissement des tâches sont présentés. Des études récentes montrent que ces effets sont moins sévères que l'indiquaient les premières recherches. En plus, des considérations méthodologiques prouvent que les résultats des études récentes sont plus exacts que ceux des recherches antérieures.

Introduction

The effects of infrasound on human health became a cause of concern during the mid 1960's when astronauts involved in the U.S. space program were found to be exposed to high levels of infrasound (in excess of 150 dB) for short periods during launch. Much of the work examining the effects of infrasound was done in response to this concern. However, infrasound is found in everyday life as well, most commonly in motor vehicles (especially trucks). In this context, infrasound is a concern because it penetrates walls and barriers with less attenuation than higher frequency sound.

Infrasound is defined as sound of a frequency less than 20 Hz. This definition was accepted at the International Colloquium on Infrasound in Paris in 1973, and has been commonly used since that time. Naturally occurring infrasound (thunderstorms, etc.) is usually in the frequency range below 2 Hz, while infrasound due to manmade sources is normally above this frequency. Levels of infrasound between 75 and 95 dB are common, while levels up to 120 dB may be produced in motor vehicles. Higher levels of infrasound must be artificially produced. These figures may be compared to a threshold of perception of 90 dB at 20 Hz. As is suggested by the threshold of perception, infrasound is not in fact inaudible, as is commonly believed. The higher frequencies in the infrasound range are audible, although it is not the pure tones which are heard, but rather harmonics generated by distortion from the middle and inner ear.

Many of the early papers which examined the effects of infrasound were alarmist, causing a great deal of excitement about possible effects. For instance, Gavreau (1968) warned of "profound effects on both men and buildings". Bryan and Tempest (1972) gained considerable newspaper publicity for their paper entitled "Does Infrasound Make Drivers Drunk?" They claimed that infrasound in motor vehicles could be the cause of many unexplained highway accidents. Close examination of these papers reveals that there is little or no scientifically derived data to support these claims. The publicity accorded these papers has had the effect of predisposing many people to believe that infrasound must have a deleterious effect, and to some extent this has hindered an accurate assessment of how hazardous it really is.

A number of papers, however, are designed to measure the health effects of infrasound using accepted scientific methods. A literature search using computerized bibliographies was conducted to find all papers relating infrasound to human health. After deleting those papers which used animal subjects, and those which were not in English (due to the limited budget for this effort, precluding translation), 19 papers remained: 7 reporting original research, and 12 review papers. These 19 form the basis for this study. The papers dealt with three aspects of health: auditory, physiological, and performance effects.

Each paper was examined to identify what information it contributes to the body of knowledge concerning infrasound and human health. In addition, each paper which contains original research was subjected to a critical appraisal designed to assess the validity of its conclusions, based on the strength of the analytical techniques used, and possible biases or confounders in the design or analysis.

This paper has three sections. The first describes the criteria used to evaluate the literature. The next assesses the literature on the effects of infrasound, on the basis of those criteria. The final section reports our conclusions.

Assessment Criteria

In other reports (Taylor et al., 1980) we have used both methodological and epidemiological criteria to assess the evidence that noise causes health problems. For infrasound, however, there are too few empirical studies to warrant using the epidemiological criteria for causation (see Sackett, 1976). Most of the methodological criteria can be applied, and provide a valuable framework for judging how much is really known about the effects of infrasound. The seven criteria used for the present study are as follows.

1. Is the problem statement clear?
2. What is the sample size?
3. How was the exposure measured, and what is the level and duration of exposure?
4. Is the outcome considered a health outcome or a physiological change?
5. Is the outcome measurement objective or subjective? Were the measurements taken in a vigorous manner?
6. Was any statistical analysis performed, and are the statistics appropriate?
7. Are there any confounding factors which will interfere with the direct relationship between exposure and outcome, or any biases in the way the sample was selected?

No matter how good each study might be individually, when judged on these criteria the overall generalizability of the results must necessarily be limited because of the limited number and scope of the studies. In order to present infrasound as the only noise source, most of the work on the effects of infrasound is conducted in a laboratory with an artificial noise source. The length of exposure to infrasound during the experiments is quite short. Also, the number of subjects in each experiment is small. Further, because the literature was largely a response to a particular exposure problem, the findings may not be applicable to some critical issues. For instance, there are no studies which directly examine the effects of infrasound from transportation sources on health, because infrasound here occurs only in combination with higher frequency sound. In addition, the existing studies are an inadequate indicator of the possible effects of exposure to low level infrasound over long periods of time, such as in an industrial setting.

Assessment of Studies

For the seven papers reporting original research, summaries in terms of the assessment criteria are given in Table 1. The dominant impression from the table is of very small samples (only one study has more than 30 subjects), and, perhaps as a consequence, an absence of statistical tests of results. For simplicity of presentation the papers will be discussed under three headings: auditory; physiological; and performance effects.

1. Auditory Effects. Three papers discuss the auditory effects of infrasound. All of the papers used temporary threshold shift as the outcome

measure; no paper examined the possibility of permanent threshold shift. Jerger et al (1966) exposed 19 subjects to infrasound levels up to 144 dB for three minutes (ear only exposures). 8 of the subjects showed no TTS, while the remainder exhibited TTS of 10-22 dB in the 3-8 kHz range. All of the subjects experienced full recovery, and there was no accumulation of TTS during successive exposures.

Mohr et al. (1965), as part of an experiment designed to study various effects of noise at frequencies between 1 and 100 Hz, exposed 5 subjects to infrasound at levels up to 150 dB for a minimum of 2 minutes (6 different frequency ranges). Some of the experiments were conducted using hearing protectors, although those tests are not identified. The authors provide only a summary of their findings but say that they found no statistically significant objective effect of infrasound. They state that no shifts in hearing threshold were detectable one hour after exposure. It should be noted here that the authors utilized only noise experienced personnel (Air Force officers) in the tests, which may be a source of bias.

One review paper also contributes additional data about the effect of infrasound on temporary threshold shift. von Gierke (in Tempest, 1976, chapter 6) reports on Johnson's work presented at the International Colloquium in Paris. The work involved two parts; whole body exposure and ear only exposure. The subjects for the whole body exposure experiment were exposed to the same levels as those of Jerger et al (120-144 dB), but for 8 minutes. There was no effect on TTS for this exposure. In the ear only exposures, the subjects were exposed to higher levels of infrasound (up to 171 dB) for periods ranging from 26 seconds to 30 minutes. Temporary threshold shift of 8 dB was measured after exposure to 140 dB for 5 minutes, and of 14-17 dB after 30 minutes exposure to the same level. All subjects recovered fully within 30 minutes after exposure.

