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acoustics and noise control in canada

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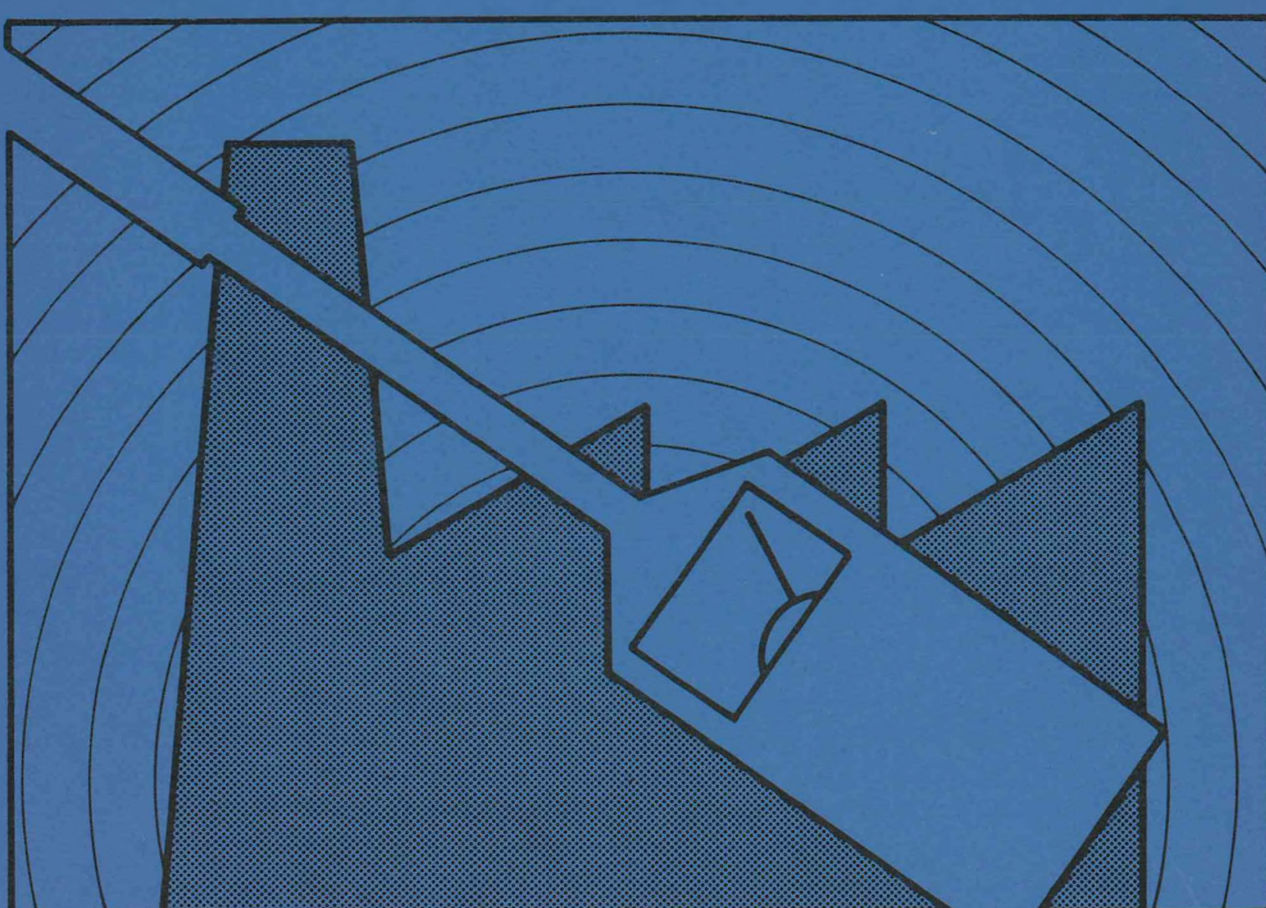

Simon Tuckett

acoustics and noise control in canada

l'acoustique et la lutte antibruit au canada

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Articles in English and French are welcome, and should be addressed to any editor.

Vous êtes invités a soumettre des articles en français ou en anglais. Prière de les envoyer a un des rédacteurs.

EDITORIAL

As the new editorial staff of "Acoustics and Noise Control in Canada" assume their duties, a word of recognition and thanks goes to Daryl May, our previous editor. A glance at the publication before and during his editorship speaks for his fine work.

Along the same path traced by Daryl, the new editorial staff will endeavour to improve the publication. The main editorial responsibilities are now shared between the editor-in-chief and the editor. While the editor-in-chief is finally responsible for the format of each issue, the task of gathering information is shared. The editor is committed particularly to improving the bilingual content of the publication. It is planned to achieve this by providing a french editorial, translation of abstracts, and soliciting more papers to be published in french.

In addition an editorial board has been established to advise and to assume responsibility for the review of papers. We hope in this way to encourage a higher standard of published papers. In addition to Joe Piercy and John Bradley, we are fortunate in having all the former editors on this board (Tony Embleton, Gary Faulkner and Daryl May), giving the publication a continuity since its inception as a newsletter in 1973.

We regard communication between acousticians in Canada as essential and this publication's main purpose is to provide a forum for this scientific dialogue. To help achieve this in addition to improving the bilingual content and encouraging more and better papers, we hope to publish more Canadian acoustics news items and a series of articles describing acoustics facilities in Canada.

Finally, we ask our readers to help us achieve our goals by writing to us to share their news ideas and to tell us about their work.

Editorial

Avec l'arrivée d'une nouvelle équipe de rédaction, notre publication prend une nouvelle orientation. On a décidé d'augmenter la partie publiée en langue française. L'objectif d'une telle augmentation serait de permettre à tout acousticien francophone de communiquer avec ses collègues à travers le Canada.

Par consequent, l'équipe de rédaction est prête à promouvoir la publication de tout genre de communications en français (des articles, des annonces de réunions, des nouvelles, etc.). Ce numéro témoigne de cette nouvelle orientation en publiant un article complet de français.

Chers lectures francophones, faites vous entendre à travers votre publication!

THIRD INTERNATIONAL SYMPOSIUM ON HAND-ARM VIBRATION

18-20 May 1981 - 3rd International Symposium on Hand-Arm Vibration, Ottawa, Canada. Jointly organized by National Research Council of Canada and Dept. of National

Health and Welfare. Fee: Approx. $75. For further information, contact Dr. A.J. Brammer, Div. of Physics, National Research Council, Montreal Road, Ottawa, Ont. K1A 0R6. Telephone (613) 993-2840.

TORONTO CHAPTER ANNOUNCEMENT

The next meeting of the Toroo Chapter of the CAA is to be held on Monday, January 19, 1981 at 7:00 p.m., at the Auditorium of the Ontario Hydro Headquarters Bldg., 700 University Avenue, Toronto. The topic for the evening is "Industrial Noise", and will consist of speakers and a question period on the proposed Ontario Ministry of Labour Noise Regulations. Speakers will be as follows: Regulations - representatives from the Ontario Ministry of Labour; Instrumentation - Greg Michel, B & K Instruments; Audiology - Dr. Peter Alberti, Mount Sinai Hospital; Enforcement Aspects - Tony Taylor, Ontario Hydro.

For further information please contact J.C. Swallow at (416) 245-7501, A. Behar at (416) 683-7516, or G. Michel at (416) 791-1642.

The following meeting is scheduled for May 11, 1981. The topic is to be "Acoustical Research in a Medical Setting", with short talks by invited speakers on: (a) brain stem evoked response, (b) basic research on auditory aspects, and (c) hearing protectors and speech intelligibility. This meeting is to be organized by Sharon Abel at (416) 596-3014.

F.A.S.E. SYMPOSIUM ON ACOUSTICS AND SPEECH

The 4th F.A.S.E. Symposium on "Acoustics and Speech" is to be held in Venice on April 21-24, 1981. The editor-in-chief (address on inside front cover), has a limited number of copies of the 1st Announcement. Additional copies and information are available on request from: E.S.A. - 37, Via Della Polveriera - 00184. Rome, Italy.

G.A.L.F. GROUP MEETINGS TO BE HELD IN CANADA

The Speech Communication section of the Group of French Language Acousticians (G.A.L.F.) has scheduled two events which will be held in Canada rather than in Europe, the usual location for G.A.L.F. meetings.

The 12th Journees d'Etudes sur la Parole, cosponsored by the Université de Montréal, will be held 23-27 May 1981 in Montreal. The general theme of the meeting is "Speech Communication: Articulation, Acoustics, and Perception." All papers and presentations are to be in French except submissions for inclusion in poster sessions which are to be in French and English.

The second event, a bilingual symposium on "Intonation in Synthesis and Automatic Speech Recognition", will be held 29-30 May, 1981 in Toronto. This symposium is cosponsored by the University of Toronto.

Further details can be obtained from G.A.L.F., Division TSS, B.O.40, 22301 Lannion Cedex, France, or from the cosponsors, Université de Montréal, Departement de Linguistique, C.P. 6128, Montréal 101, and the

University of Toronto, Experimental Phonetics Laboratory, 39 Queen's Park Crescent, Toronto, Ontario, M5S 1A1, Canada.

NEW RESEARCH CONTRACTS

We are grateful to Past President Bill Bradley for keeping us posted on the latest research contracts awarded by the federal government:

To Institut national de la recherche scientifique, Verdun, Québec, $35,200 for "Use of digital compression techniques for voice signals in satellite communication systems - Phase I". Awarded by the Department of Communications.

To University of Saskatchewan, Saskatoon, Sask. (Drs. D.E. Dobbs and G. Wacker), $13,000 for "Subjective evaluation of delta coding in quality music and sound distribution - Phase II". Awarded by the Department of Communications. To Université de Sherbrooke, Sherbrooke, Québec (J.P. Adoul), $30,003 for "Digital transmission and processing of voice data". Awarded by the Department of Communications.

To Bell-Northern Research Ltd., Ottawa, Ont., $89,426 for "Development of a specification for the miniaturization of signal conditioning electronics for a multi-element hydrophone array". Awarded by the Department of National Defence.

B.C. SCIENCE COUNCIL GRANT

To Barron Associates, Acoustical Consultants, Vancouver, B.C., $58,000 for the development of a computer system to allow acoustical designers to hear a performance in a hall before it is built.

INTER-NOISE 81 - CALL FOR PAPERS

The 10th International Conference on Noise Control Engineering (Inter-Noise 81) will be organized by the Netherlands Acoustical Society NAG in cooperation with the Belgian Acoustical Association ABAV under sponsorship of International/INCE. It is to be held at the RAI Congress Building in Amsterdam from Tuesday 6 through Thursday 8 October 1981.

The theme of the conference is PRACTICE OF NOISE CONTROL ENGINEERING. The technical program will highlight research and development in noise control engineering, state-of-the-art summaries and tutorial/clinical workshops. Contributions are welcome. For further information write to: INTER-NOISE 81, P.O. Box 85542, 2508CE, The Hague, The Netherlands.

CSHA CONVENTION '81

The Canadian Speech and Hearing Association 1981 Convention is to be held May 6-9, 1981, Chateau Lacombe, Edmonton, Alberta. Subjects include: auditory evoked potentials and hearing impairment. Deadline for abstracts is March 1, 1981. For further information contact: Elaine Heaton, Glenrose Hospital, Edmonton, Alberta, T5G 0B7.

HEAR HERE

"Hear Here" is the newsletter of the Canadian Speech and Hearing Association. Non-members may subscribe to the newsletter at a cost of $8.00 per annum. Subscriptions should be mailed to the Administrative Secretary - Louise Coderre, Université de Montréal, Section d'orthophonie et audiologie, 2375 Cote Ste. Catherine, Montréal, Québec, H3T 1A8. Telephone (514) 343-7841.

ACOUSTICS LETTERS SUPPLEMENT

This is a new bimonthly supplement containing summaries of the contributions to "Acoustics Letters", an established acoustical publication. The supplement will also carry news of people, events, meetings, companies and products in acoustics. The supplement is available free of charge to named individuals engaged in acoustic activities from: Acoustics Letters Supplement, 14 Broadway, London, SW1H 0BH, England.

HEARING RESEARCH

Hearing Research, now in its 3rd year, is a forum for all papers concerned with basic auditory mechanisms. Emphasis is placed on experimental studies but theoretical studies are also considered. The journal publishes original research papers (in the form of full length papers, short communications and reviews) dealing with auditory neurophysiology, ultrastructure, psychoacoustics and behavioural studies of hearing in animals, and models of auditory functions. Papers on comparative aspects of hearing in animals and man, and on the effects of drugs and enviornmental contaminants are also considered for publication. Clinical papers are not accepted unless they contribute to the understanding of normal hearing functions.

For further information and/or free specimen copy, write to: in the U.S.A. and Canada; Journal Information Center, Elsevier's Science Division, 52 Vanderbilt Avenue, New York, N.Y. 10017, U.S.A.

LETTERS

Acoustical Consultant Registration

Professionalism and protection for the public should require the acoustical consultant be either a registered architect or engineer. He may further indicate his qualifications as he progresses through meeting the requirements for membership in the appropriate professional organizations just as the pathologist who, in the U.S., must first pass his M.D. license requirements. Later he may become a member of the American College of Patholigists by examinations, etc. A person in the U.S. holding a Phd in Pathology cannot practice as a pathologist without passing the M.D. license requirements for medical doctor. The M.D. is free to practice in any speciality without any additional requirements.

In my opinion acoustics relates to architecture and engineering in the same manner as illumination, air-conditioning, heating, refrigeration, radio-communication, etc. These, and other specialties, operate under the blanket of architecture and/or the various engineering disciplines. Until acoustics becomes a separate accredited undergraduate degree program then we acoustical consultants should remain under the blanket registrations available. I believe the architectural and engineering boards are negligent in not requiring acoustical consultants meet existing legal requirements and become registered in either architecture or engineering.

W. Robert Nichols, P.E.,
W. Robert Nichols, P.E. and Ass., Acoustical Consultants,
Kent, Washington, U.S.A.

EDMONTON 1981

Notice of Edmonton Acoustics Meetings

The 1981 Annual Meeting and Symposium of the Canadian Acoustical Association is planned for Edmonton on October 8th and 9th, 1981. It will be preceded by a meeting of the Acoustics and Noise Control Committee of the Canadian Standards Association on October 7th, and two seminars on October 6th, one on "Hearing Loss Prevention", and the other on "Transportation Noise Buffering".

Parallel technical sessions are planned on October 8th and 9th to include all segments of acoustical interests.

Special emphasis is being given to encourage those attending to bring their spouses and participate in a Post-Session Tour of the Jasper-Banff Area.

A formal call for papers will be made in the April issue (Volume 9(2)), of "Acoustics and Noise Control in Canada".

Annonce des réunions sur l'acoustique à Edmonton

La réunion et le colloque annuels de l'Association canadienne de l'acoustique pour 1981 devraient se tenir à Edmonton, les 8 et 9 octobre. Ils seront précédés d'une réunion du Comité de l'acoustique et de la lutte anti-bruit de l'Association canadienne de normalisation, qui aura lieu le 7 octobre, et de deux débats, qui se tiendront le 6 octobre, sur "La prévention d'une perte de l'acuité auditive" et sur "Aménagement des zones tamponneuses de bruit du transport".

Parallèlement, des séances techniques sont prévues pour les 8 et 9 octobre afin d'inclure tous les aspects du domaine de l'acoustique.

Nous encourageons tout particulièrement les assistants à amener leur conjoint et à participer, après la tenue des réunions, à une visite organisée de la région de Jasper-Banff.

La demande officielle de documents paraîtra dans le numéro d'avril (Volume 9 (2)) de la revue Acoustique et lutte anti-bruit au Canada.

LA DOSE DE BRUIT
COMMENT LA MESURER DANS LA GRANDE ENTREPRISE

MM. JACQUES COTE ET MARCEL MORIN

Société d'électrolyse et de chimie Alcan Ltée
Service du développement technologique et
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C.P. 500, Arvida, Québec, G7S 2C5

SOMMAIRE

Une perte d'acuité auditive causée par une exposition prolongée au bruit étant reconnue, il en est de même pour le principe de la dose de bruit comme moyen pour prédire une telle perte. Toutefois, les méthodes pour mesurer la dose de bruit sont multiples. Une brève revue de quelques méthodes est donnée ainsi qu'une évaluation de chacune d'elles. Dans une grande entreprise et surtout en présence de bruit et de durée de travail variables, la technique de l'audio-dosimétrie - sonométrie semble un choix valable pour mesurer la dose d'exposition et identifier la ou les sources responsables d'une surexposition.