The studies examining the auditory effects of infrasound all agree that exposures of relatively short duration result only in temporary threshold shift, which disappears within 30-60 minutes after exposure. Levels of approximately 140 dB were necessary to produce TTS, and the degree of effect was a function of the duration of exposure.

2. Physiological Effects. Because the middle ear is the most susceptible part of the body to infrasound, it has been suggested that the physiological tolerance limit to infrasound will be determined by the middle ear. The pain threshold for the middle ear is 140 dB at 20 Hz. Perhaps for this reason many of the experiments which study the physiological effects of infrasound use noise levels around that threshold. Three papers examine the physiological effects of whole body exposure to infrasound including one (Mohr et al, 1965) previously discussed under auditory effects. Using 5 noise-experienced personnel, Mohr et al measured a number of physiological changes, both objectively and subjectively. They detected no significant objective effects, but point out that the objective tests were gross and would not necessarily be able to measure small changes which would not be noticed subjectively. Some subjects reported experiencing middle ear pressure build-up (which could be alleviated using valsalva), mild abdominal wall vibration, and at the extreme levels, chest wall vibration, voice modulation (although no change in speech intelligibility), mild middle ear pain, visual field vibration, and a feeling of gagging. None of these symptoms

were experienced when ear protectors were worn. The authors concluded that although the subjects felt that the exposures were "unpleasant", none of the levels experienced exceeded the voluntary tolerance limit.

The second paper (Slarve and Johnson, 1975) also examined the effect of infrasound on a number of physiological parameters. Four subjects were exposed to infrasound with a maximum level of 144 dB for 8 minutes. The authors found no effect on respiration rate, pulse rate and the general condition of the eardrum. They did find effects of middle ear pressure build-up (above 126 dB) and voice modulation and chest vibration (above 135 dB).

Again, one review paper (Johnson, 1975) provides details from a study not otherwise available to us. This is the study by Borredon (Centre de Recherches de Medecine Aeronautique, 1973), in which 42 subjects were exposed to infrasound (7.5 Hz) at 130 dB for 50 minutes. In this study a small increase in miminum arterial blood pressure was noted, although the effect was not statistically significant. In addition, some subjects reported feeling "drowsy", although there was no objective measurement to back this up as a definite effect.

In general, the papers examining the physiological effects of noise appear to be well done, with the conclusions well supported. All 3 studies seem to be in agreement that no serious physiological effects can be measured at levels which are most commonly experienced. The most important effects noticed were subjective ones, which were found in each experiment.

3. Performance Effects. Six papers examined the effect of infrasound on either balance or other tasks (Table 1). The first paper (Green and Dunn, 1968) examined the effect of naturally occurring infrasonic waves (from weather systems) on the incidence of automobile accidents and school absenteeism. It differs from the rest of the papers as it examines the effects of infrasound which is theorized through the examination of historical weather records rather than actually measured. Although the authors found some evidence of increased accidents and absenteeism during periods of supposed infrasonic activity, there are many possible biases, including the effects of local weather conditions themselves on the outcomes measured.

The next paper (Evans and Tempest, 1972) measured visual nystagmus (involuntary eye movement in a horizontal, vertical or rotary direction) as well as reaction time and visual acuity for 25 subjects who were performing a shape recognition task. Evans and Tempest claim that the experiment measures the effect of transporation sources, but in fact the levels they use (130-146 dB) are above those normally found in motor vehicles. The authors report a significant nystagmus effect. However, this is refuted by Harris et al (1976), who state that examination of sample charts reveals that much of the eye movement can be accounted for by normal eye blinks. Evans and Tempest found no effect on visual acuity, but report a 30% increase in reaction time at levels of 115-120 dB. Unfortunately, this assertion in the text is not supported by any table or figure, and no statistical test of the change is reported, so it is impossible to assess the validity of their conclusion.

One review paper (von Gierke and Parker, 1976) reports additional data from experiments which further refute Bryan and Tempest's claim of nystagmus. The authors report on a number of experiments which measured visual nystagmus in both humans (142-155 dB exposure) and animals (158-172 dB). In no case was visual nystagmus observed.

In another review paper, Johnson (1975) reports on a rail balancing task in which subjects were exposed to infrasound of various frequencies at levels up to 140 dB. There was no significant effect on rail task performance. In addition, Johnson reports personal experimentation with a balancing task at levels of 165 and 172 dB, and found no effect.

Two papers deal with the effect of infrasound on task performance. Harris and Johnson (1978) examined cognitive performance using serial search and complex counting tasks. They found no significant effect for exposure lengths of 15 and 30 minutes, for various levels of infrasound. They conclude that very high levels of infrasound are necessary to produce effects on performance. Kyriakides and Leventhall (1977) compared the effects of infrasound, audible sound and alcohol. They utilized a high priority pointer-following task in conjunction with both central and peripheral components of a secondary task. The subjects were exposed to a level of 115 dB for 36 minutes while performing the task. The authors found that this level had no significant effect on performance of either the primary or secondary tasks. However, they observed a difference in performance over time between the infrasound and audible sound conditions. In the presence of audible sound, performance was maintained over time, while a degradation of performance was evident when infrasound was present. This led the authors to conclude that there may be an effect on performance if the time of exposure were increased.

An effect of infrasound on task performance has not been established in the literature. The one paper which reports an effect (Evans and Tempest) has serious flaws in the measurement of the outcome parameters. The last two papers, which were well conducted and documented, show no significant effect of infrasound on performance. However, both of those papers suggest that an effect may be present at longer exposure durations.

Conclusions

From the literature reviewed here, we may make the following conclusions about the effects of infrasound:

1. whole body effects

   - middle ear pressure build-up at 130 dB
   - no subjective effects until > 150 dB.

2. auditory

   - some TTS for exposures > 137 dB
   - if exposure ≥ 30 minutes, TTS 14-17 dB
   - full recovery within 30 minutes.

3. respiratory

   - rhythm change at 130 dB.

4. performance

   - limit not reached
   - may be an effect if time of exposure > 40 minutes.

The authors of the review papers examined come to roughly the same conclusions, with a few additions. As far as auditory effects are concerned, they conclude that 150 dB is acceptable if exposure time is kept below 30 minutes (Johnson, 1980, p. 11). In addition, they report a definite effect on respiration at 166 dB from animal experiments (Johnson, 1980, p. 8). For performance effects, below 142 dB the only effect of infrasound is on speech interference (Johnson, 1980, p. 7). Finally, there is no vestibular effect up to 155 dB (Johnson, 1976, p. 8).

From the papers examined, we can conclude that infrasound must be regarded as at worst a small part of the problem of the health effects of noise. The literature has demonstrated that objective effects of infrasound are found only at quite high noise levels. The early reports of drastic effects were greatly exaggerated, a conclusion we share with most of the review papers examined. It is necessary to keep in mind, however, that these findings are applicable only to specific, short-term exposures. There has been no attempt to quantify the effects of low-level infrasound when exposure is of longer duration. Therefore, the question of possible effects of industrial exposure or exposure in motor vehicles remains unanswered.

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Table 1

Summary of Literature Assessed

Author	Problem Statement	Outcome	Sample	Noise Measure	Outcome Measurement	Analysis and Statistics	Possible bias and Confounders	Conclusions
Jerger, J. Alford, B. Coats, A. French, B. 1966	"...to explore the frequency region from 2 to 22 cps in an attempt to determine critical sound pressure levels leading to temporary threshold shift."	temporary threshold shift	19	119-144 dB 2-22 Hz 3 min.	noise level required to produce 10 dB threshold shift after 3 minutes of exposure	descriptive		-no clear-cut functional relationship between TTS and exposure signal -8 subjects no TTS, 11 subjects TTS 10-22 dB. -all TTS produced by exposure to 137-141 dB. -frequencies affected 3-8 K Hz
Mohr, G.C. Cole, J.N. Guild, E. von Gierke, H.E. 1965	to investigate human tolerance to high intensity, low frequency noise.	-auditory -physiology -voluntary tolerance	5	up to 150 dB 1-100 Hz 2 min.	-auditory acuity -voluntary tolerance subjective & objective: -visual acuity -spatial orientation -speech intelligibility -EKG -fine finger dexterity	not specified	-used only noise - experienced personnel -wore hearing protectors	-no significant objective changes -many severe subjective complaints -did not reach the voluntary tolerance limit.
Slarve, R.N. Johnson, D.L. 1975	"...to verify that the levels produced were safe for at least an 8 min. exposure."	physiological psychological	4	up to 144 dB 1-20 Hz 8 min.	-examination of tympanic membrane -audiogram -subjective: -vibration -respiration -psychological	not specified		-"no objective evidence (including audiograms) of any detrimental effect due to infrasound." -pressure build-up in middle ear, voice modulation, body vibration occurred consistently.
Green, J.E. Dunn, F. 1968	To see if distantly produced infrasonic waves (from weather systems) affected selected aspects of human behaviour	human behaviour	100 accidents claims 1500 students	75-95 dB theorized	incidence of -automobile accidents -school absenteeism	correlations	many possible e.g. effect of local weather conditions itself on parameters	-increases in times of intense disturbance "a correlation may exist"

Author	Problem Statement	Outcome	Sample	Noise Measure	Outcome Measurement	Analysis and Statistics	Possible bias and Confounders	Conclusions
Evans, M.J. Tempest, W. 1972	"...to see if infrasound, at the levels measured in vehicles has any effect on the sense of balance and psychological fitness of normal human observers."	balance and psychological awareness	25	130-146 dB 2-20 Hz 60 sec.	-involuntary eye movement - nystagmus -reaction time and visual acuity in a shape recognition task	none	random eye movements	-no effect on visual disturbance -some effect on reaction time (no gradient) -nystagmus evident; most pronounced at 7 Hz "...infrasonic noise has a significance in both comfort and safety in trasportation..."
Harris, C.S. Johnson, D.L. 1978	To assess the effects of infrasound on cognitive behaviour	task performance	I 12 II 12 III 16	-125, 132, 142 dB infrasound at 7 Hz -65 dB ambient -110 dB low frequency background I 15 min. II 30 min. III 15 min.	I. no of searches completed in serial search task II and III. % correct in complex counting task	analysis of variance		-no significant effects found "Very high levels of infrasound, more than 150 dB, may be necessary to produce decrements in cognitive performance."
Kyriakides, K. Leventhall, H.G. 1977	To assess the degree to which the performance of a number of tasks can be maintained or changed by exposure to infrasound	task performance	I 6 II 26	115 dB 2-15 Hz 36 min. control-70 dBA background	scores in central and peripheral tasks in following a moving pointer and responding to lights	analysis of variance -Wilcoxon		-no significant decrements in performance -degradation of performance over time -changes in performance over time different than for audible noise.

CALENDAR OF ACOUSTICAL EVENTS

Date	Conference	Information
	1983	
Oct. 9-11	13th Annual Mtg. Australian Society for Ultrasound in Medicine Melbourne, Australia	J. Jellins Box R374, P.O. Royal Exchange Sydney, N.S.W., Australia
Oct. 17-21	American Institute of Ultrasound in Medicine New York, USA	A.I.U.M. Executive Office 4405 East-West Highway Washington, D.C., USA
Oct. 20-21	CAA Annual Symposium Vancouver, B.C.	S.H. Eaton, Workers' Compensation Board of B.C. 6951 Westminster Highway Richmond, B.C. V7C 1C6
Oct. 31 -Nov. 2	IEEE Ultrasonics Symposium Atlanta, GA	M. Levy, Dept. of Physics University of Wisconsin Milwaukee, WI, USA
Nov. 7-11	The Acoustical Society of America Meeting San Diego, CA	Robert S. Gales, Code 5152 Naval Ocean Systems Center San Diego, California 92152, USA
	1984	
Mar. 7-13	European Congress on Ultrasonics in Medicine. Strasbourg	
Mar. 27-29	DAGA 84 (German Acoustical Association Meeting). Darmstadk, Germany, F.R.	G.M. Sessler, Institute of Electro-acoustics, Merchstrasse 25, 6100 Darmstadt, Fed. Rep. Germany
May 4-11	The Acoustical Society of America Meeting	H.H. Hubbard, Acoustics & Noise Reduction Dis., NASA Langley Research Center, Langley Station, Mall Stop 462, Hampton, VA 23665, USA
May 7-12	5th Meeting European Federation Ultrasound in Medicine and Biology Strasbourg, France	Prof. F. Weill, Dept. de Radiologie Viscerale, CHU Besancon 2500, France
July 25-28	International Symposium on Nonlinear Acoustics, Kobe	
Aug. 21-24	FASE 84, 4th FASE Congress, Sandefjord, Norge	FASE 84, ELAB N-7034 Trondheln, NTH, Norway
Sept. 15-19	American Institute of Ultrasound in Medicine Kansas City, MO	A.I.U.M. Executive Office 4405 East-West Highway Washington, D.C., USA

TRANSPORTATION NOISE

Activity Interference & Noise Annoyance.
S.M.Taylor, F.L.Hall & S.E.Birnie. Department of Geography, McMaster University, Hamilton, Ontario, L8S 4K1.
Past research on noise annoyance suggests that activity interference is a central component in the causal chain linking noise exposure and annoyance. This paper examines the relationships between annoyance and four types of activity interference - speech indoors, speech outdoors, difficulty getting to sleep and awakening. Three transportation noise sources are considered: aircraft, road traffic and trains. Logit models are estimated to predict the probability of being highly annoyed by the source noise as a function of interference. The results show that all four types of interference have a significant effect on annoyance. The equations are quite similar for the three sources. There is good correspondence between the predicted probability of high annoyance and the observed proportion of respondents highly annoyed with the most accurate predictions being for the road traffic case.