ABSTRACT

A hearing loss caused by prolonged exposure to noise is well known. It must also be recognized that the noise dosage should be used as a means to predict such hearing loss. However, methods for measuring the noise dosage are numerous. A brief review of a few methods and their evaluation are given. In a large plant and especially in the presence of variable noise levels and exposures the audio-dosimetry-sound level meter method would appear a valuable choice for measuring the noise dosage and identify the noise source(s) responsible for over-exposure.

INTRODUCTION

La surdité professionnelle est un déficit auditif permanent dû à l'exposition prolongée à des doses d'exposition au bruit produites au cours de l'activité professionnelle.

Le problème de la surdité professionnelle est depuis longtemps reconnu. Karmy[1], dans un article intitulé "Occupational Deafness" fait un bref historique des premiers auteurs qui ont décrit ce type de surdité. Des exemples classiques de surdité professionnelle sont les travailleurs d'un village de France, préposés à la fabrication des cloches, qui ont été baptisés "sourdins", et la surdité des riveteurs de bouilloires désignée par la surdité des chaudronniers.

Cependant à ces époques on ne pouvait que qualifier le déficit auditif et l'ambiance sonore. La technologie ne permettait pas de quantifier les déficits auditifs, les niveaux sonores et la nature des bruits.

Les premiers instruments pour mesurer les niveaux sonores semblent avoir fait leur apparition en 1930 [2]. Cependant c'est à partir des années 1960 et surtout dans les années 1970 que la technologie a progressé pour permettre l'apparition d'appareillage diversifié et versatile pour la mesure acoustique [2].

Les études pour quantifier les causes à effet de la surdité professionnelle n'ont cessé de se faire depuis les années 1940. A ce titre, il serait peut-être bon de rappeler les travaux de pionniers tels que ceux de Rosenblith [3] en 1942, de Ruedi et Furrer [4] en 1946, de Cox et coll. [5] en 1953 et plus récemment, de Guignard [6] et Johnson [7].

Pour établir des relations de cause à effet et pour protéger l'acuité auditive des travailleurs, de nombreux critères et normes d'exposition au bruit ont été élaborés. Une bonne revue des divers critères d'exposition proposés a été effectuée par NIOSH [8] aux Etats-Unis.

Depuis plusieurs années, des normes d'exposition au bruit sont apparues dans divers pays et provinces ou sont sur le point de l'être ou d'être modifiées (plus restrictives).

La majorité des normes d'exposition au bruit se base sur le concept de la dose d'exposition journalière ou hebdomadaire. La dose d'exposition tient compte de trois paramètres importants:

1) le niveau sonore exprimé en dBA (unité qui tient compte également du contenu fréquentiel du bruit)
2) la durée d'exposition à chacun des différents niveaux sonores
3) le temps permissible à chacun de ces niveaux sonores.

Plus les niveaux sonores augmentent, plus le temps permissible pour une dose journalière diminue. Dans le contexte nord-américain, un taux d'échange de 5 dBA * est utilisé, comparativement à un taux d'échange de 3 dBA dans la plupart des pays européens.

De nos jours, il existe trois raisons majeures pour mesurer les doses d'exposition au bruit:

1) vérifier si les normes sont respectées
2) déterminer les priorités d'action dans les étapes de réduction de bruit
3) établir des relations possibles de cause à effet.

Méthodes pour mesurer ou évaluer l'exposition au bruit

Les méthodes proposées pour mesurer ou évaluer l'exposition au bruit sont nombreuses et des plus diversifiées. Certaines méthodes proposées (liste non

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* En Amérique du Nord, présentement seule la Colombie-Britannique utilise un taux d'échange de 3 dBA.

exhaustive) utilisent une approche statistique[9-11], graphique[12], une combinaison de niveaux sonores, temps d'exposition approximatif et informatique[13,14] et cartes de bruit[15,16].

Toutefois, les méthodes les plus couramment utilisées ont été revues entre autres par Martin[17], Kamperman[18] et Yerges[19] et sont résumées ci-après:

a) sonométrie - chronométrie

b) niveau équivalent par sonométrie ou autre technique[20]

c) enregistrement magnétique et/ou graphique du bruit

d) audio-dosimétrie.

Toutes les méthodes ci-haut mentionnées comportent des avantages et des inconvénients. La technique parfaite pour mesurer la dose d'exposition ne semble pas exister encore[19,21,22].

Faire une critique de chacune de ces méthodes n'est pas possible ici mais signalons les inconvénients les plus souvent soulevés: la complexité, le coût (appareillage et personnel qualifié) et une information limitée.

Néanmoins, à titre d'exemple, regardons la méthode sonométrie - chronométrie. Cette méthode consiste à mesurer le bruit avec un sonomètre (dBA en mode lent) et à chronométrer le temps exposé aux différents niveaux sonores. Les bruits inférieurs à 85 ou 90 dBA ne sont pas considérés. A la fin de la journée il faut calculer, manuellement, à l'aide de calculatrices ou de l'informatique, la dose d'exposition partielle à chaque niveau sonore (ou classe de niveau). L'addition de toutes les doses partielles donne la dose totale journalière.

Cette méthode comporte les désavantages suivants:

a) difficulté inhérente à prendre les données de deux instruments séparés (sonomètre - chronomètre) et d'en noter les résultats;

b) imprécision des lectures sonomètre - chronomètre dans des champs sonores variables et imprévisibles dans le temps et le niveau;

c) difficulté et parfois impossibilité de suivre un travailleur (ex.: travailleurs d'équipes d'entretien) à cause des difficultés d'accès ou de danger;

d) échantillonnage limité: un technicien ne peut que mesurer la dose d'exposition d'un travailleur par jour.

D'autres désavantages d'ordre administratif ont été signalés par Dear[23].

Pour une usine employant des milliers de travailleurs, la technique sonométrie - chronométrie est à toutes fins pratiques irréaliste. Toutefois cette technique a l'avantage d'identifier adéquatement les sources de bruit et la durée d'exposition responsables des doses de surexposition.

Dans une grande entreprise où les travailleurs peuvent être répartis dans des centaines de diverses occupations, aussi bien reliées à l'opération qu'à l'entretien, la mesure de l'exposition au bruit par audio-dosimétrie nous apparaît la plus simple et la plus pratique.

En effet, la méthode de mesurer la dose d'exposition par audio-dosimètre a fait son apparition vers le début des années 1970 et n'a cessé depuis de gagner en popularité[23-31].

Brièvement l'audio-dosimètre est un appareil qui, porté par un travailleur, accumule les bruits pondérés en dBA à partir d'un certain niveau sonore (80, 85 ou 90 dBA) et tient compte du temps à chacun de ces niveaux et les compare au temps permissible décrit dans une norme. L'audio-dosimètre donne alors, à la fin de la journée, la dose totale d'exposition généralement exprimée en pourcentage de la dose permissible.

Une fois les règles d'étalonnage respectées, l'audio-dosimétrie offre donc l'avantage d'être simple et permet un vaste échantillonnage quotidiennement.

DISCUSSION

L'audio-dosimétrie offre l'avantage primordial de répondre à la question suivante: les normes sont-elles respectées? Si les normes sont respectées, l'information obtenue par audio-dosimétrie peut être suffisante.

Si les normes d'exposition sont dépassées, l'audio-dosimétrie ne répond toutefois pas à la question: quels sont les endroits et sources de bruit responsables de la surexposition?

Pour remédier à cette lacune, la technique audio-dosimétrie - sonométrie peut être utilisée avantageusement. Cette approche consiste à mesurer les niveaux sonores des principaux endroits et outils de travail des employés sur lesquels les audio-dosimètres ont été placés.

Cette technique combinée offre plusieurs avantages notamment:

a) vérifier rapidement si les résultats obtenus par audio-dosimétrie sont valides; en effet, à partir des relevés des niveaux sonores auxquels les travailleurs sont exposés durant la journée de travail et des durées approximatives de travail (obtenues des contremaîtres ou des travailleurs) il est possible de vérifier si la dose d'exposition mesurée semble plausible ou si la dose semble erratique présumément à cause d'un mauvais fonctionnement de l'appareillage ou d'une plaisanterie de la part du travailleur;

b) identifier assez précisément la ou les sources de bruit responsables d'une surexposition;

c) éviter de suivre chaque travailleur pas à pas, ce qui peut être difficile ou gênant pour plusieurs d'entre eux;

d) permettre assez de temps quotidiennement pour s'enquérir de la charge de travail des employés étudiés, des paramètres de production et d'effectuer une compilation quotidienne des données recueillies.

Si les tâches à mesurer sont des postes "fixes" et où le niveau sonore est assez stable, la technique sonométrie - chronométrie peut sembler pratique mais plusieurs tests resteraient nécessaires pour déterminer la variabilité des doses d'exposition. Ceci représente donc un homme-test, ce qui est long, fastidieux et fort coûteux.

L'audio-dosimétrie a pour avantage principal de faciliter la prise des données. En effet la personne chargée de la mesure peut distribuer et surveiller plusieurs audio-dosimètres par jour. On comprendra donc la praticabilité dans la grande entreprise, où on y rencontre en outre de nombreuses occupations rattachées à l'entretien, du choix de la technique audio-dosimétrie - sonométrie pour mesurer la dose d'exposition au bruit.

Certains s'élèveront sûrement contre la précision des mesures obtenues par audio-dosimétrie[32] et de l'inter-variabilité d'un appareil à l'autre[33]. Il n'est pas possible ici de faire une critique en profondeur des marges d'erreurs reliées à l'appareillage ou aux méthodes mais signalons que la principale source d'erreur semble se manifester en présence de bruit impulsionnel ou quasi impulsionnel[19,34]. En effet en présence de ces bruits, l'audio-dosimètre semble surévaluer la dose d'exposition.

Actuellement, toutes les normes sur l'exposition au bruit considèrent séparément la dose d'exposition au bruit plus ou moins continue d'une part et l'exposition au bruit impulsionnel d'autre part.

En pratique, les travailleurs sont exposés simultanément à ces bruits et rien encore n'indique comment l'addition doit se faire pour établir une dose totale reliée à des études de cause à effet. Toutefois, l'approche suggérée par Cluff[22] à cet égard doit être prise sérieusement en considération.

Compte tenu qu'une marge d'erreur est possible avec l'audio-dosimètre (comme d'ailleurs avec toute autre technique), il convient d'établir une gamme de probabilités des résultats obtenus[27]. Cette gamme couvrira en majeure partie les imprécisions inhérentes aux mesures. La gamme recommandable est la suivante:

a) dose permissible inférieure à 75%: grande certitude que la norme est respectée

b) dose permissible entre 75 et 133%: incertitude statistique si la dose excède ou non la norme

c) dose permissible supérieure à 133%: certitude que la norme est excédée.

Actuellement l'audio-dosimétrie demeure donc un moyen valable pour mesurer adéquatement l'exposition au bruit[35] car comme il a été mentionné précédemment, la technique pratique parfaite n'existe pas.

L'audio-dosimétrie - sonométrie permet non seulement d'obtenir un bon nombre de résultats quotidiennement mais a aussi l'avantage d'étudier pratiquement plusieurs travailleurs à des jours différents afin d'établir la variabilité des doses d'exposition.

L'appareillage et la méthodologie pour l'audio-dosimétrie ne cessent d'évoluer et de se perfectionner[36-39] et qui sait si dans un proche avenir, avec les améliorations techniques qui y seront apportées, cette technique ne deviendra pas des plus versatiles et des plus précises.

En conclusion, la technique de l'audio-dosimétrie - sonométrie pour mesurer la dose d'exposition au bruit semble un choix des plus pratiques dans la grande entreprise.

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THE ACOUSTICS OF THE NEW MASSEY HALL

Report of the II Technical Meeting of the CAA
Toronto Chapter, September 29, 1980

By Courtesy of
Arthur Erikson, Architects
Toronto

We are sincerely pleased to report that this meeting was again a success because of the quality of the speakers as well as of the number of attendants.

The meeting was again held in the Ontario Hydro Auditorium, where over 60 members and guests (among them Lenn Blizzard with a bunch of enthusiastic George Brown students), assembled to hear the presentations and to ask questions.

Our first speaker was Mr. Keith Loffler, Director of Operations, Arthur Erikson and Ass., Architects. He presented in a very lively manner some background of the Massey Hall project. Then he concentrated on the design of the hall itself and how it had changed from early "imitations" of the Boston Hall and the actual Massey Hall to its final shape. Impressive slides of different models used during the study showed how the hall was then "enclosed" into the building and how it is related to the projected development.

The question and answer session that followed Mr. Loffler's presentation was lively and helped everyone get a more comprehensive idea of the whole project.

The highlight of the coffee break following was the pastries prepared by Mrs. Oetlinger which were much better accepted than the traditional donuts.

The second part of the meeting was the presentation by Dr. Theodore Shultz. He started with an overview of some of the existing concert halls and the underlying characteristics that are considered as fundamental for their musical quality. After reviewing the importance of reverberation time, he concentrated on early acoustic reflections and how to obtain and control them. He then explained how these concepts are applied in the New Massey Hall.

Specific acoustical details discussed were as follows: Sound absorbing banners hanging from the center of the ceiling will change the reverberation time from 1.5s to 2.5s in steps of 0.25 by raising or lowering parts or all of them. Another highlight is reflecting surfaces over the podium that reflect the sound toward the audience. Other details discussed were the very low background noise (NC = 15) and the particular arrangement of some of the seats behind the podium.

Dr. Shultz's well known skill as a speaker enabled him to present in an easy manner some of the fundamentals behind the design of the acoustics of the hall.

The question and answer period following complemented well the whole presentation.

We all enjoyed very much the excellent presentations as well as the fact of having such an enthusiastic audience.

A. Behar
Ph: (416) 683-7516

ACOUSTICS WEEK IN MONTREAL

This highly successful week from October 20-25, 1980, consisted of 3 parts:

(1) Seminar on "Occupational Exposure to Noise and Vibration: Effects, Measurement and Control",

(2) Canadian Acoustical Association Annual Meeting and Symposium",

(3) Canadian Standards Association Acoustics and Noise Control Committee Annual General Meeting.

Individual reports on each of these items follow:

SEMINAR REPORT

The seminar, jointly organized by National Research Council and Health and Welfare Canada, was well attended, with 150 participants. The 2 day seminar was divided into 2 parts, the first day on "Occupational Exposure of the Hands to Vibration" and the second day on "Occupational Exposure to Noise". Each day concluded with a panel discussion on related subjects. Lectures and authors were as follows:

Occupational Exposure of the Hands to Vibration

"Vibration White Finger. Symptoms, signs and objective tests for diagnosis". Drs. P.L. Pelmear (Ont. Min. of Labour) and P.V. Pelnar (McGill Univ.); "Occupational Exposure of the Hands to Vibration in Canada", Drs. G.W. Gibbs (Celanese Can.) and P.V. Pelnar; "Measurement of Hand-Transmitted Vibration", "Relations between Exposure to Vibration and the Development of the Vibration Syndrome", "Limited Exposure of the Hands to Vibration", all by Dr. A.J. Brammer.

Occupational Exposure to Noise

"Review of Effects of Noise on Man and Their Relation to Noise Exposure", Dr. E.A.G. Shaw; "Regulating Occupational Exposure to Noise - A Review", Mrs. D.A. Benwell; "Consequences of Occupational Exposure to Noise in Canadian Industry", Dr. P.W. Alberti (Univ. of Toronto); "Measurement of Noise Exposure and Its Related Descriptors", Drs. G.S.K. Wong and E.A.G. Shaw.

D.A. Benwell
Co-Organizer

CAA ANNUAL MEETING AND SYMPOSIUM - CONVENOR'S REPORT

One hundred and thirty-four registrants attended our 19th Annual Meeting in Montreal.

60 from Quebec
54 from Ontario
4 from Alberta
3 from British Columbia
3 from Nova Scotia
1 from New Brunswick
1 from Manitoba
3 from Denmark
1 from Australia
1 from Sweden
3 from U.S.A.