The Sound Absorptive Properties of Hard Porous Materials.
J.J.Hajek. Ontario Ministry of Transportation & Communications, 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8.
Different methods of improving sound absorptive properties of porous concrete-based materials (for use as sound absorptive high-way noise barriers) were investigated, including (a) changing the material porosity and thickness, (b) incorporating the resonators, (c) creating Helmholtz resonator cavities, and (d) sealing one face of the material (the face away from the noise source). The investigation encompasses both analytical analyses and laboratory measurements using an impedance tube and a reverberation room method. The results indicate that the most promising method is sealing one face of the porous material.

The Accuracy of Highway Traffic Noise Predictions
J.J.Hajek, R.Krawczyniuk, Ontario Ministry of Transportation & Communications, 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8.
The prediction accuracies of several highway traffic noise prediction models currently used in Ontario (NRC/CMHC, Ontario, FHWA), as well as models used elsewhere, were compared. The results indicate that the accuracies achieved by these models were very similar. The standard deviation of differences between the measured and predicted sound levels was about 2.0 dBA and cannot be improved without the inclusion of additional unconventional variables, such as ground impedance and ground planes, weather-related variables and reflections off building facades and barrier surfaces. Recent advances in this area are reviewed.

ARCHITECTURAL ACOUSTICS

Auditorium Renovation - A Review of Recent Projects
Ewart A.Wetherill,MRAIC, Bolt Bernanek & Newman Inc. & Canoga Park, California.
Despite the ever-increasing cost of performance facilities, the design and construction of a completely new auditorium is preferred with striking consistency to the alternative of renovating or remodelling an existing unused - or under-used - auditorium. In many instances, the new facility simply reflects the obsolescence of the existing one - too few seats, inadequate stage facilities, etc. In others, however, the re-use of an existing hall may yield - in addition to substantial cost savings - such advantages as prime location, existing social recognition, and historical significance. From the viewpoint of acoustics, the renovation must be compatible with the basic requirements of (a) good seating and sightlines, (b) true flexibility of use, (c) comfort, and (d) reasonable control of cost. The application of current acoustical design goals to existing auditoria is illustrated by the use of several recent renovation studies.

Sound Fields Near Building Facades.
J.D.Quirt, National Research Council Canada, Ottawa, Ontario, K1A 0R6.
Measurement of sound transmission through the exterior facade of a building requires a determination of the incident sound power. Direct measurement of the sound field near the relevant surface seems preferable to the use of a 'calibrated source' because of variability in outdoor propagation associated with ground reflections and atmospheric conditions. The interpretation of sound pressure level measurements in this environment is, however, complicated by the interference between incident sound waves and those reflected from building surfaces. This paper presents experimental results obtained both adjacent to real building facades and near a reflective surface in an otherwise anechoic room. The outdoor test sites used either a loudspeaker system (point source) or highway traffic (line source) to provide the sound field. The data are compared with a simple predictive model. Qualitative agreement with this model is good; deviations from the predictions are examined.

NOISE CONTROL

Simulation de L'environnement Sonore d'une Salle Industrielle.
Jean Nicolas et Gilles Lemire, Universite de Sherbrooke, Genie mecanique, Sherbrooke, Quebec, J1K 2R1.
Il est souvent souhaitable de pouvoir prédire les niveaux sonores dans une salle industrielle lors de sa conception, ou à priori de predire l'efficacité d'un traitement acoustique ou d'un réaménagement de la salle. La modélisation sur ordinateur d'une salle industrielle et des sources sonores qu'elle renferme a été réalisée dans le but d'être l'outil qui permettrait de répondre à ces questions. La modélisation qui repose sur

la theorie des sources images permet de tenir compte de l'emplacement, de la puissance et de la directivité de chacune des sources, et de l'absorption propre a chacune des parois. Les points faibles de la modélisation sont l'évaluation expérimentale des coefficients d'absorption et la difficulté de modéliser le propagation du son entre les obstacles que sont les machines de production que l'on rencontre souvent dans une salle industrielle. Les résultats de la simulation d'une salle de production de l'industrie textile primaire seront présentés en comparaison avec les resultats expérimentaux.

Mesure et calcul du dephasage et de la variation d'amplitude de pression acoustique introduits par un guide d'ondes a "ondes lentes" - application au controle des bruits de basses frequences. Maurice Amram, Ecole Polytechnique, Campus de l'Universite de Montreal, Case postale 6079, Succursale A, Montreal, H3C 3A7, P.Q.
Les ondes sonores de basses fréquences étant diffractées par n'importe quel type d'obstacle, nous avons imaginé un guide d'ondes "ralentisseur" qui créera un déphasage de 180° entre la partie de l'onde sonore diffractée et celle transmise par transparence à travers ce guide. Ce système pourra de plus assurer une amplitude de pression acoustique diffractée et transmise équivalentes. Le résultat a été, pour les bruits de basses fréquences, la création de sources linéaires cohérentes dipolaires, donc d'interférences destructives à une certaine distance de l'obstacle. Une difficulté qui a été partiellement applanie lors de l'optimisation du guide d'onde a été de créer ce déphasage sur une large bande de fréquences (de l'ordre d'un octave) avec des lignes sources de puissance equivalente donc dipolaires. Le déphasage et les amplitudes relatives ont été calculés pour le modèlè investigué et coïncident avec la mesure dans la limite de précision envisagée.

Noise Abatement in the Noranda Group - A Progress Report. P. Nguyen, Noranda Research Centre, 240 Hymus Boulevard, Pointe Claire, Quebec, H9R 1G5.
A noise abatement program has been carried out by the Noranda Research Centre in collaboration with Noranda Group mining, metallurgical, forest product and fertilizer operations since 1975. The work typically includes plant noise surveys, the application of conventional noise abstement techniques, and the development and demonstration of new noise suppression technology. Four demonstration projects are described: a load-haul-dump machine, stoper drill, vibrating screen and fluidized-bed roaster. The engineering approach and costs are indicated, as well as the noise reduction achieved to date, and the future work planned.