Forty-six papers were read. We hope that many of these will be published in "Acoustics and Noise Control in Canada".

The speaker at the CAA Annual Dinner was Dr. Brian Slack, Chairman of the Department of Geography at Concordia University, and, an expert on Montreal as a World City. He spoke (without pulling any punches) on "Montreal - The Challenge of Transportation".

We toured the Transport Canada Motor Vehicle Test Centre at Blainville. This installation includes: Environmental Chambers to -40°C, collision testing facilities, a 6.5 Km track with "hands off" speeds to 180 Km/h, grass and ice test areas, and a mobile acoustical laboratory for vehicle noise measurements.

I thank Claude Cossette, Bob Cyr, Richard Guy, Geoff Perry, Cameron Sherry and Mike Stinson who worked hard to make this meeting a success. Special thanks are also due to Rita Winslade, secretary to Cameron Sherry and my wife Jill who put in many hours behind the scenes and on the registration desk.

C.W. Bradley,
Convenor.

CAA ANNUAL MEETING - SECRETARY'S REPORT

Minutes of the Annual General Meeting of the
Canadian Acoustical Association
Held at the Constellation Hotel, Montreal, on October 22, 1980

1. The meeting was called to order by President T. D. Northwood at 5:45 p.m.

2. The minutes of the previous annual general meeting were read by the Executive Secretary, J. Manuel. On a motion by B. Dunn seconded by E. Bolstad these were accepted as read.

3. The Executive Secretary read the correspondence received since the previous meeting was held. There was no further comment or discussion.

4. President T. D. Northwood presented the report on the meeting of Directors held prior to the annual general meeting. He noted that at the last general meeting in Windsor the membership approved the formation of a Task Group to take appropriate steps to prepare an invitation to the International Congress on Acoustics to hold the 1986 meeting in Canada. The Task Group looked at three cities; Montreal, Ottawa and Toronto, taking into consideration the facilities available and the funding possibilities. After two meetings, the Task Group concluded that it was indeed feasible to invite ICA to hold the 1986 meeting in Canada.

   At a third joint meeting of the Task Group and all the CAA Directors in Toronto, it was decided that Toronto and particularly, the University of Toronto Campus, was the preferred site. Upon reaching this decision, an invitation and brochure was prepared by the Task Group for presentation to the International Commission on Acoustics in Sydney during the 10th ICA 1980 meeting.

The Chairman said that he had also written to the Chairman of the International Commission on Acoustics advising him, in advance, that Canada was preparing an invitation for the 12th ICA in 1986. He, the Chairman, thought that we had paved the way very well and this sentiment was confirmed in a subsequent letter received from the ICA Chairman R. T. Beyer, who wrote, "(the Canadian delegation) had more than done their homework and virtually every potential question had been researched and appropriate answers were available". "I think I may say that the unofficial opinion of the Commission tilted strongly in (Canada's) direction." "However, there was sentiment at the Commission meeting to delay a decision at the present time". Chairman T. D. Northwood said that the CAA would continue to take a fairly aggressive stance to get a firm commitment on the 12th ICA. To this end, contacts would be maintained and promoted by Officers and the Task Group.

5. The Chairman informed the meeting that steps are being taken by the Directors to work out a simple and satisfactory procedure for the "Directors Award". More information on this would be included in the Newsletter.

6. In order to make the CAA more attractive to francophone acousticians, the Chairman noted that the Directors had appointed M. Osman as an Honorary Officer for this purpose.

7. With respect to the Newsletter, the President noted that D. N. May had resigned as Editor-in-Chief. To fill the vacancy D. Benwell is being nominated as Editor-in-Chief. Also D. J. Whicker has been relocated to Vancouver and the secretary of the CAA (J. Manuel) will assume responsibility for membership registration, records and mailing list.

8. The Chairman then called on Treasurer L. Russell, to present the financial report. The Treasurer noted that the CAA was in good financial shape as of the end of 1980. Total surplus on August 31, 1980 was $5,142.38. He said that there was sufficient funds to permit an upgrading of the Newsletter quality as had been agreed to by the Directors. The report was accepted without further discussion.

9. The Auditor's report was presented by T. Brammer. He said that he had examined the CAA books which had been kept in exemplary order. He felt that the Treasurer's report fairly reflects the financial state of the Association.

10. T. Brammer moved and A. Behar seconded the motion that the Auditor's report be accepted as read. Carried unanimously.

11. In the subsequent discussion, the Treasurer noted that the financial report did not include the income from the 1979 Windsor meeting which amounted to $1,494.85. The CAA year-end assets, in fact, now exceed $7,000 because of the Windsor meeting revenue and miscellaneous advertising revenues.

12. L. Russell moved and J. Hemingway seconded the motion that the Treasurer's report be accepted. Carried unanimously.

13. It was resolved that "the annual membership fee, the annual subscription fee and the annual membership fee for students be continued at the present levels". Carried unanimously.

14. Election of officers. The report of the Nominating Committee was presented by W. Bradley. In his remarks he noted that the CAA constitution provides that the organization be run by Officers elected or reelected annually at the pleasure of the membership. The CAA is governed by Directors appointed for four year terms. He then nominated the following Officers:

President:	T. D. Northwood	(continuing)
Executive Secretary:	J. Manuel	(continuing)
Treasurer:	L. T. Russell	(continuing)
Editor-in-Chief:	D. Benwell	(new, replacing D. N. May).

15. The President accepted these nominations and then called for further nominations from the floor. There being no further nominations B. Dunn moved and R. Johnston seconded closure of nominations. Carried.

16. President T. D. Northwood, on behalf of the Officers, accepted the appointments and thanked the membership for their confidence in the Officers. He congratulated D. Benwell on her election.

17. Election of Directors. W. Bradley reported that the Nominating Committee had nominated S. Eaton and J. Foreman to fill the Directorships being vacated by G. Faulkner and H. Jones.

18. The President accepted these nominations and noted that because a third nomination, that of M. Osman, had been received in writing pursuant to the CAA constitution, a secret ballot was necessary. As a result of the secret ballot of members in good standing, S. Eaton and M. Osman were declared elected.

19. In congratulating the new Directors, the Chairman confirmed the 1980/81 list of CAA Directors as follows:

S. Eaton	-	4 year term	(B.C.)
M. Osman	-	4 year term	(Ont.)
R. Cyr	-	3 year term	(Que.)
J. Hemingway	-	3 year term	(Ont.)
D. Whicker	-	2 year term	(B.C.)
J. Piercy	-	2 year term	(Ont.)
C. Sherry	-	1 year term	(Que.)
E. Bolstad	-	1 year term	(Alta.)
H. Jones	-	retired	(N.S.)
G. Faulkner	-	retired	(Alta.)

20. President T. D. Northwood commented on the work of the Editorial team. He said that the past year had seen the Newsletter improve issue by issue. He explained that the reason for establishing the annual fee structure was to cover the cost of producing the Newsletter. The Chairman noted that CAA was budgeting for a slight deficit next year to allow for the quality upgrading. He thanked D. N. May and his team for their excellent effort. A vote of thanks was moved by J. Piercy and seconded by T. Brammer. Carried unanimously.

21. President T. D. Northwood said that there were thoughts that the name of the Newsletter be changed to something more appropriate. He proposed that this question be referred to the Directors for further discussion. Any suggestions on a suitable name would be welcomed by him.

22. The President noted that Internoise '80 would be held in Miami in December 1980. The CAA would be represented at meetings of International INCE during that period.

23. G. Bolstad noted that he would act as Convenor of the 1981 CAA Symposium to be held in Edmonton on October 8-9, 1981. On behalf of his committee, he reported on the proposed location and plans for the event. The theme "Why Hearing Preservation Rather Than Conservation" was the basis for a planned one-day industry-management seminar planned for that week. The seminar would be supported by the University of Alberta Extension Department, the Alberta Chamber of Resources, the Canadian Association of Oil Well Drilling Contractors and the Edmonton Chamber of Commerce.

24. At the suggestion of J. Manuel, the membership agreed to hold the 1982 CAA Symposium and annual meeting in Toronto.

25. There being no further business, the meeting was adjourned at 7:15 p.m.

J. Manuel, Secretary

CAA ANNUAL MEETING - TREASURER'S REPORT

The Treasurer's report consists of the following parts: (a) Statement of Cash Receipts and Expenditures for the Period of September 1, 1979 to August 31, 1980 and (b) a breakdown of these figures reflecting the major income and expenses up to October 31, 1980.

Leslie T. Russell,
Treasurer.

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS FOR PERIOD SEPT. 1, 1979 TO AUG. 31, 1980.

Receipts

Newsletter, advertising, membership and contributions	$ 6,302.39
Interest	$ 198.97
Miscellaneous	10.62
	$ 6,511.98

Disbursements

Bank Charges	$ 2.00
I/INCE fees	203.90
Receiver General of Canada	30.00
P.O. Box rental	10.00
Printing of Newsletter	3,697.41
Refund to Occupational Health Library	90.00
Miscellaneous	33.11
	$ 4,066.42

Excess Receipts Over Disbursements	$ 2,445.56

BALANCE SHEET AS OF AUG. 31, 1980

Assets

Cash on hand	$ 3,542.38
Bank of Montreal Term Deposit	1,600.00
	$ 5,142.38

Liabilities

Surplus Balance Forward, Aug. 31, 1979	$ 2,696.82
Add: Excess Receipts over Disbursements	2,445.56
	$ 5,142.38

SUMMARY - INCOME TO OCT. 31, 1980

Opening balance, Sept. 1, 1979	$ 1,096.82
Receipts - Sept. 1, 1979 to Aug. 31, 1980 as per statement	6,511.99

1979 Conference Net Receipts	$ 1,494.85	
Memberships, newsletters, ads., etc. Aug. 31, 1980 to Oct. 31, 1980	1,360.00	
		$ 2,854.85
TOTAL=		$10,463.65

DISBURSEMENTS - SEPT. 1, 1979 to AUG. 31, 1980

As per statement	$ 4,066.42	
Newsletter and misc. expenses	572.52	
		$ 4,638.94
NET BALANCE=		$ 5,824.71
BANK OF MONTREAL TERM DEPOSIT		1,600.00
NET ASSETS=		$ 7,424.71

CSA ACOUSTICS AND NOISE CONTROL COMMITTEE REPORT

The Technical Committee Z107 on Acoustics and Noise Control of the Canadian Standards Association met at the Constellation Hotel Montreal on 24 October 1980, immediately following the Annual Meeting of the Canadian Acoustical Association. Some 15 members of the Committee and almost an equal number of interested guests were in attendance.

Highlights of the meeting included the following items:

a) Seven subcommittees reported on the current status of Canadian Standards in their respective technical areas. CSA Z107.51 "Procedure for in-situ measurement of noise from industrial equipment" is now available from CSA at a price of $11. Several other draft standards relating to industrial/commercial/domestic machinery noise standards, audiometers, sound level meters, and acoustical-materials testing will be balloted or printed within the next year.

b) The Canadian Advisory Committee of ISO/TC43 on Acoustics functions in several aspects as one of the subcommittees of CSA Z107. A similar mode of operation was approved for ISO/TC108 SC4 on Human Exposure to Vibration. Dr. A.J. Brammer of N.R.C. will be the subcommittee chairman.

c) Several new members were appointed to the Technical Committee on Acoustics and Noise Control. They are: Mrs. D. Benwell, Health and Welfare Canada, Ottawa; Mr. L. Bergsten, Caterpillar Tractor Co.; Mr. B. Clarke, Workmen's Compensation Board of B.C.; Dr. G. Faulkner, University of Alberta, Edmonton; Dr. A. Lightstone, Valcoustics, Toronto; Mr. D. McVittie, Construction Safety Association of Ontario; Dr. D. Quirt, National Research Council, Ottawa; Dr. L. Russell, Nova Scotia Technical University, Halifax.

d) Deirdre Benwell will become coordinator of the Task Force on Occupational Noise.

T.F.W. Embleton
Committee Chairman.

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The effectiveness of hearing protectors in practice

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Toronto, Canada

Abstract. A series of workmen being evaluated for pensions for occupational hearing loss were asked to bring their own hearing protectors from work, to fit them themselves, following which attenuation studies were made. The muffs and most earplugs produced similar attenuation levels at high frequencies, although the muffs produced less attenuation at low frequencies. In all cases the mean attenuation was significantly lower than optimum figures suggested in the literature, and the standard deviation was relatively high. Personally molded earplugs were significantly less effective than the other plugs used. Reasons are discussed for the relatively poor performance of these devices and the concept of assumed protection, *i.e.* mean minus one standard deviation, is discussed. There is need for better instruction on how to use hearing protectors if they are to be effective.

Considerable emphasis is placed upon the use of personal hearing protective devices in current hearing conservation programs[1,2]. Although good hearing protectors have been available since the 1940's in the form of both plugs and muffs, they have only come into widespread use in the last decade. Hearing protectors are usually accompanied by a label indicating the attenuation, which they are claimed to provide at various 1/3 octave bands.

Various standardized techniques[3-6] have been developed to measure the attenuation of hearing protectors and lists have been published of the attainable protection for many types[7-10]; classifications have been produced dividing protectors into classes A, B, and C[6], according to amount of attenuation found; regulations have been written identifying the need to wear certain classes of protector in certain noise levels. The U.S. Environmental Protection Agency has produced a draft document[11] for the labelling of hearing protectors, and indeed states that they have chosen hearing protector devices as the first product for which labelling will be required under Section 8 of the U.S. Noise Control Act in the belief that this can be readily done. All of this presupposes that the protective devices provide the same attenuation when worn by the workman as they apparently do under rigorous laboratory conditions.

Many industrial noise-exposed workmen are seen in our department for the Workmen's

From the Department of Otolaryngology, Mount Sinai Hospital, University of Toronto.

Supported by a generous grant from the Workmen's Compensation Board of Ontario.

Presented at the 31st annual meeting of the Canadian Otolaryngological Society, Montebello, Quebec, June 1977.

Address reprint requests to Dr. P. W. Alberti, Suite 405, 600 University Avenue, Toronto, Ontario, M5G 1X5, Canada.

Compensation Board of Ontario (WCBO). So many adverse comments were heard about personal hearing protectors from workmen that we questioned whether the figures obtained for attenuation under ideal laboratory conditions using ideally fitted and new protectors on trained subjects was a valid basis for making generalizations about the practical, day to day effectiveness of personal hearing protective devices. We therefore decided to evaluate the attenuation of protectors as actually worn by the workforce. The WCBO kindly cooperated by requesting that the workmen bring their own hearing protectors with them from their place of work so that they could be tested with their own devices during the routine pension assessment. This study is a report of the preliminary findings based on an evaluation of those data.

METHOD

The subjects were 88 workmen referred for assessment of noise-induced hearing loss by the WCBO. Their age range was 35-65 years, with a mean of 53 years. The type, location, and duration of noise exposure varied widely amongst individuals in the group, although all had been exposed to noise levels considered by the WCBO to be potentially hazardous for periods of time of more than five and usually closer to 20 years. The majority were miners and steelmakers. Each subject brought his own ear defenders from his place of work and fitted the device himself as he would wear it at work. There were four types: three commonly used earplugs — the EAR (N = 22), Willson Sound Silencer (N = 21), and custom molded (N = 28), and a group of assorted muffs, some on a headband and some attached to hard hats (N=17). A log was kept of comments about the protectors made by the workmen and observations of method of wearing them, and the condition of the protectors.

For the test each workman was seated in a RINK double walled, soundproof booth. Two six-inch diameter round speakers (Madsen Electronics (Canada) Limited) were used for presentation of the test sounds. These were mounted on the side walls of the booth about 38 inches on either side of the subject's chair, the position of which was carefully marked so that it could be replicated from test to test. Ambient noise levels within the booth were within the permissible level of ANSI S3.1-1977. The test sounds were narrow band noises centered at the following frequencies: 125, 250, 500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hz. They were generated by a Madsen OB 70 audiometer. The audiometer and the booth were calibrated prior to and during the experimental period.

Free field hearing thresholds were determined by the method of limits for each of the eight test sounds with the open ear. The subject then fitted his own protective device and the threshold was again measured. The difference between the two measures at each frequency gave the attenuation score.