Noise Survey, Equipment Sound Levels and Workers' Exposure to Noise in a Nuclear Generating Station
A series of sound level measurements were carried out at Bruce NGS A (4 X 788 MW) during the period August 17 to 25, 1981. The measurements included a general survey, detailed sound levels for a selected number of equipment and a sample of workers' exposure to noise. The findings and results of the study identify some essential design requirements regarding sound levels and equipment noise control in a nuclear station. Because future nuclear stations will have similar equipment layout to that of Bruce NGS A, most of the reported conclusions can be used as a noise design guide for these stations. The major recommendations address the need for a comprehensive noise policy based on workers' exposure. A listing of the equipment items that are major noise sources is presented. One basic finding: the turbine-generator is the major equipment affecting noise control measures because it produces the "background" noise in most floors in the station. Hence, any reduction in the noise level of other equipment is governed by that "background" level produced by the turbine-generator. Regarding workers' exposure to noise, the noise doses based on the proposed regulation (1980-81), indicate that only the workers in the Operator category may be subjected to an over-exposure.

SOUND INTENSITY MEASUREMENT (I)

Sound intensity measurement applied to a digital computer. A Chawla and N. Popplewell, University of Manitoba, Winnipeg, R3T 2N2.
A preliminary investigation has been initiated in conjunction with a local manufacturer to determine the sound power of a digital computer and to rank its various sound sources. The predominant frequency of the major sound source is about 50 Hz. which is somewhat lower than normally encountered in sound intensity measurements. This aspect will be discussed together with difficulties arising from a fairly substantial air movement in the measurement medium. The relative merits of several alternative solutions will be outlined. Finally, problems encountered with the tracking of comparably low frequency vibration paths will be discussed.

PSYCHOACOUSTICS & PHYSIOLOGICAL ACOUSTICS

Own-Speech Masking Via Several Routes. Bruce E.Dunn and Cate Hanington, University of Calgary.
There is much of literature to suggest that when communicating by voice, speakers do not respond adequately to an increase in the noise level. Given a 10 dB increase in the noise level, a speaker in general will only raise his/her voice about 3 to 6 dB. Data from the laboratory at University of Minnesota suggest that this is due to the signal which is generated by the speech and transmitted via bone conduction to the cochlea. Since the masking is external to the mouth and head structure, it does not effectively mask the bone conducted part of the speech. In the present study the subject heard his own speech either directly via air conduction, through ear phones, via a bone-conduction transducer or via bone

conduction and either via open air conduction or via ear phone. Several types of maskers were presented via one or via a combination of presentation modes. The intensity and percentage of noise presented via each route was varied. It was found that by presenting masking noise via bone conduction the speakers response to an increase of the level of the masker was more adequate when masking was presented via the bone conduction route. Type of masker was also important. This further supported work done at the University of Minnesota.

Signal Delay with Pure and Complex Tone Stimuli in a Forward Masking Paradigm. Eileen A. Stan and Bruce E. Dunn, University of Calgary.
A forward masking paradigm was used to investigate the effects of a variety of stimuli on the degree and slopes of the masking function using the equation: $M = a(b*\log dt)\ (Lm-c)$, where "M" is the amount of masking, "t" is the signal delay in msec, "Lm" is the masker level in dB SPL. The values "a", "b", and "c" are constants established empirically. The study attempted to replicate findings which showed that the slope of the masking function is effected by time delay, frequency and by the structure of the masker. A comparison was also made between maskers producing similar pitch experiences, but with drastically different representation on the basilar membrane. Stimuli with a perceived pitch of 200 Hz were used: 1) A 200 Hz pure tone, 2) A complex modulated at 200 Hz, 3) A complex wave form producing a perceived pitch of 200 Hz, but from which the 200 Hz component was missing. Each stimuli served as a masker and as a probe. All nine combinations were used. The predictions with the pure tones were generally upheld. However, the results using combinations of pure and complex tones gave complex results, which are not completely explainable by any current theory. The pure tones produced steeper masking slopes than did the complex tones in most cases. This was not unexpected. The values of the three constants were hard to explain.

Masking of Speech Signals Via Bone Conduction. Cate Hanington and Bruce E. Dunn, Univ.of Calgary.
There is much literature to suggest that when communicating by voice, speakers do not respond adequately to an increase in noise level. Given a 10 dB increase in the noise level, a speaker in general raises his/her voice about 3 to 6 dB. Data from the laboratory at the University of Minnesota suggest that this is due to the signal which is generated by the speech and transmitted via bone conduction to the cochlea. Since the masking is external to the mouth and head structure, it does not effectively mask the bone conducted part of the speech. In the present study speech was presented to a group of subjects via air and bone conduction. Noise was mixed with the signals. The percentage of the noise that was presented via bone conduction and the percentage that was presented via air conduction was varied. The frequency components of the masker as well as the type of masker were also varied. The recent work from the University of Minnesota regarding the optimal frequency responses of the signal via bone and air conduction were generally confirmed. It was also shown that the bone conduction representation is most affected by the white noise presented via bone conduction. The results can be interpreted as supporting the notion that the failure to increase vocal output may well be due to the separation of the bone conducted and air conducted signal.

Lateral Difference in Hearing Sensitivity
David Y.Chung, Workers' Compensation Board of British Columbia, Richmond, V7C 1C6.
Results from large-scale surveys have demonstrated that the right ear is statistically more sensitive than the left ear. At the Workers' Compensation Board of British Columbia, we have done a series of studies on the asymmetry of hearing based on a large population of noise-exposed industrial workers. The effect of asymmetrical noise exposure due to industrial or non-industrial sources was studied. One important finding was that the amount of asymmetry is a function of hearing loss. It is speculated that susceptibility to noise damage could be asymmetrical, with the left ear being statistically the more susceptible one. This notion is supported by indirect evidence from a study using a group of workers manifesting a 2-kHz asymmetry.