RESULTS

The mean open ear free-field hearing thresholds for the four protector groups are shown in Figure 1. The change in threshold with frequency is typical of a noise-induced high frequency hearing loss. It should be noted the figure is calibrated in SPL rather than the more commonly used HL. At 125 Hz the thresholds are about 30 dB SPL and at 6 kHz they are about 55 dB SPL. The groups are not significantly different at most of the frequencies tested: of the 42 possible pairwise comparisons of the four groups at eight frequencies only six showed statistically significant differences ($p < .05$) of the order of 10 dB.

The mean attenuation scores for the four types of protector are shown in Table 1 and Figure 2.

The attenuation increases with the frequency from 125 Hz to 3 kHz for each type, although above 3 kHz there is some dropoff.

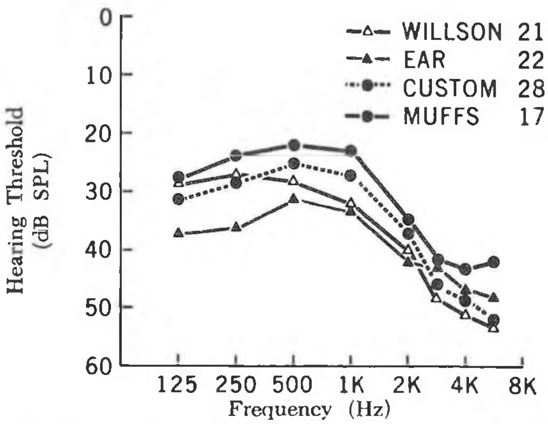

Fig. 1. Free field hearing thresholds for four groups of subjects.

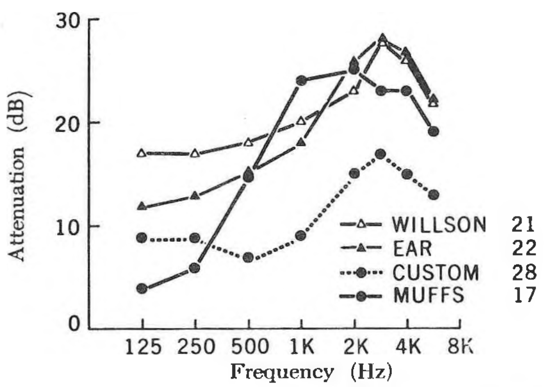

Fig. 2. Average attenuation for four types of protector.

At the lowest frequencies, 125 and 250 Hz, the Willson and EAR plugs give significantly more attenuation (about 15 dB, $p < .05$) than the muffs (about 4 dB). The Willson plugs are significantly better than the custom plugs, 18 dB compared with 9 dB ($p < .01$). The attenuation provided by muffs increases dramatically between 500 and 6,000 Hz. In this range the muffs provide similar attenuation to Willson and EAR plugs, but the custom molded plugs provide significantly less attenuation than any of the foregoing ($p < .01$), across frequencies the difference being about 10 dB.

The distribution of individual scores at 500, 1,000, and 3,000 Hz is shown in Figure 3 for three types of plug. They are compared with the scores obtained for a group of 102 plugs, comprising the 88 plugs studied together with an additional 14 plugs of assorted types. The distribution curves indicate that at each frequency attenuation scores cover a broad range, from 0-40 dB. For the group of 102 plugs, there is a clear trend toward higher scores with an increase in frequency. A comparison of the curves for the three main protector types indicates that at all frequencies the attenuation scores for custom molds are largely concentrated between 0 and 15 dB. At 1,000 Hz 50 per cent of the EAR and Willson plugs give 20 dB or more attenuation, and at 3,000 Hz only 5 per cent of these two plug types give less than 20 dB. The average attenuation and standard deviation for the group of 102 plugs is shown in Figure 4 for the eight frequencies tested. The distribution of attenuation scores of plugs and muffs is shown in Figure 5. Both groups

Table 1. *Attenuation Scores* for Four Protector Types*

Type	125	250	500	1,000	2,000	3,000	4,000	6,000
	Frequency Hz							
Custom	8.9 ± 8.8	8.8 ± 8.3	7.3 ± 6.3	9.1 ± 7.2	14.8 ± 9.2	16.8 ± 9.3	15.2 ± 9.1	13.2 ± 8.9
EAR	11.2 ± 9.1	12.7 ± 9.1	15.2 ± 7.3	18.2 ± 7.2	26.4 ± 6.9	28.3 ± 7.7	27.1 ± 8.9	21.7 ± 7.5
Willson	17.3 ± 11.1	17.4 ± 9.3	17.9 ± 9.3	20.0 ± 9.4	23.3 ± 8.6	27.6 ± 8.3	25.7 ± 9.5	22.4 ± 9.7
Muff	4.2 ± 5.4	6.4 ± 7.7	15.3 ± 8.7	24.1 ± 6.2	25.3 ± 8.4	22.6±12.4	22.9±10.8	19.4 ± 9.3

*Mean ± 1 standard deviation.

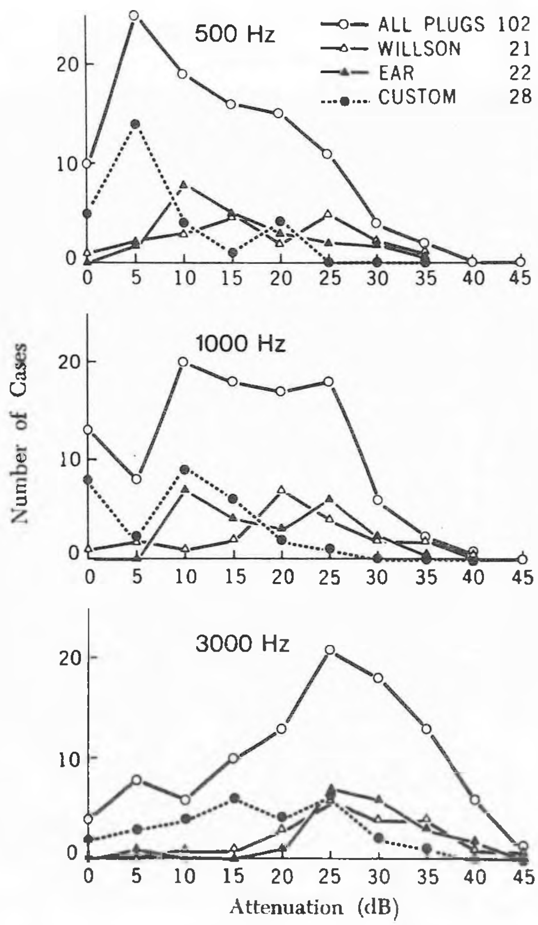

Fig. 3. Distributions of attenuation score.

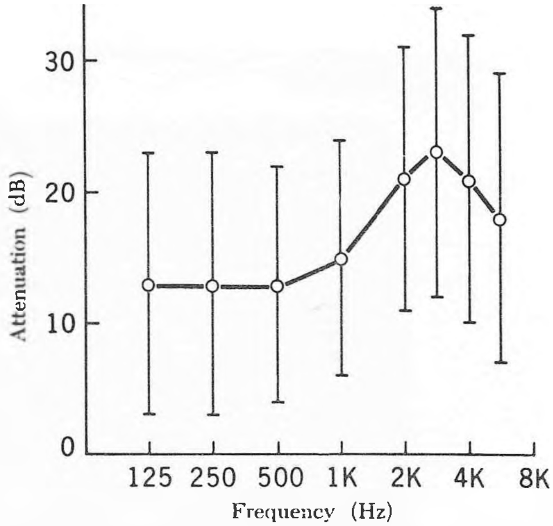

Fig. 4. Average attenuation for 102 plugs (mean ± 1 S.D.).

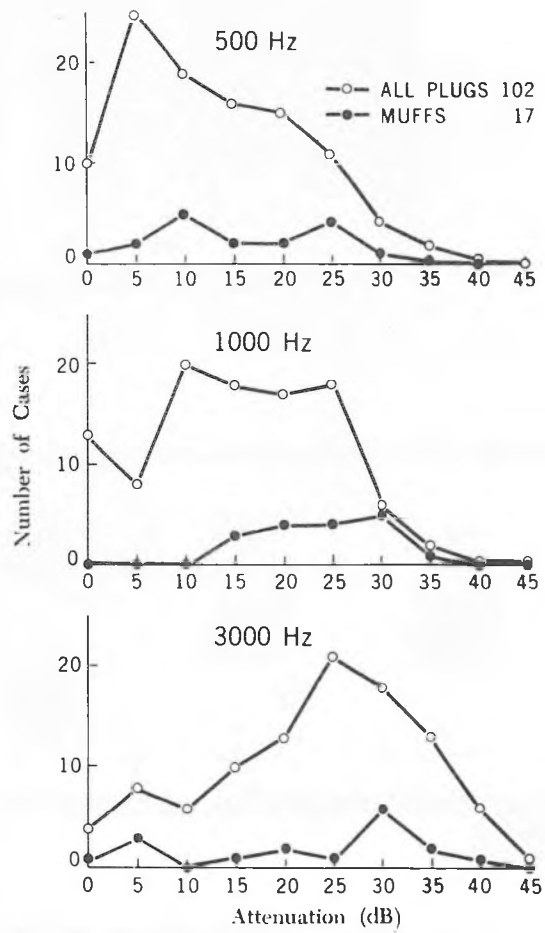

Fig. 5. Distributions of attenuation score.

cover a broad range. At 1,000 Hz half the plugs but 82 per cent of muffs provide 20-35 dB of attenuation, but at 3,000 Hz the distribution of the two groups is similar.

The degree of relationship between the amount of hearing loss and the attenuation scores was investigated. Using these two measures for each subject, correlation coefficients were computed for each type of protector at each frequency. Only two cases were significant at the .05 level. At 125 and 250 Hz with a custom plug, the attenuation score decreased as the free-field hearing threshold increased.

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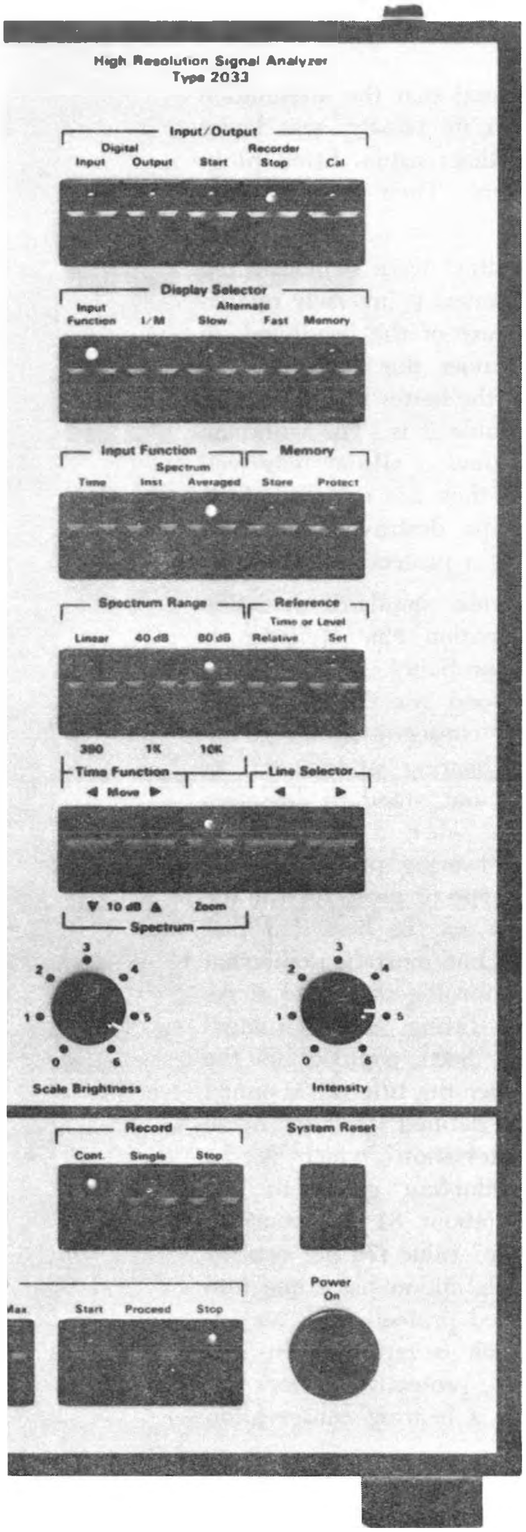

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DISCUSSION

The mean attenuation figures found in this study were lower than the figures generally accepted for both plugs and muffs. This is a reflection of the difference between optimum laboratory methods and real life practice. Our own observations suggest that the poor low frequency attenuation of earmuffs could be accounted for by long hair, inadequate pressure from springs, poor seals between the muff and the head; leaks between the temple of eye glasses, the muff and the head, and poorly maintained muffs. For plugs some idiosyncrasies were noted in fitting related to size of ear canal and the technique for inserting them, including inadequate insertion of the plug into the ear canal and inadequate holding in of sponge plugs while they expand. Nevertheless the plugs protected as well as the muffs, and thus, in this sample at least, belie the belief that muffs are a more effective method of hearing protection in real life than plugs.

Custom molded plugs have had a considerable vogue. They are attractive to those initiating hearing conservation programs. Their use demonstrates interest in the individual worker, by provision of a specific customized device; although they are more expensive than most plugs they theoretically last a considerable period of time and thus in the long run are cheaper than many disposable plugs and they cost less than most muffs. At their best they are excellent, but they are difficult to fit exactly and the fitting is critical. Some of the plugs we saw had been tampered with by the workman to make them more comfortable, thereby destroying their seal, in others the external coating had worn off, some were actually cracked. In this group of workmen, they did not stand up to use as well as any of the other devices tested. In practice we are not alone in criticizing the attenuation which they provide[7]. Our findings in general are similar to those of Regan[12], and Edwards *et al*[13], who also found that the attenuation of hearing protectors in industry was lower than expected and that custom fitted plugs gave least attenuation. Their samples were however, small.

Flugrath and Wolfe[14] have demonstrated that earmuff effectiveness is inversely related to weight and pressure of the headband, in other words the heavier the muff and the tighter the spring – the better its attenuation but the less comfortable it is. The workmen having to use these devices all day may well adjust them so that they are more comfortable, thereby perhaps destroying some of their effectiveness as a protective device.

The extremely wide standard deviation found in the attenuation characteristics is disappointing but probably realistic, and gives considerable food for thought about programs of hearing conservation based entirely on personal hearing protectors. As Martin[10] has pointed out, standard deviation is important because when dealing with a total workforce the hearing protection provided by a specific type of protector for the population at risk is not the best that that device can produce, but must be somewhat less than the mean for the device to make allowance for poor fitting and individual variation. This has been codified in the United Kingdom under the title of "assumed protection" which is defined[15] as the "mean minus 1 standard deviation" which is the minimum sound reduction given to the "majority of users" (about 84 per cent) or as the "lower quartile" value (75 per cent of users). The former definition has come into general use. "Assumed protection" is an important concept which is rarely taken into account when specific protective devices are being considered for a hearing conservation program.

Thus in this study the mean attenuation of 102 plugs is at all frequencies better than 12 dB and in the higher frequencies 20 dB, whereas the mean minus 1 standard deviation

— the *assumed protection* — is no more than 5 dB up to 1 kHz, and at the best frequency of 3 kHz is only 12 dB. Certainly in this study we have found a large gap between the theoretical attenuation which hearing protectors should be able to provide under optimum conditions, and the practical protection provided by the devices as worn by workmen. This outlines the need for considerable education of safety personnel and workers in how to fit and how to take care of protective devices. It also suggests that those responsible for applying hearing conservation programs must be realistic in suggesting the potential protection that can be expected from a program based upon personal hearing protection.

ACKNOWLEDGMENT

Thanks are due to the 88 workmen who cooperated in this study, to Drs. Margaret Hayley and R. Thakur of the WCBO for their cooperation, and to the staff of the Division of Audiology for undertaking the tests.

Résumé. Une étude de l'atténuation sonore fut effectuée sur les protecteurs d'oreilles employés par une série d'ouvriers réclamant de dommage auditif causé par un traumatisme acoustique industriel. Les cache-oreilles et les bouchons produisent la même atténuation des hautes fréquences mais les caches-oreilles atténuent moins les basses fréquences. Dans tous les cas, l'atténuation moyenne était moins bonne que le suggère la littérature. Les bouchons moulés étaient moins efficaces que les autres bouchons. Nous avons discuté des raisons qui expliquent les piètres performances de ces divers appareils et le concept de la protection assumée: la moyenne moins une déviation standarde. Il est nécessaire de bien démontrer comment employer les protecteurs pour qu'ils soient vraiment efficaces.