HEARING CONSERVATION PROGRAM

Hearing Protectors Evaluation at Ontario Hydro
A.Behar, Ontario Hydro, 757 McKay Road, Pickering Ontario, L1W 3C8.
Approximately 9,000 workers are exposed to high noise levels in Ontario Hydro. Although administrative and engineering controls have been progressively implemented, personal hearing protectors (PHPs) are still the most used method to reduce the risk of hearing loss. In 1980, a Recommended List of Hearing Protectors was implemented by the Health and Safety Division selecting 11 PHPs among those already in use. The list comprised of: 3 plugs, 2 cap-mounted muffs, 5 muffs, and 1 semi-insert. Since then a comprehensive program was set up to evaluate and to update the list replacing the existing by newer and better devices. The program consists of two main elements: (a) Laboratory Measurements (existing and new HPD): Acoustical attenuation as well as head band force of muffs are measured according to the ANSI S3.9 1974 Standard. Comfort of new devices is evaluated by workers answering a specially designed questionnaire. (b) Field Surveys: They are performed at different generating stations using existing audiometric facilities. Volunteers among workers are requested to bring their own HPD. Its attenuation is measured using a procedure similar to that specified by the mentioned standard. Headband force of muffs is also measured. Finally, a questionnaire on comfort is filled out. The paper will provide details on the measuring procedures and results as well as the benefits obtained from the HPD evaluation program.

A Bayesian Approach for Predicting Judged Impaired Hearing Founded upon the Common Law Doctrine of the Balance of Probabilities. Richard Phaneuf and Raymond Hétu, Univ. of Montreal and Jim Hanley, McGill University.

A method of determining the cut-off point for an administrative decision to award compensation is proposed. Grounded on the Common Law Doctrine of the Balance of Probabilities, judged hearing impairment was used as the criterion with audiometric scores as the determining variables. To construct the predictive system a Bayesian approach and discriminant analysis were employed. The highest precision in predicting judged hearing impairment was obtained with an average audiometric score at 1000, 2000, 3000, 4000 Hz in the worse ear. Assuming that judged hearing impairment is a valid predictor of handicap the cut-off point based on the balance of probability (50th centile) was obtained at 25 decibels. The study also confirmed results from previous studies: (1) hearing sensitivity in frequencies higher than 2000 Hz is required to predict hearing disability and handicap, (2) judged hearing handicap is better correlated with hearing sensitivity in the worst ear, (3) the audiometric cut-off point for a medical legal definition of impairment should be lower than what certain technical groups have proposed in the past.

Sociacusis in Two Industrial Populations. Richard Phaneuf and Raymond Hétu, University of Montreal.

Cross-sectional studies were carried out on large two industrial populations in which both hearing sensitivity and exposures to non-industrial noise (power tools, tractor, lawn mower, snow blower, shooting-hunting, snow mobiles, motor cycles or motor car racing, outboard motor boats, airplanes, discos, load music) were assessed. Subjects having probable conductive loss were excluded in multiple regression models. The only plausible relationship which emerged in the analysis was shooting (hunting). The effect of shooting was of the order of 5 + 2 dB at 4000 Hz. Implications of these results are discussed in terms of criteria for compensation of occupational hearing loss.

Evaluation of Hearing Conservation Program with Industrial Audiometric Data. Margaret Roberts and David Y. Chung, Workers' Compensation Board of B.C. Richmond, B.C. V6X 2X1.

Industrial audiometric data as part of a hearing conservation program should be used to monitor individual threshold changes in an effort to protect an individual's hearing, and also to analyse the data collectively in order to evaluate the effectiveness of the overall program. In this study we have applied some measures used recently by other researchers to evaluate hearing conservation programs existing in the different firms in British Columbia. As a firm in British Columbia has the option to use either an in-house facility or a mobile contractor, in this study we have paid special attention to the difference in the performance of the Industrial Audiometric Program in the firms selecting one option versus the other. Results show that in-house programs are more effective and have audiometric data which demonstrate higher reliability. Implications of results are discussed.

Activities of International Standards Organization Technical Committee 43, Subcommittee 1 "Noise", Working Group 19, "Occupational Noise" D.A.Benwell, Environmental Health Centre, Tunney's Pasture, Ottawa, K1A 0L2.

The revision of ISO 1999 (1975) "Assessment of occupational noise exposure for hearing conservation purposes" is described. The revised document ISO/DIS 1999 (1981) provides criteria that are as accurate and as practically useful as possible. The various features of this standard and its limitations are discussed. A new standard presently being drafted by the working group, "Guidelines for the measurement and assessment of exposure to noise in the working environment", is also described and related to current Canadian work on a C.S.A. standard for noise exposure measurement.

Enquete concernant les incapacites auditives et les desavantages sociaux lies a la surdite professionnelle. Raymond Hetu, Universite de Montreal, Monique Lalonde, Hopital Saint-Luc, 2225 rue Rachel est, Montreal, P.Q.

Dans le cadre d'une enquete de surdité professionnelle, un groupe de 139 travailleurs et travailleuses ont répondu avec leur conjoint, à un questionnaire relatif à leur audition. D'une part ce questionnaire portait sur la sévérité et la perception subjective du problème auditif, de même que sur les mécanismes d'adaptation utilises. D'autre part, il traitait des conséquences de la déficience et des incapacités auditives sur les relations avec les proches, composantes fondamentales du handicap lié à la surdité. Les resultats preliminaires de cette enquête sont présentés et discutés en terme d'indicateurs pour la définition d'un groupe cible pouvant éventuellement bénéficier de services de réadaptation pour surdité professionnelle. L'analyse des données révèle que la clientèle potentielle ne cherche pas ces services, et que la famille du travailleur atteint pourrait etre la cible privilégiée à atteindre en premier lieu et aux premiers stades de la surdité professionnelle.

MISCELLANEOUS

Modelisation des Proprietes Acoustiques des Milieux Anisotropes D'Epaisseur Finie. Jean Nicolas, J - L Berry, Universite de Sherbrooke, Genie mecanique Sherbrooke, Quebec, J1K 2R1.

La prédiction du champ sonore aussi bien à l'extérieur qu'à l'intérieur des locaux necessite la connaissance des propriétés acoustiques des matériaux en présence (imperméabilite, porosité..) et la modélisation du type de réaction à l'interface de deux milieux. Le coefficient de réflexion est le paramètre fondamental qui intègre ces éléments. Des mesures ont été réalisées tant en chambre semi-anéchoide sur des matériaux absorbants contrôlés (mousse réticulée, laine minérale) qu'en extérieur pour différentes quantités de neige, pour des fréquences allant de 300 Hz à 8 kHz. Ces résultats expérimentaux sont ensuite comparés à des modèles théoriques basés sur les formules d'impédance de Delany & Bazley et modifiés pour tenir compte des effets d'épaisseur finie et d'anisotropie des milieux ainsi que du type de réaction (locale ou étendue). L'apparition d'une onde de surface en extérieur sur la neige est également abordée eu égard aux configurations géométriques (distance et épaisseur de neige) et aux conditions météorologiques (vent).