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MODEL STUDY OF DOUBLE TRAFFIC NOISE BARRIERS

by

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ABSTRACT

This paper investigates double barriers using a scale modelling technique.

SOMMAIRE

Cet article est une étude sur l'attenuation de bruit du trafic par des écrans doubles realisée à l'aide d'un modèle réduit.

Introduction

Each year, governments spend literally millions of dollars on building highway noise barriers. As a result, much research has concerned attempts to achieve the highest overall barrier performance at the least cost. Barriers of various shapes and materials have been tested. This paper examines the performance of double barriers and compares them to conventional single barriers used commonly on highways.

Method

It was decided to investigate double barriers using a scale modelling technique that uses tone bursts as a source signal and a gating unit to eliminate unwanted reflections (1). Variable frequency tone burst signals were produced using an oscillator, tone burst generator, power amplifier and high frequency loudspeaker. The loudspeaker which had been modified to approximate a point source was used over a range from 2 to 20 KHz. On the receiving side, the signal from a 1/4 inch microphone was amplified, high-pass filtered, and fed to the gating unit. The gating unit was used to eliminate undesirable reflections such as those sounds reflected off the laboratory ceiling and other objects. The signal present when the gate was open was integrated and fed to a level recorder. As the level recorder and oscillator moved in synchronization, continuous frequency response curves were plotted automatically. The technique allows one to evaluate the attenuation due to model barriers as a function of frequency in an ordinary room and to accurately include the effects of the ground surface.

FIG.1 10' APART DOUBLE BARRIERS

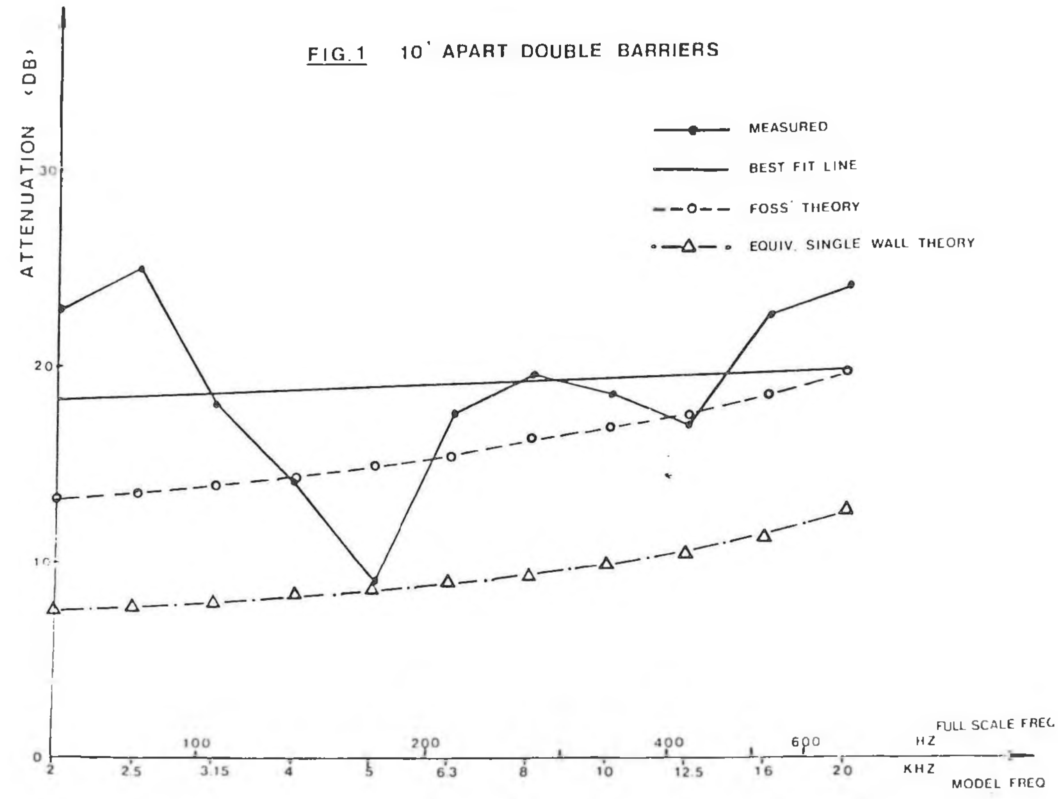
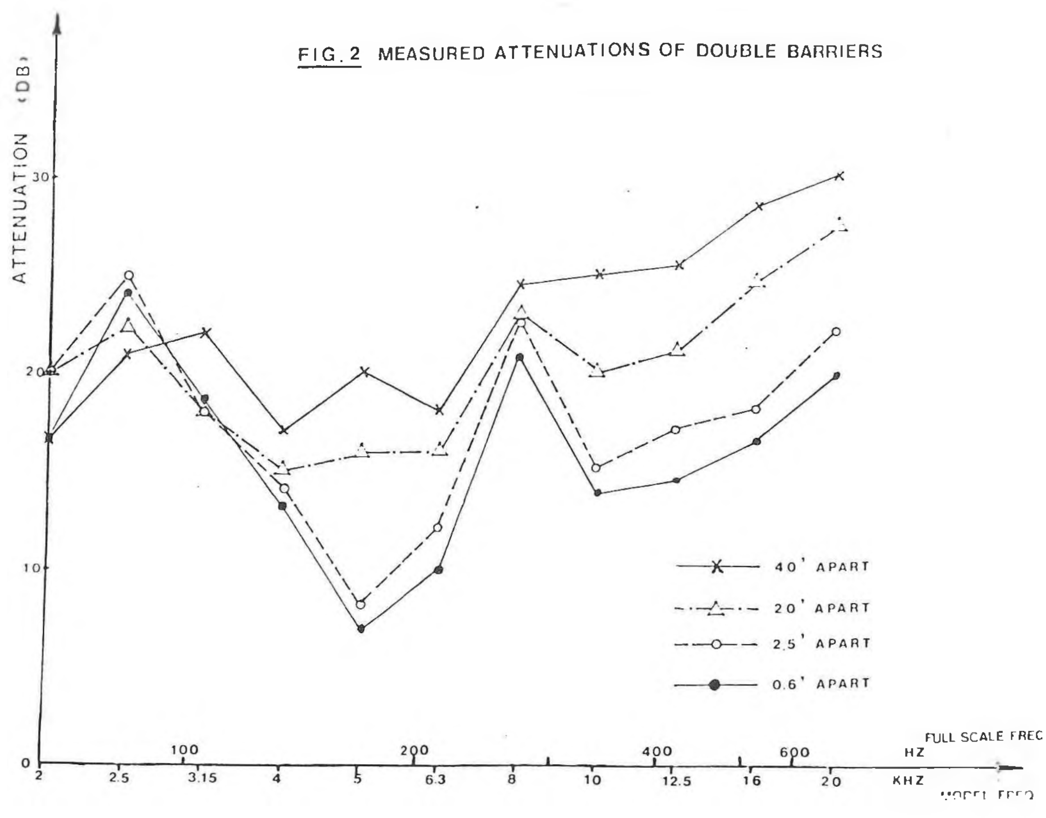


FIG. 2 MEASURED ATTENUATIONS OF DOUBLE BARRIERS



The model used a scale of 1:30. The position of the microphone and the source were fixed on each side of the barriers with 40 inches in between, which is equivalent to 100 feet in full scale. (Unless otherwise specified, all measurements refer to the full scale case.) The source and receiver heights were each 10 feet. The distance between the source and the first barrier was kept constant at 50 feet. Only the second barrier was moved so that barrier separations of 0.6, 2.5, 10, 20 and 40 feet were measured. The barrier was assumed to be infinitely long and the ground was assumed to be perfectly reflective. Any sound that travelled around the two ends of the barriers was eliminated by the gating unit. The height of the barrier was 15 feet. The frequency of the sound source varied from 67 Hz to 667 Hz (corresponding to 2 KHz to 20 KHz at model frequencies), thereby covering a critical but limited portion of the real-life frequency spectrum.

Double Barrier Prediction Techniques

In the past, as a very simple approach, an equivalent single wall theory has been used to predict double barrier performance based on work by Maekawa (2). This theory predicts that the combined attenuative effect of the two walls is equivalent to the effect of a hypothetical single wall located between the barriers, to the point of intersection of lines from the source and receiver to the top of each barrier. This method has been widely used but not thoroughly validated. Recently, Foss (2) found that the equivalent single wall method consistently underpredicts the amount of attenuation and came up with another approach. Foss calculated the diffractive attenuation caused by the first wall as if the other wall were not present. Similarly, he calculated the attenuation caused by the second wall as if it is by itself. The larger attenuation between the two was chosen and denoted as F. Then, he imagined a source located at the top of the first wall, and used this source to calculate an attenuation J. The sum F + J represents the actual attenuation due to the two walls. Both of these methods have been developed for free space and ignore the effects of ground reflections. Work at NRC by Isei et al (3) has clearly demonstrated that outdoor sound propagation over barriers depends on the complex interference of direct and ground reflected waves. The present work examines the attenuation of the double barriers including the ground reflections and compares the results with the previous two prediction methods.

Results

For a single barrier, in addition to the direct path over the barrier, there are three other possible ground reflected paths. Obviously, the combination of these different paths will create interference effects. By considering only the principal interference frequencies of the three paths, it can be calculated that there will be destructive interference at 167 Hz and 333 Hz if the source and receiver are 100 feet apart and the barrier is 91 feet away from the source. The calculated frequencies were confirmed by the measured results shown by the single barrier curve in Figure 4. It can be seen from this figure that the peak attenuation at the destructive interference peak is almost 20 dB above the constructive interference point. This is a considerable difference. It is clear that a simple smooth curve prediction of these measured results would not be a good representation.

Now, let us look at the double barriers case. There are then 8 different paths between source and receiver, and the situation is more complicated. It is not at all easy to predict theoretically the total amount of attenuation when ground reflected sound paths are included.

FIG. 3 COMPARISON OF MEASURED AND PREDICTED RESULTS

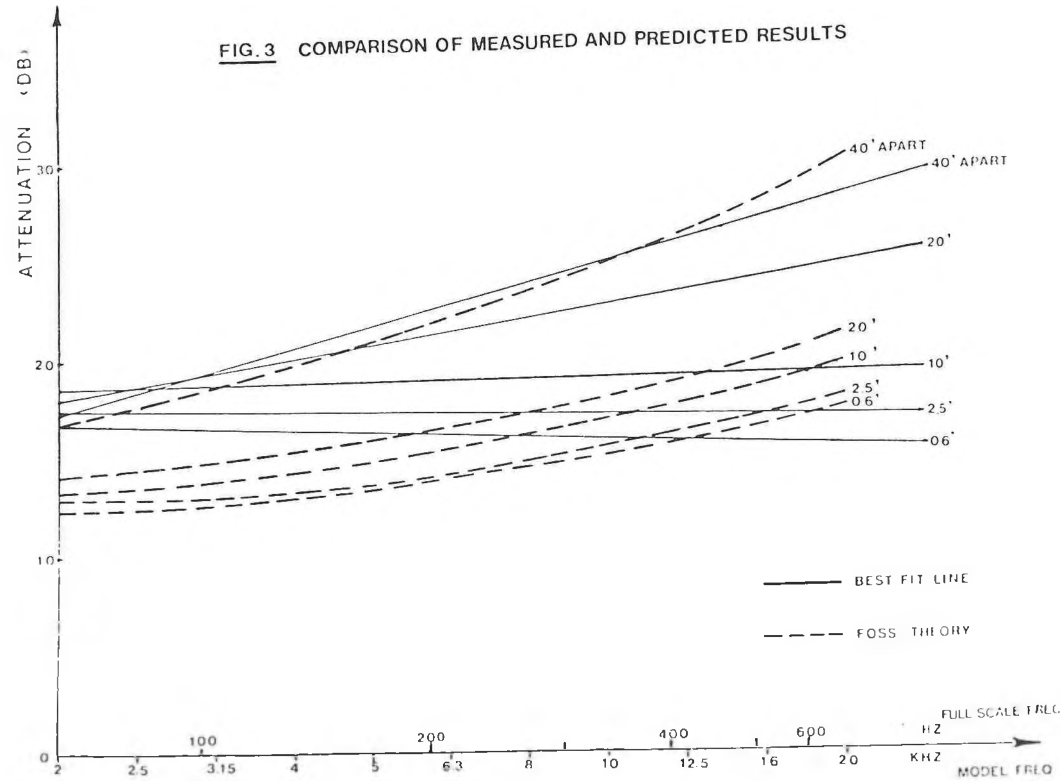
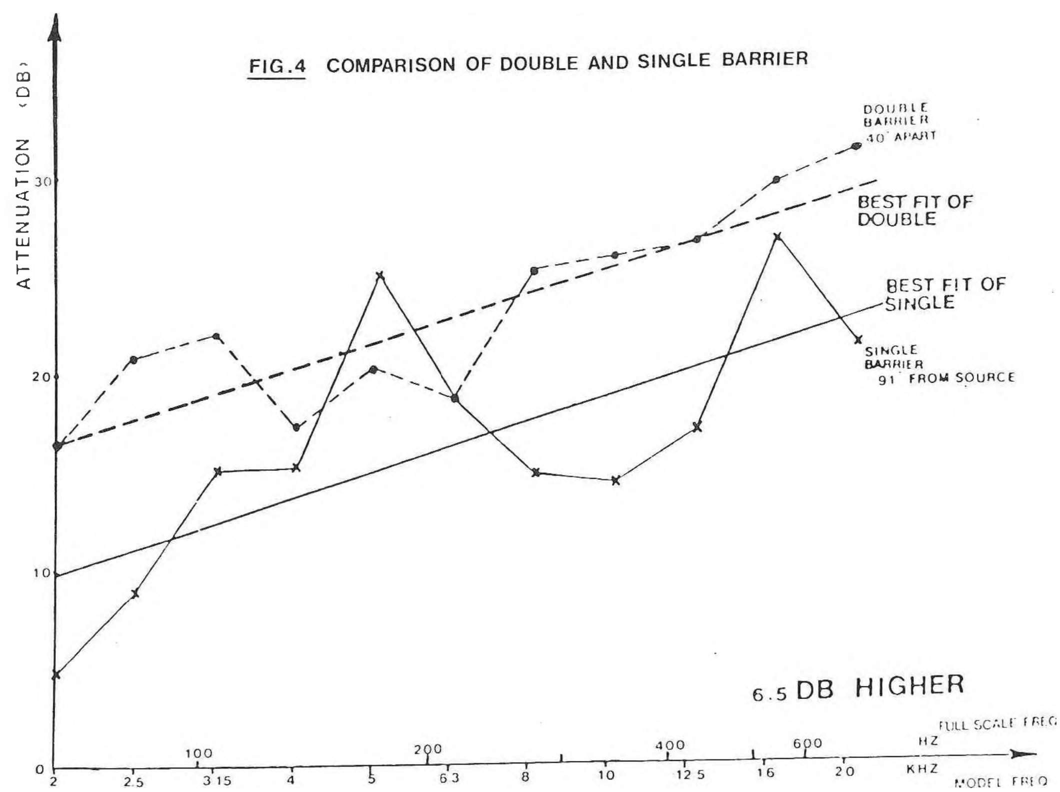


FIG. 4 COMPARISON OF DOUBLE AND SINGLE BARRIER



The first double barrier results are given in Figure 1, which is a plot of attenuation versus frequency for a 10 foot separation between barriers. The peaks and dips occurring at various frequencies are due to the interference among the different sound paths. Also shown are the predictions of Foss and of equivalent single wall theory which both ignore the ground effects completely. In order to consider the overall trends as the barrier spacing was varied, a best fit straight line of the measured results was obtained for each case. For this case, it shows an average of around 3 dB more attenuation than Foss's theoretical prediction. The equivalent single wall method predicted attenuations of about 6 dB less than Foss's method at all frequencies. This shows that the use of the equivalent single wall theory to predict double wall attenuations considerably underestimates their effectiveness.

Similar results were also obtained for double barriers spaced 0.6, 2.5, 20 and 40 feet apart. Figure 2 gives the measured attenuations versus frequency for those four barrier spacings. Figure 3 compares the best fit straight lines to the measured values of Figure 2 and the predictions of Foss's method. The best agreement between measured attenuations and predictions using Foss's technique occurred for the largest barrier spacing. The effectiveness of the double barriers is seen to increase as the separation between the two barriers increased. This increased effectiveness can be seen by comparing measured attenuations for a double barrier with those for a single barrier. Figure 4 compares measured attenuations for the double barriers with a 40 foot spacing with attenuations for a single barrier of the same height at the location of the most effective member of the double barrier pair. The double barriers attenuated more than the single barrier at all frequencies except at 167 Hz. By comparing the two best fit lines, the double barriers are about 6.5 dB higher than the single barrier. The single barrier would have to approximately double its height to give 6.5 dB more attenuation, which would presumably be much more expensive than a second barrier of the same height.

A block barrier was built by putting one more piece of barrier on top of the double barriers to give an outline shape like a building. The attenuations were measured for the block barrier and as illustrated in Figure 5, it shows similar performance to a double barrier. It seems that the building type barrier performs like a double barrier and is thus more effective than would be expected by the equivalent single wall prediction method.

A "T" cross-section barrier was also built by putting one more piece on top of a single barrier. Such a configuration has been found to produce 6.5 dB more attenuation than a similar single barrier (4). The result obtained in this study, as seen in Figure 6, shows that this barrier was not much better than a single barrier. It is possible that a thinner top piece would have produced improved results, but further studies of their effectiveness should be considered.

Conclusions

As a result of this work, several conclusions can be made:

1. It is essential to include ground reflections when predicting the attenuation of barriers.

2. In some cases, double barriers may be more econimical and provide better performance than a single barrier. They have not been considered seriously in the past because the commonly used single equivalent wall prediction method underestimated their performance.

FIG. 5 COMPARISON OF DOUBLE AND BLOCK BARRIER

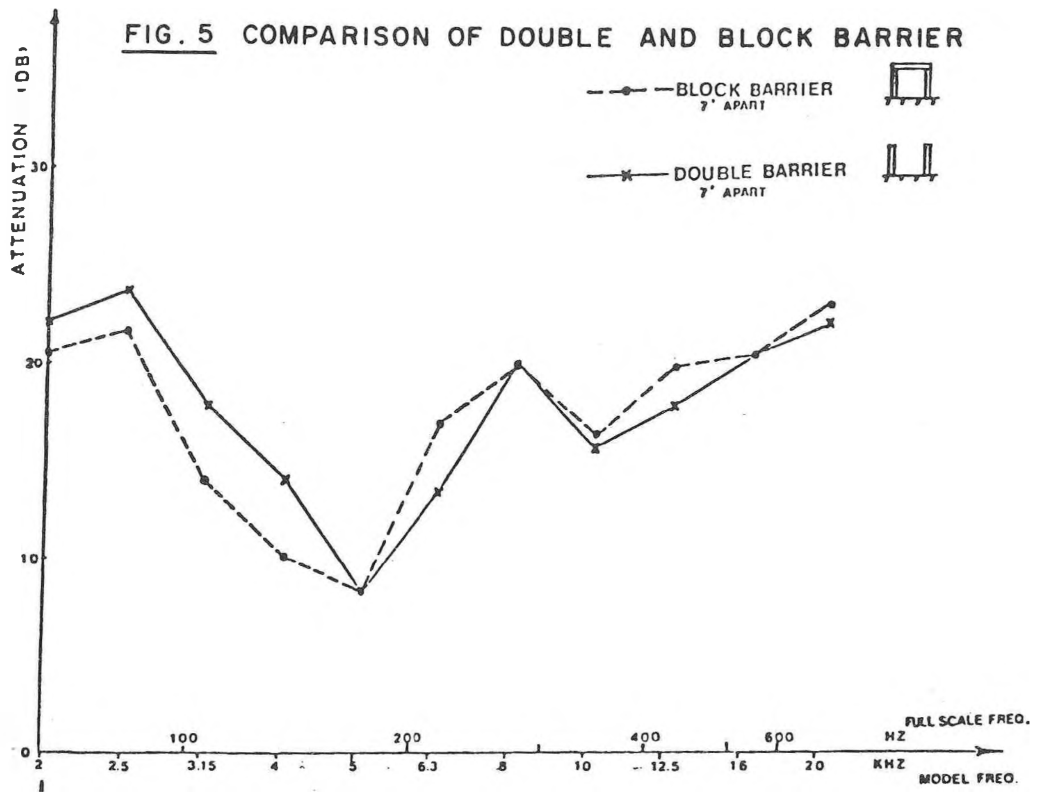
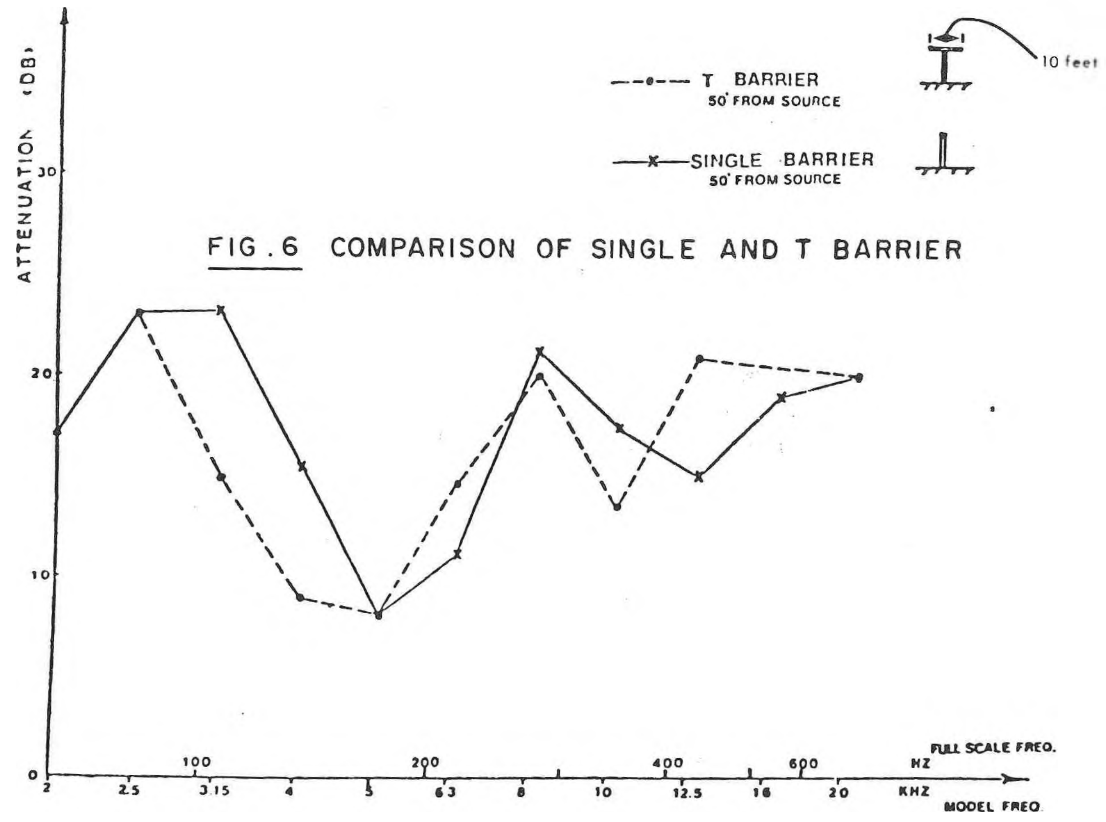


FIG. 6 COMPARISON OF SINGLE AND T BARRIER



3. Foss's theory gave better predictions of the double barrier attenuations than did the equivalent single wall theory.

4. The average performance of double barriers, with the ground effect, increases as the distance between them increases.

Acknowledgement

All the experimental work was done under the supervision of Dr. J.S. Bradley in the Sound and Vibration Laboratory at The University of Western Ontario. I would like to express my gratitude to Dr. J.S. Bradley for his guidance and advice.

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CANADIAN ACOUSTICAL ASSOCIATION
ANNUAL MEETING MONTREAL
OCTOBER 22 - 24, 1980

SUMMARY OF SESSION ON MEASUREMENT AND PROTECTION OF HEARING IN INDUSTRY

Thursday a.m., November 23rd, 1980

Chairman: A.Behar

Seven papers were presented in this session. Abstracts for the first six of these are as follows: --

COMPUTERIZED AUDIOMETERS FOR INDUSTRIAL AUDIOMETRY

by

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Current and proposed legislation specify that for compliance purposes, a minimally effective Occupational Hearing Conservation Program consists in part, of the following.

1. A baseline audiogram for all employees exposed to noise levels equal to or in excess of the standard.

2. Periodic audiograms for each overexposed employee.

3. Analysis of audiogram's with retesting and/or referral to an Otolaryngologist or qualified physician when a significant threshold shift occurs.

These requirements provide a clue to the enormous amount of data generated by the audiometric component of a hearing conservation program. The task becomes gargantuan if manual techniques are used to: test a large number of employees each day, generate written records for each test, separately analyze each test result and produce the necessary report. The purpose of this paper is to present an electronic data processing approach designed to facilitate analysis of audiometric data obtained from a hearing conservation program.

ATTENUATION OF HEARING PROTECTORS AND THE NRR

by

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The Noise Reduction Rating (NRR) was adopted by the Environmental Protection Agency (USA) in September, 1979, as a single number to assess noise attenuation of hearing protectors. By substracting the NRR value from an existing noise level the result is supposed to be the dBA level of 98% of the protected population. This is a fast method to be used instead of the so-called "long" method recommended by OSHA. Another advantage of the NRR is that it avoids the need of an octave band measurement of the existing noise, by simply measuring the dBC level. (That of course, requires the use of a SLM with the dBC weighting network.)

This paper compares dBA levels of the protected ear as obtained by using both the NRR and the "long" methods.

Six different type of noises were used, three artificial and three existing. They all were "applied" to six hearing protectors: two muffs, three plugs and one semi-insert.

The results can be summarized as follows:

a) dBA levels obtained by using the NRR are always higher than by using the "long" method.

b) This difference changes with the type of protector as well as with the spectrum of the particular noise.

Although the mean value of those differences was 3.5 dBA, individual differences were found to be as high as 9.0 dBA.

Because of the better protection obtained by using the NRR and of the simplicity of its use, its application for industrial hearing conservation programs is strongly recommended.

SPEECH INTELLIGIBILITY IN NOISE WITH EAR PROTECTORS

Sharon M. Abel, Ph.D.;
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Caroline Haythornthwaite, B.Sc., M.A.; and
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This research investigated the effect of ear protectors on the intelligibility of speech in noise. The listeners were adults, 35-65 years old, with normal hearing, bilateral high frequency or flat loss between 500 and 4000 Hz. Half the subjects were fluent in English and half had learned English as a second language and were poorly conversant. Taped lists of 25 words were presented free field under a variety of conditions in which the signal-to-noise ratio (+5 and -5 dB), the spectrum of the background noise (white versus crowd), and the presence of ear protection were varied.

The data indicated that in normal listeners the number of words correctly repeated decreased as the signal-to-noise ratio decreased and that speech perception was poorer in noise than in quiet. For no combination of noise background and amplitude of speech did the protector have an effect on intelligibility. In marked contrast, subjects with either a noise-induced, high frequency or flat loss showed a substantial protector effect. For all hearing categories, non-fluency with the English language contributed an additional decrement of 15 to 20 percent, but this was independent of the particular conditions for listening. Significant differences in performance were noted for different muff and plug types.

AGE-EFFECT CORRECTIONS IN IDENTIFICATION AUDIOMETRY AMONG NOISE EXPOSED WORKERS

by

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An epidemiological procedure for the classification of results from screening audiometry among noise exposed workers is proposed. It relies essentially on (a) the identification of the workers suffering from a hearing loss of an extra-occupational origin and (b) the estimation of the proportion of workers showing noise-induced hearing losses greater than that attributable to age-effect in at least 90 per cent of the population. Available age-effect data will be discussed

in terms of the sensitivity and specificity of the classification procedure as it is applied to an industrial population.

THE ACCURATE QUANTIFICATION OF INDUSTRIAL HEARING LOSS

by

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Industrial hearing loss in Canada is compensated on rating scales based on puretone audiometry. Accurate puretone quantification of hearing loss is therefore a matter of significant interest of Workmen's Compensation Boards. A number of factors, however, exist which can contribute to audiometric error: inherent variability in psychoacoustic test, instrument calibration errors, test environment errors, technical errors in administering the audiogram and a variety of patient factors including learning, fatigue and deliberate exaggeration can all affect audiometric test results. This paper will discuss clinical techniques used to accurately quantify industrial hearing loss and some of the audiometric findings in a large group of workmen seen for the Workmen's Compensation Board of Ontario.

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*** Professor of Otolaryngology, University of Toronto. Otolaryngologist-in-Chief, Mount Sinai Hospital, Toronto.

THE AUDIOMETRIC TEST PROGRAM AT INCO METALS COMPANY

by

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The Ontario Division of INCO Metals Company commenced implementing a formal hearing conservation program for its employees in 1965. The audiometric test program for all employees has been an integral and important part of this program since its inception. It includes an annual screening survey with open discussion of test results with individual employees. Employees who are found to have problems are interviewed and may be given further tests which include impedance and speech discrimination. Those employees requiring diagnostic service and treatment are referred to appropriate medical authorities including a consulting otolaryngologist.

This paper describes INCO's audiometric test program and provides an assessment of its results.

(Continued on page 52)

AN IMPROVED TRANSDUCER MOUNT FOR GROUND VIBRATION MEASUREMENTS

Mohan Barman, M.A.Sc., P.Eng.
John E. Coulter, B.A.Sc., P.Eng.

BARMAN COULTER SWALLOW ASSOCIATES, REXDALE, ONTARIO

1.0 INTRODUCTION

Standardization of soil vibration measurement has been an area of very limited consideration up until the last decade or so. To date measurement methodology has only been partially documented. The current demand for land in built up areas has led to building construction near, and on top of rail transportation corridors, and caused sufficient difficulties to demonstrate a requirement for reliable vibration measurement methods.

This paper discusses transducer mounting methods for obtaining accurate soil vibration measurement. Proposed, is an inexpensive system believed to offer considerable advantage over current practices.

2.0 COUPLING TO THE SOIL

It would be best to have a soil vibration transducer package which is homogeneous with the soil, thus not affecting the soil's motion. This is achievable only by matching the mechanical properties of the transducer system to the soil's bulk mechanical characteristics. Table #1 shows the pertinent mechanical properties of soil and several candidate materials from which a mount might be constructed. Matching the soil bulk characteristics is nearly impossible since:

a) most potential mounting materials are much stiffer than the soil

b) the range of Shear modulus of soils is approximately one decade. A different mount would be necessary for each type of soil.

Note that clay in particular has a range of properties varying from soft mud to soft rock. Testing noted later in this paper demonstrates this variability by showing a 2:1 change in transducer mounting resonant frequency from hard to soft clay.

Work partially carried out while in the employ of Vibron Limited

TABLE 1

Bulk characteristics of soil and possible mount material.

MATERIAL	SHEAR MODULUS (psi)	DENSITY (lb'/ft^3)
CLAY & SAND	3,000 - 20,000	100 - 120
DENSE GRAVEL	15,000 - 40,000	120
STEEL	11×10^6	487
ALUMINUM	3.8×10^6	170
WOOD	$0.30 \times 10^6 - 0.55 \times 10^6$	40 - 60
PLASTER OF PARIS	$0.08 \times 10^6 - 0.24 \times 10^6$	50 - 80

TABLE 2

Likely usable Frequency range of various Mounting Methods in soft soils (assumes worst-case soils which might reasonably be tested) (assumes plates and stakes are optimized in size to transducer mass, and careful soil preparation and installation)

	VERTICAL Hz	HORIZONTAL Hz
FLAT LIGHT, STIFF PLATE ON WELL PREPARED SOIL	0 - 300	0 - 300
TRANSDUCER ALONE BURIED IN SOIL	0 - 20	0 - 20
18" STEEL STAKE DRIVEN 14" INTO SOIL	0 - 100	0 - 25
EMBEDDED 1' CUBE OF PLASTER OF PARIS	0 - 70	0 - 70

Any practical mount is likely to be made from a stiff material and will act as a rigid body at frequencies below internal resonance. The mounting system will couple to the distributed mass and stiffness of the soil resulting in a 6 degree of freedom system with 6 potential resonant motions. If the device is symmetrical in the horizontal plane, two of the rocking modes will be identical as will be the two horizontal modes. The effects of the twisting mode about the vertical axis, (although the mode is unlikely to be excited) can be minimized by mounting horizontal transducers on or near the axis of rotation. This leaves the vertical mode, 2 identical horizontal modes and 2 identical rocking modes to be considered.