Acoustic Control of the Mixing Processes in a Gas Turbine Combustor. P.J.Vermeulen, Univ.of Calgary
The air mixing processes in a gas turbine combustor control the efficient burning of the fuel and also the exit plane temperature distribution. The exit plane temperature distribution critically affects the operational lifetime of the turbine. Consequently an original technique has been developed using acoustic control over the air-jet mixing processes which govern the combustor's exit plane temperature distribution, the dilution-air jet flows. Using a model combustor early work on temperature measurements showed that acoustic modulation of the dilution-air flows can be used to selectively and progressively control the exit plane temperature distribution. The effectiveness of the process was found to depend on the excitation frequency and power of the loudspeaker drivers. Reductions in the exit plane temperature profile, by as much as 545°C, were observed. Later work with a small combustor of normal design, employing acoustic control of the dilution-air flows, was successfully tested up to "half-load" condition and the ability to trim the temperature profile was convincingly demonstrated. The acoustic driver power requirements were minimal, indicating that driver power at "full-load" will not be excessive. The nature of the acoustically modulated dilution-air flows has been clearly established as that of a pulsating jet flow with superimposed toroidal vortices. The pressure loss of the unit and its combustion efficiency were insignificantly affected by the acoustic drive. The work contributes to the design of combustors such that a desired exit plane temperature distribution may be achieved. This paper is based entirely on the author's work already published by The American Society of Mechanical Engineers.

VIBRATION

Nonlinear Oscillation of a Class of Mast Antenna structures by the Finite Element Method. C.W.S.To Dept.of Mechanical Engineering, Univ. of Calgary.
A brief survey of various finite element formulations for the nonlinear dynamic response of structures is presented. A simple strategy for the numerical solution of nonlinear oscillation of a quarterscale physical model of a class of ship mast antenna structure is included. Specific focus is on the elasto-plastic dynamic response of the mast antenna structure involving small deformation, strain-hardening and hysteresis. Numerica results are compared with those of the linear structure. For its simplicity, the strategy can easily be implemented in a microcomputer.

The Influence of Various Excitations on the Dynamic Characteristics of Mast Antenna Structure
D.W.S. To, Dept.of Mechanical Engineering, Univ. of Calgary.
This paper discusses various methods of base excitation used in determining the resonant frequencies and mode shapes of a quarterscale physical model of a class of ship mast antenna structures. The various methods of excitation considered are the quasi-steady state, rapid sine sweep, impact, and steady state approaches. Experimentally obtained results are compared with those using the finite element method and exact solution of a simplified mathematical model.

UNDERWATER ACOUSTICS

Acoustic Measurements of Wind Speed and Precipitation over a Continental Shelf. David D. Lemon, Arctic Sciences Ltd., Sidney,B.C.V8L 3S1, David M.Farmer,Institute of Ocean Sciences, Sidne B.C.V8L 4B2, D.Randolph Watts, Graduate School of Oceanography, Univ.of Rhode Island, Kingston,R.I.
Ambient noise measurements at three frequencies between 4.3 kHz and 14.5 kHz were collected on th continental shelf of British Columbia during the summer of 1982. Simultaneous observations of win speed from anemometers moored nearby and of precipitation from local lightstations provided an opportunity both for extending earlier comparison between wind speed and ambient noise at ocean depths to the continental shelf and also for exploring the possibility of measuring rainfall fro ambient noise. Calibration coefficients establish ed from ambient noise observations demonstrate a consistency with the generally accepted logarithmic relationship to wind speed to within ± 1.5 ms^{-1} over the observed wind speed range of 0 to 12ms^{-1}. The calibration differed between the two coastal sites and from previous deep ocean results by up to 5 dB at low wind speeds, but by only ± 1.5 dB (equivalent to ± 0.5 ms^{-1}) at speeds of 10 ms^{-1}. Time series analysis revealed noise fluctuations that have an unexplained dependence on acoustic frequency. Acoustically measured rainfall rates show good agreement with the presence or absence of rain at the nearby lighthouse sites and agreement to better than a factor of 2 in the measurec quantity of rain. Given the likely influence of nearby land mass on spatial variability in rainfall, these results provide encouraging evidence for the potential use of ambient noise measurements in estimating both wind speed and precipitation. A second series of noise measurements at four frequencies between 4.3 and 25 kHz were take during the winter of 1982-1983. The results of these measurements, during which wind speeds up t 30 ms^{-1} were encountered, will be discussed briefl

Hydroacoustics at the Pacific Biological Station in Nanaimo. R.E. Kieser, Pacific Biological Stn.

Hydroacoustic methods play an important roll in commercial fishing, fisheries management and fisheries research. The three endeavours rely on conceptionally similar methods, but differ in the required accuracy, precision and timeliness of the results. Both acoustic and conventional methods are difficult to QUANTIFY and to VERIFY. Consequently it is difficult to conclusively demonstrate their relevance and usefulness. Our work at P.B.S. has focussed on finding situations where acoustic methods are indeed appropriate and to demonstrate their relevance to fisheries management. The presentation will concentrate on the hydroacoustic methods that are currently in use at P.B.S.: Measurement of acoustic backscattering strength, from single and schooled fish; Echo integration: This method determines fish biomass; Echo counting: This method determines fish number density; Single beam target strength determination: This method determines fish size; Acoustic fence, Acoustic smolt counters.

<u>The Analysis of Arrays using STARPAK</u>. Warren Wolfe and Michael Wilmut, Royal Roads Military College, FMO, Victoria, B.C.
The theory, development and some typical applications of STARPAK (Simulation for Testing Array Response) is presented. STARPAK is a package of Fortran subroutine designed to study the performance of an arbitrary planar array in a variety of signal noise environments. Either real frequency domain data may be input or the user may define control signal-noise parameters to generate purely simulated data. For the simulated data STARPAK will output gaussian random samples having the appropriate second order statistics. Examples are presented to illustrate the use of STARPAK in array design and evaluation of conventional optimal and Bienvenu processing techniques.

<u>Spectral Spreading of Doppler Sonar Signal</u>, Leonard J. Zedel, Institute of Ocean Sciences.
Several factors contributing to broadening of the backscattered sound spectrum observed by a Doppler sonar are discussed. These include effects due to shear, turbulence, pulse modulation, and beam geometry. The dominant effects are identified for given system parameters and the relevant expressions presented. Some examples of these effects are shown using data collected from inlets on the British Columbia coast.

<u>Remote Sensing of Oceanic Microstructure Using Oblique Scattering - Preliminary Considerations</u>
Greg Crawford, Institute of Ocean Sciences.
We are currently investigating the use of oblique acoustic scattering as a method for remote sensing of temperature and velocity microstructure in the ocean. Preliminary theoretical work has been undertaken, with emphasis on the design of a field project on a submarine planned for later this year. In particular, a numerical model is being developed to simulate the experiment and provide insight to design and analysis considerations. The results of this work and the implications with respect to the project will be discussed.

<u>Recent developments with the echometer</u>,
R.D.Huston, Institute of Ocean Sciences.
An underwater acoustic interferometer (echometer) is being developed to measure sound speed profiles remotely from a subsurface reference. To provide insight to the received signal a numerical model of the system incorporating real sonar beam characteristics and a scatterer distribution based on direct biological observation has been developed. Combining these results with previous field experiments a versatile instrument was built to test fundamental principles over a wider range of parameters. Preliminary results from experiments performed on board the VECTOR in June 1983 will also be discussed.

<u>Acoustic Propagation in a Shallow Sound Channel</u>
S.E.Dosso and N.R.Chapman, D.R.E.P.
An experiment was carried out off the west coast of Canada to investigate the effects of a shallow sound channel on propagation for the frequency range from 20 to 4000 Hz. Using small explosive charges deployed in the shallow channel, the propagation loss was measured at receivers located in both the shallow and deep sound channels. The shallow channel behaved like an acoustic waveguide with an optimum duct propagation frequency of 800 Hz. At the optimum frequency, the propagation loss closely approached that due to cylindrical spreading, while at frequencies less or greater than the optimum the loss increased by up to 20 to 30 dB. The sound channel propagation was strongly dependent on changes in the environment with range, therefore the parabolic equation was used to model the experimental results. The parabolic equation model correctly predicts the range and frequency dependent trends observed in the measured data.

<u>Acoustic shadowing, reflection and enhancement by an isolated seamount</u>. G.R.Ebbeson & N.R.Chapman D.R.E.P..
Acoustic shadowing, reflection and enhancement effects near an isolated seamount have been studied by examining the propagation loss measurements obtained in both shot and CW runs that passed over the seamount peak. Source depths of 18 and 184 meters were used in the experiment. The receiving system had hydrophones spaced in depth from 323 to 633 meters. In the acoustic shadow, the propagation loss for the shallow sources increased by 10 to 15 dB over the loss expected in the absence of the seamount. Examination of the pressure-time history for the shots revealed that the signals consisted of two components. The first and dominant pulse was determined to be a diffracted wave while the subsequent group of weaker pulses was attributed to a series of surface-bottom interactions. Strong back reflections from the seamount were observed when the shallow source was 3 to 5 kilometers from the seamount peak. At closer distances to the peak, downslope reflections caused signal enhancements of up to 10 dB. Only minimal shadowing effects were observed in the results for the deep sources because most of the source energy propagated

along the sound-channel axis above the seamount peak.

Sonar Detection of Riverine Fish Migrants using the Pulse Pair Covariance Doppler Frequency Estimator. James W. Waite & Edward O. Belcher, Applied Physics Laboratory, Univ.of Washington, Seattle, Washington 98105.
A time domain method of determining the mean frequency of the symmetrical spectrum is investigated for its applicability to the riverine fish detection and counting problem. The computationally efficient pulse pair covariance technique examines a complex sonar echo signal in range-gated bins calculating Doppler frequency of the signal for each bin. The Doppler measurements aid in the separation of fish echo return from reverberation.

SOUND INTENSITY MEASUREMENT (II)

Modal Behaviour & Intensity Flow. Gunnar Rasmussen, Brüel & Kjaer, 2850 Narum, Denmark.
Analysis of structures is of great importance for studying modal behaviour, damping, energy flow and acoustic radiation. This paper discusses measurement techniques, comparing modal analysis, vibration surface mapping, pressure mapping, intensity mapping, intensity flow in the near field, and vibration intensity mapping. Examples of measurements on the same specimen using these old and new techniques will be shown.

Measuring Intensity. Gunnar Rasmussen, Brüel & Kjaer, 2850 Narum, Denmark.
This paper describes the calibration of intensity measuring instrumentation especially in regard to practical field calibration, the choice of microphone configuration using the two microphone method, the application of intensity measurements in reactive fields, vibration intensity and briefly the use in study of modal behaviour of structures.

Frequency Response Function Measurements using FFT Analyzers. Roger Upton, Brüel & Kjar, 2850 Narum, Denmark.
A system frequency response is traditionally calculated in an FFT analyzer by dividing the cross spectrum measured from input to output with the input autospectrum, (H_1). An alternative method would be to divide the output autospectrum with the cross spectrum measured from output to input. Although H_1 can often yield the optimum estimate of a frequency response function, it has recently been discovered that cases exist where H_2 offers distinct advantages. This paper compares H_1 and H_2 both on a theoretical and practical basis, and discusses applications of the two methods.

Diagnosing Faults in Gears and Bearings, R.B. Randall, Brüel & Kjaer, 2850 Narum, Denmark.
The paper concentrates on the use of spectral and related techniques for the diagnosis of faults in gears and rolling element bearings which are found in many machines, often together. They have in common that the vibration signals, generated by various faults, are quite complex, in both time and frequency domains. Both typically give rise to whole families of spectral components rather than individual frequencies. They differ in that gear frequencies correspond exactly with rotational harmonics, whereas bearing frequencies in general do not. The paper discusses a number of techniques for separating the various effects from each other, and from background noise, and make use of practical examples to illustrate the interpretation of the results.

CAA NOMINATIONS/NOMINATIONS DE L'ACA

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/L'ancien président de l'ACA Tom Northwood nous a appris qu'il nommera les personnes suivantes: President/Président: Cameron Sherry (continuing); Executive Secretary/Secrétaire: Deirdre Benwell; Editor/Editeur: John Bradley; Treasurer/Trésorier: Jean Nicolas (continuing).

Directors: The terms of two of our directors, Bob Cyr and John Hemingway, expire this year. To replace them, John Leggat (Defence Research Establishment Atlantic) and Peter Vermeulen (University of Calgary) will be nominated to serve for a four year period.

Further nominations are invited and should be in the hands of the Executive Secretary (John Manuel), together with the consent of the nominees to serve, prior to the Vancouver meeting./Autres nominations sont invitées et doivent être reçues avec le consentement des nominés par le Secrétaire (John Manuel) avant le Réunion Générale Annuelle à Vancouver.

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