The problems have been analyzed and demonstrated by Morita and Omata (Ref. 1 & 2).

Figure 1A shows an embedded mounting system and it's simplified mechanical model (Ref. 3 & 4). A plate on top of the soil would be modelled similarly but without the coupled stiffness and mass associated with the embedded sides.

Figure 1B shows a driven stake and its model. Of particular note here is the large moment of inertia in the rocking mode and the attachment to the soil below the centre of gravity. This results in an easily excited rocking mode. On several occasions the writer has observed this mode to be in the 30-60 Hz range. This mode makes horizontal measurements above 30 Hz questionable by this method.

We have attempted to draw together the experiences of other (ref. 1, 2, & 5), our own undocumented experiences from the past plus the extrapolation, based on references 3 and 4, of testing done for this paper. For the softest soils (ie lowest resonance) one is likely to measure, we have estimated in Table 2 the reliable upper frequency limit for each mounting system.

3.0 SUMMARY OF CURRENT MOUNTING METHODS

The present methods of mounting vibration transducers on soil include:

1. Placing the transducer package loosely on the ground.

FIG. 1A MOUNTING BLOCK METHOD

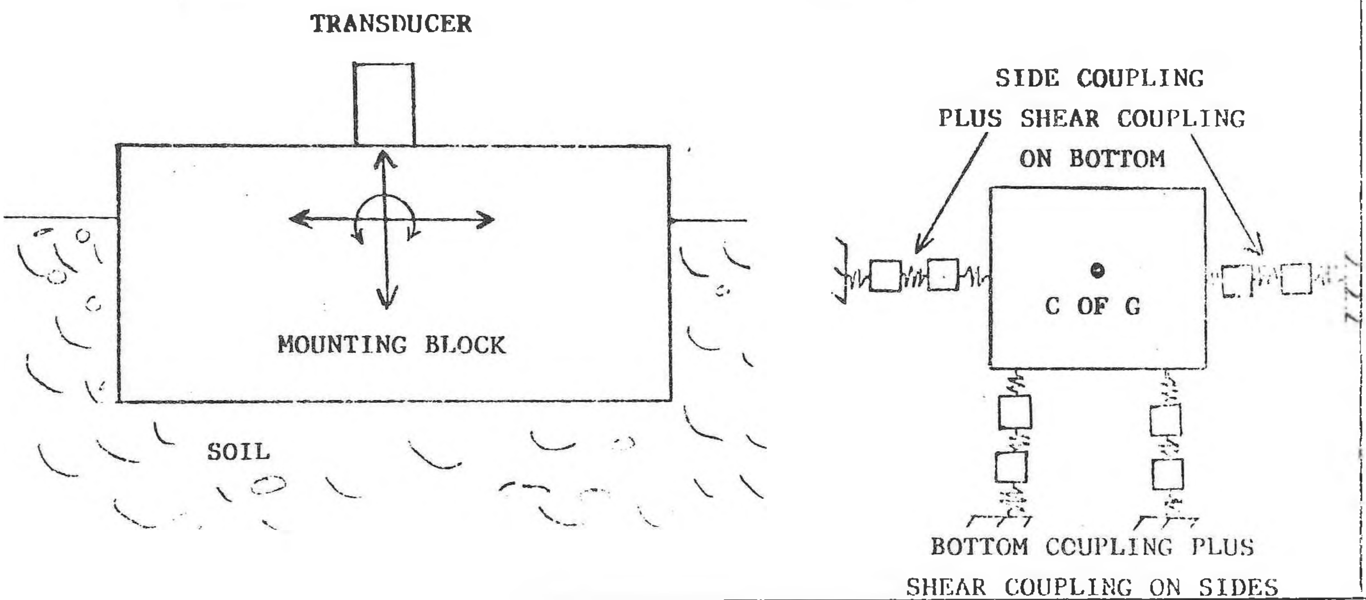
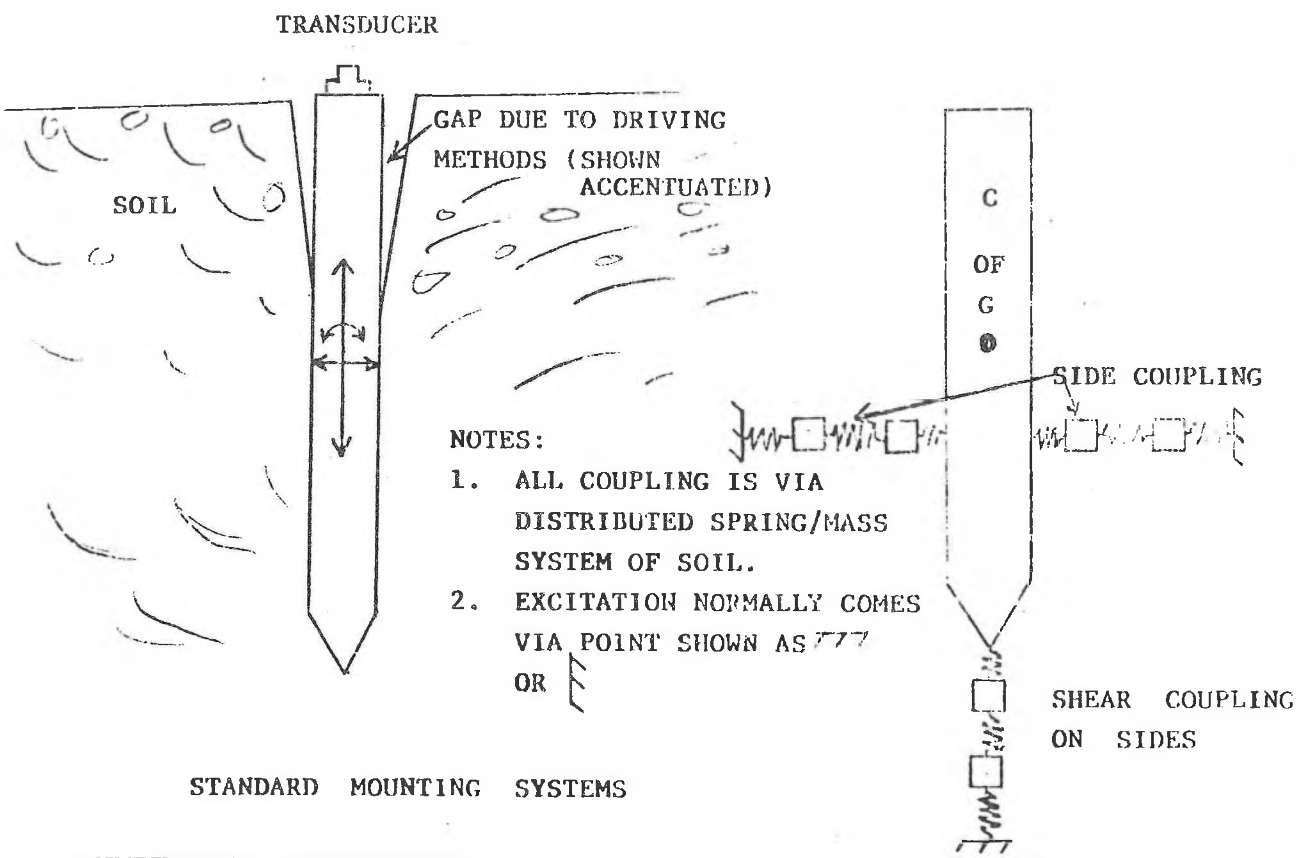


FIG. 1B DRIVEN STAKE METHOD



NOTES:

1. ALL COUPLING IS VIA DISTRIBUTED SPRING/MASS SYSTEM OF SOIL.
2. EXCITATION NORMALLY COMES VIA POINT SHOWN AS ⁄⁄⁄ OR ⁄⁄⁄

STANDARD MOUNTING SYSTEMS

2. Burying the package in the ground.

3. Driving a stake into the ground and mounting the transducer(s) on the stake.

4. Pouring a Plaster of Paris base and mounting the transducer(s) on the plaster.

METHOD #1 - placing the transducer directly on the soil.

This can work under the following conditions:

a) the transducer system must have a large contact area with the soil in comparison to its mass and to the height of its centre of gravity.

b) the base area of the transducer package must mate well with the soil surface and the soil must be undisturbed in the contact area.

If the ground can be properly prepared, this first method can be made to work, especially if a base plate is added to the transducer to increase the contact area. However, the data so collected remains in question because of the difficulty in ensuring good contact between the soil and base plate. In a poor installation the vertical resonance may fall in the 30-60 Hz range, the most critical area for most soil vibration problems.

METHOD #2 - to bury the device in the ground several inches below the surface.

Considering the amount of soil disturbance this method is of little advantage over placing the device on the surface as above.

METHOD #3 - driving a stake into the ground.

This is in effect mounting the transducer on relaxed tip pile. It is perhaps the most common mounting method at present. For an 18" deep stake weighing five pounds, we can expect a relatively underdamped vertical resonance between 100 and 250 Hz dependent upon soil type. This would be adequate for many types of work provided that the noise in the second octave band generated by the vibration in that frequency range was not considered to be a problem. The stake has horizontal resonances that experience has shown to be as low as 30 Hz.

METHOD #4 - using Plaster of Paris, to add a base to a transducer.

Unlike Method #1, the Plaster of Paris base guarantees good contact with the soil provided the soil is relatively root free and undisturbed.

The base lowers the centre of gravity, stiffens the rocking, horizontal and vertical modes while being of low density. Thus all resonant frequencies will be raised and both vertical and horizontal monitoring can be carried out up to 300 Hz if the base area is tailored to the total transducer mass. The thickness (or depth) of the plaster should be only that required to provide sufficient internal stiffness of the mounting pad since increasing depth usually increases mass faster than it increases the soil stiffness coupled to the mount. As a rule, the thicker the plate, the lower the mounting resonances. The main drawback to this method is its awkwardness and the time involved in preparation. It has also been found wanting in damp or cold soil conditions where the extra moisture can interfere with the plaster hardening process.

4.0 DEVELOPMENT OF A NEW MOUNT

A mounting system should meet the following criteria:

1. To be an improvement over a plate of Plaster of Paris it should be clean.
2. To keep the mounting system small, the transducer(s) should have low mass. Should the system be too large, it will become a significant fraction of a wave length in soft sandy soil (velocity 300-500 ft/sec, λ = 3'- 5' at 100 Hz) at the upper portion of the desired frequency range. The size should normally be kept less than 0.15 of the wave length at the highest frequency of interest.
3. To prevent rocking, the centre of gravity of the transducer/

mount system should be near the centre of the horizontal support.

4. The system should have a base with a relatively large area in proportion to the mass if resonances are to be kept above 200 Hz, the normal upper limit of most soil vibration measurements.

5. Mounting hardware should not have internal resonances which are in the frequency range of interest.

6. The coupling to undisturbed soil should be guaranteed.

7. The system should meet the proposed criteria of vibration measurement for ISO/TC 108/SC 2 Proposal 4866.

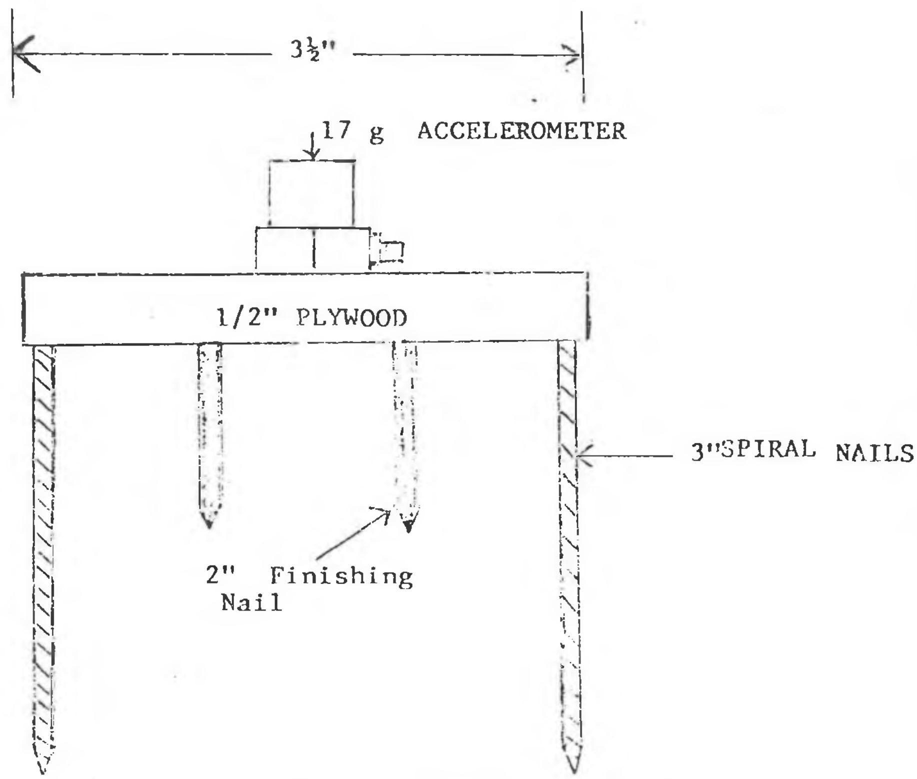
Taking the above in turn, the system should be an all mechanical one without chemicals and thus relatively clean. General purpose 20 gram accelerometers are likely to be the best choice as transducers because of their light weight, sensitivity down to levels below human perception, and ease of mounting. Where 100-200 Hz measurements are required, the accelerometers are inherently more sensitive than velocity type transducers. The centre of gravity will stay low provided the transducer is mounted immediately on a base and is small compared to the base. The base should be of a low density material to keep the resonant frequency of the system high. It should also be very stiff and well damped to control internal resonances.

The problem of guaranteed coupling to the soil must be addressed. The base could be made larger, but it becomes difficult to prepare a large area of flat soil surface on which to mount the device. For intimate contact, we can borrow the idea of the stake, placing thin piles along the edges of the base. The piles should be thin enough to allow them to be inserted iln the soil without disturbing the surface. To improve the coupling further, a second set of thinner, shorter piles may be added inside the first set. The piles guarantee contact with the undisturbed soil.
To meet the ISO/TC 108/ SC2 Proposal 4866, the system should meet the following formula:

$$\frac{Mo}{\rho Ro^3} < 2 \qquad (1)$$

where Mo is the detector systems mass
ρ is the mass density of the soil
Ro is the effective radius of contact with the soil

FIG. 2 TRANSDUCER MOUNTING SYSTEM



A mounting system was designed, and is shown in Figure 2. Plywood was used for the base plate, 3" spiral nails for the long piles, and 2" nails for the short piles. If magnetic mounting is to be used, a thin sheet of steel can be glued to the upper side of the plate. Because of the low mass of the transducer, the plate need only be $3\frac{1}{2}$" x $3\frac{1}{2}$" x $\frac{1}{2}$". For this system with a 20 gram accelerometer the ISO Formula (equation (1)) above yields the value 0.7, well within the criterion of < 2. The labour involved in making the mounting pad is no more than that needed to prepare a single Plaster of Paris measurement point. However, the mechanical mount is reusable. The end result, clearly, is exceedingly simple.

5.0 TESTING

To design and build a system turned out to be rather simple. In fact, had one asked a bright civil engineer how to design a high frequency foundation, he would give the solution of a capped pile grouping in short order.

Testing the system is another matter. As acousticians, we tend to test systems by comparing them with older ones that we have used in the past. Thus new equipment is compared to older, often less accurate methods. In this case we could try each of the mounting methods, comparing them to each other. If there are differences we then have to determine which system is correct. Generally, it is difficult to reliably excite the ground at frequencies above 60 Hz and below 20 Hz. Thus testing a measurement system's response by

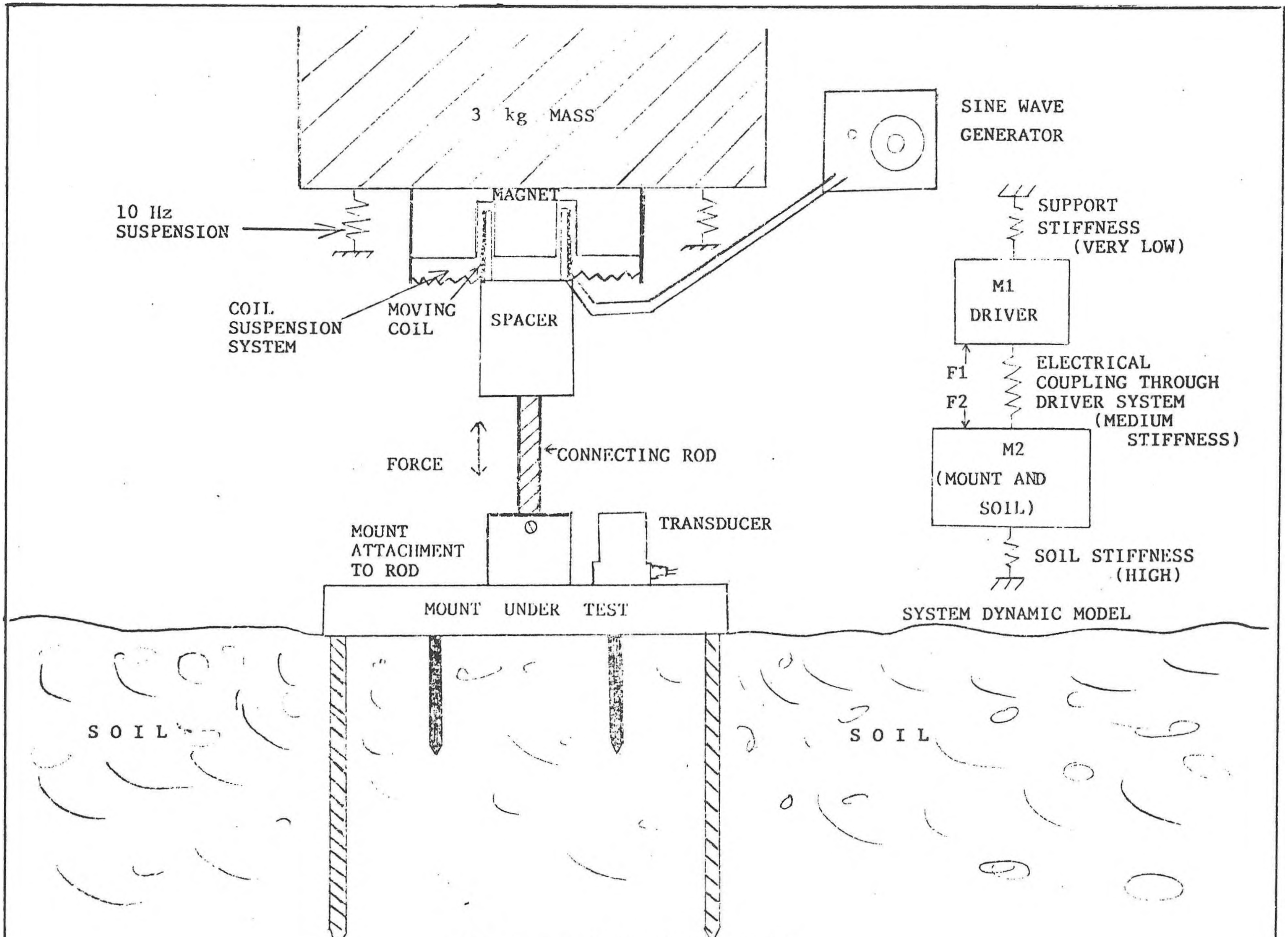


FIG. 3 - MOUNT TESTING SETUP

comparing it to other systems is difficult in controlled conditions. To date we have limited our testing to vertical measurements.

We chose to find the mount's characteristics by driving the mount rather than the soil. The mount was driven by a moving coil transducer derived from a speaker. Figure 3 shows a schematic of the test set up. Three types of soil were used; a well compacted clay soil undisturbed for 15 to 20 years, a very soft clay soil heavily disturbed several weeks before the test and a clay soil under a typical suburban lawn. The three soils represent a large range of soil types as far as shear modulus and density are concerned. Figure 4 shows the results of testing. The transducer mounting vertical resonance appears at about 600 Hz for the very soft soil (low soil stiffness) and 1000 to 1200 Hz for the harder soils. The driver resonance shown to the left of the graph is the result of the test mount stiffness being connected to the driver mass via the driver coil's electro-mechanical coupling. This coupling could be virtually eliminated if the driver amplifier were a constant current rather than a constant voltage device.

The reason for a large shift in driver resonant frequency from approximately 45 Hz to approximately 25 Hz was a change in the driver used. The two drivers had different coupling coefficients.

Calculations based on foundation design methods indicated that a vertical resonance could be expected near 1200 Hz in hard soil. They also indicate horizontal resonance at 1000 Hz and rocking resonance at 2000 Hz. The correspondence of the field data to calculations of the vertical characteristics gives confidence in the calculation methods. We are therefore reasonably assured that the mount is adequate for horizontal as well as vertical soil vibration measurements below 500 Hz.

6.0 TESTS FOR OTHER MOUNTING METHODS

For comparison, tests were carried out on a 18" stake and a 1' x 1' x 9" deep block of Plaster of Paris in a stiff clay soil, (See Figure 5). The stiff soil used resulted in higher natural frequencies than will normally be encountered. The results are shown in Figure 6. The block's and stake's characteristics indicate a relatively low resonant frequency. The Plaster of Paris system would be useful at higher frequencies if it is made as a thin plate.

7.0 FIELD APPLICATION

A few notes on the use of the mount might be helpful. We recommend that any disturbed soil or soil filled with grass roots be removed carefully. The mount should sit on flat undisturbed soil. Occasionally soil is found with hard crust on the surface. This crust can act somewhat independently of the soil beneath. In the extreme cases, the soil can be made up of several layers all acting somewhat independently.

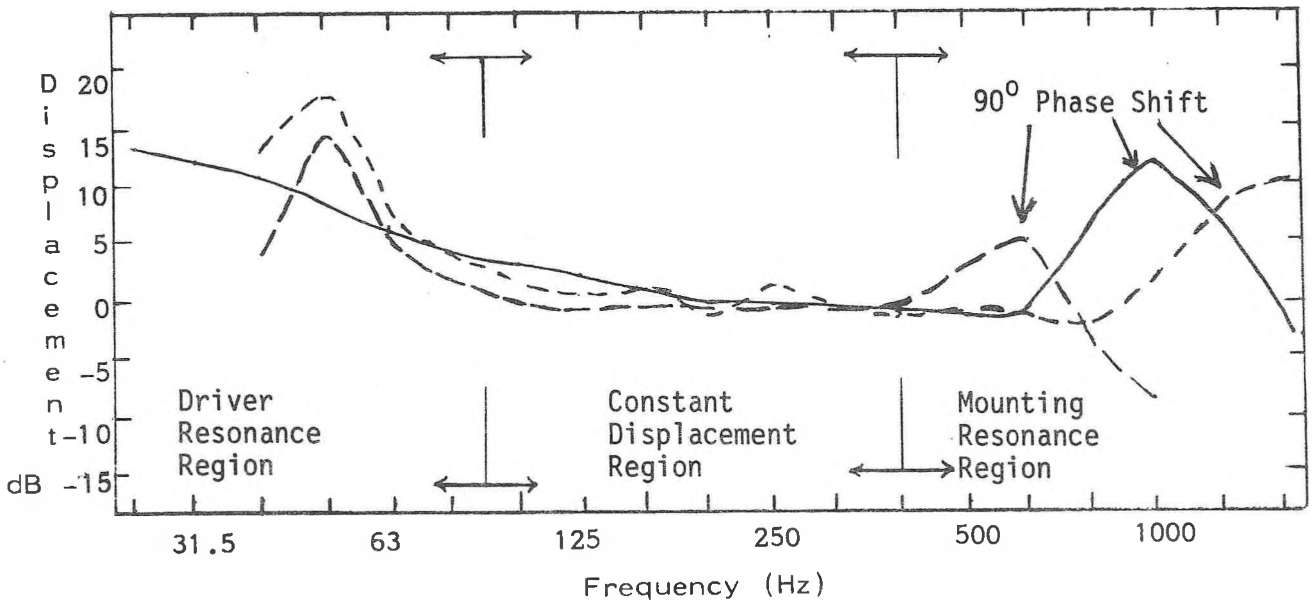


Fig. 4 VERTICLE DISPLACEMENT VS FREQ. FOR 3" x 3" PAD MOUNT

- Hard Packed Clay (G > 10000 psi)
- Very Soft Disturbed Clay Loam (G < 3000 psi)
- Typical Clay Loam Mix (G = 4000 - 8000 psi)

Note: All curves shifted vertically to an arbitrary 0dB reference to allow comparison of curve shapes.

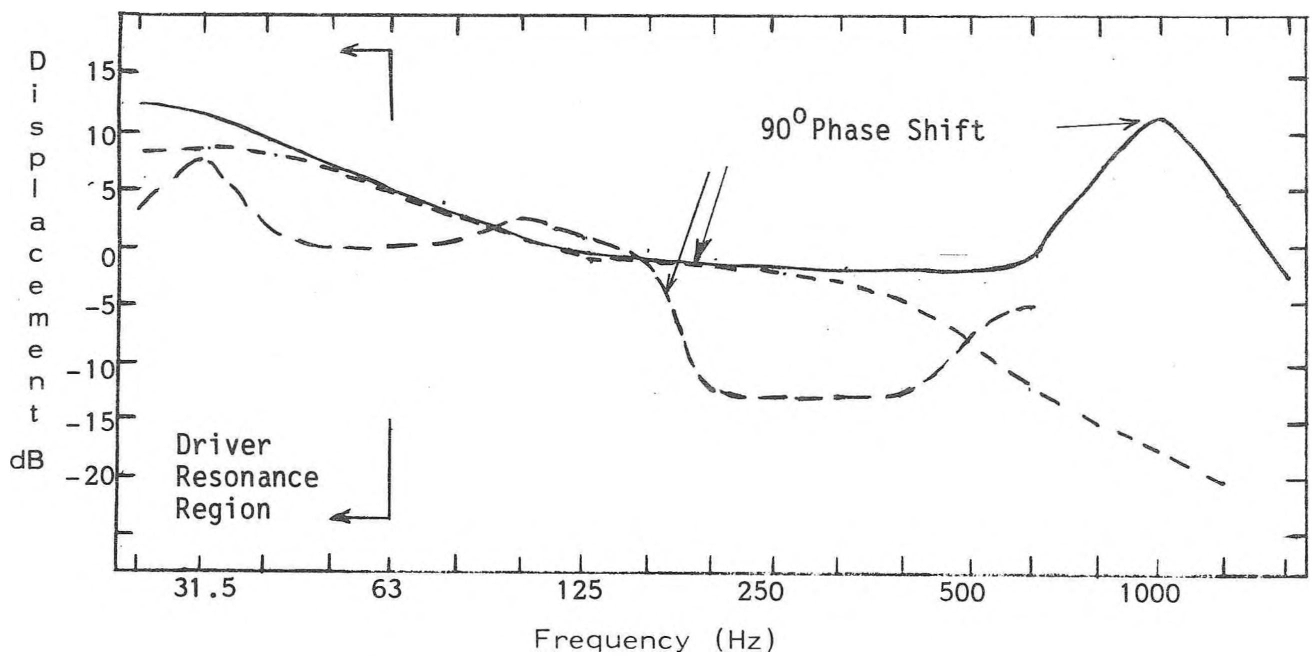


Fig. 6 COMPARISON OF TRANSDUCER MOUNTING SYSTEMS

- 1' x 1' x 9" Plaster Block
- 18" Steel Rod 1" Diameter
- 3" x 3" Pad Mount

Note: All curves shifted vertically to an arbitrary 0dB reference to allow comparison of curve shapes.

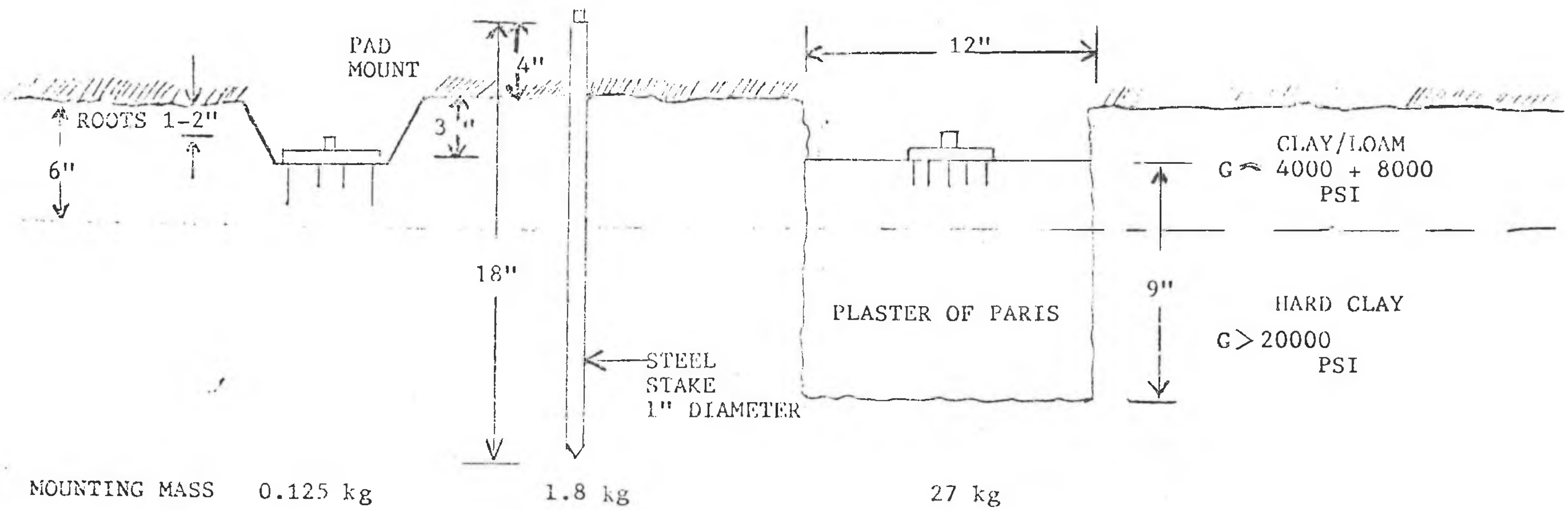


FIG. 5 - MOUNTING TEST CONDITIONS

In carrying out measurements, it is necessary to determine which layer should be monitored. The transducer mount should then be embedded in that layer.

To achieve highest horizontal and rocking frequencies, the mount should be pushed (preferably not hammered) straight down into the soil. This will minimize the disturbance of the soil in the area at the top of the spikes.

8.0 CONCLUSION

A simple, reliable method of mounting general purpose accelerometers on soil has been demonstrated. Its characteristics are such that for frequencies and vibration levels of importance to acousticians and vibration engineers, the device gives a proper coupling of the transducer to the soil immediately under it.

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(Continued from page 39)

The session was closed by Dr. E.A.G. Shaw (Acoustics, Division of Physics, NRC, Ottawa, Ontario, K1A 0R6), who spoke on "THE ACOUSTICAL PERFORMANCE OF HEARING PROTECTORS". In this paper the theoretical background of how a hearing protector works was presented. The author showed equivalent circuits of both muffs and plugs. Then he explained how their different mechanical characteristics can influence their final performance, which can never be better than the theoretical limit set by the bone conduction. He discussed some practical aspects such as the attenuation reduction due to the wearing of safety glasses. Finally future trends in new protectors such as using electronic negative feedback to reduce the noise were described.

In summary, thanks to the excellent papers presented, the session was lively, interesting, stimulating, and of practical benefit to the audience.

A. Behar

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