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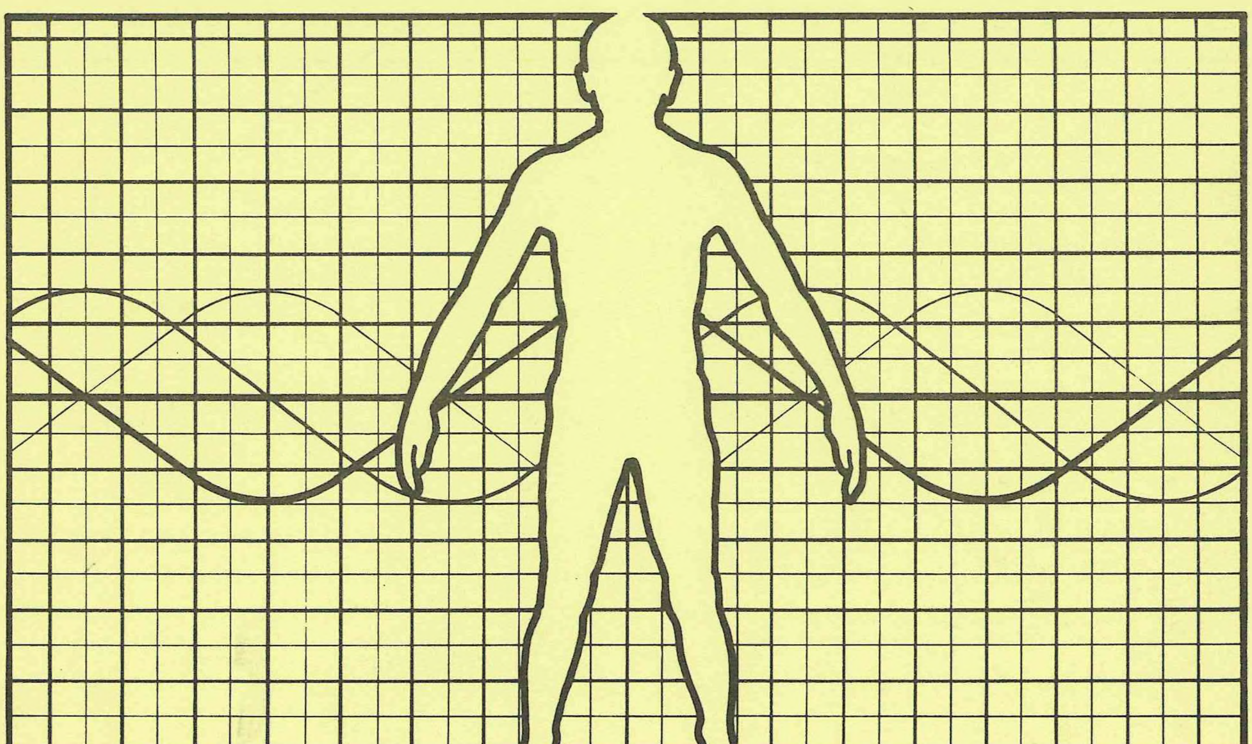

Simon Tuckett

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

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

EDITORIAL

Félicitations à M. L.J. Leggat pour avoir gagné le Prix des Directeurs de l'ACA, 1981. Une photo de lui se trouve à cette page. Le prix est offert une fois par an à un(e) jeune Canadien(ne), âgé(e) de moins de 35 ans, qui est nommé(e) comme premier auteur d'un article publié dans l'Acoustique Canadienne de la même année. M. L.J. Leggat a gagné ce prix pour son excellent article "LNG Carrier Underwater Noise Study for Baffin Bay", MM. L.J. Leggat, H.M. Merklinger, et J.L. Kennedy, vol. 9 (4), p. 31-51.

Vous trouverez également dans ce numéro des nouvelles sur le 11e CIA à Toronto en 1986. Nous espérons publier un rapport sur le prochain CIA à Paris, au mois de juillet 1983, dans le numéro à venir.

Finalement, nous vous invitons à soumettre vos sommaires pour la prochaine réunion annuelle de l'ACA à Vancouver (octobre 1983), avant les vacances d'été, pour permettre au Comité d'organisation de publier le programme dans le prochain numéro.

Nous vous souhaitons de très belles vacances, et nous espérons vous voir à Vancouver en automne.

EDITORIAL

Congratulations to L.J. Leggat, who is pictured in this issue being presented with the CAA Directors' Award, 1981. This award is given annually to a young Canadian (35 years or under), who has a paper published in CANADIAN ACOUSTICS in that year, and is first named author of the paper. L.J. Leggat gained this award with the excellent paper "LNG Carrier Underwater Noise Study for Baffin Bay", L.J. Leggat, H.M. Merklinger, J.L. Kennedy, Vol. 9(4), pp.31-51.

Also in this issue is an item on the progress of ICA Toronto 1986 activities. We hope to publish a report on ICA Paris 1983 in the next issue.

Finally we again urge you to submit your abstracts for the CAA meeting in Vancouver, October 1983, NOW, before summer holidays, to help the Local Organizing Committee, and to enable them to be published in the next issue.

Have a happy summer. We look forward to seeing you in Vancouver in the fall!

Presentation du Prix des Directeurs de l'ACA 1981.

Presentation of CAA Directors' Award 1981. From left to right are: Dr. L.T. Russell, CAA; Dr. L.J. Leggat, Author; Mr. F. Ferguson, Chief, Defence Research Establishment Atlantic.

NEWS

CONGRATULATIONS - TIM KELSALL

Hatch Associates Ltd., Toronto, announced in February that Tim Kelsall has been recognized as a Certified Industrial Hygienist by the American Board of Industrial Hygiene. According to the company, Kelsall is the first acoustical consultant in Canada to be certified by the Board in that area. Kelsall is a member of the company's oh&s group under Dr. Howard Goodfellow.

TORONTO REGIONAL CHAPTER MEETING

The last meeting of the 1982-83 season, organized by John Swallow and Chris Krajewski, was held in the Ontario Hydro Auditorium on April 12. The subject "Environmental Acoustics and Vibration" attracted an unusual crowd of over 70 enthusiastic attendants tempted by the quality of the speakers and of the refreshments (courtesy of GenRad Limited and Ontario Hydro).

Because of the considerable interest aroused during the discussions and the question and answer period, the meeting went on long after the usual 21:30 hours closing time and by that became the most successful event we have ever had.

The first of the speakers was H. Gidamy (MOE), whose talk was on Philosophy on noise control criteria in land use planning. Basically he discussed the different institutions that involved when a potentially noisy factory or yard is to be built. The bottom line of his presentation was that (a) nothing is that simple and (b) Murphy's law applies also in land use planning.

John Coulter, our second speaker (Barman Coulter Swallow Associates), reviewed the history of noise source regulations in Ontario over the last 10 years. Ontario has been a leader in this area but many problems remain to be resolved. John detailed numerous problems which the acoustic consultant faces. He strongly encouraged all levels of government, but particularly the Province, to press on and resolve these problems, and also offered many suggestions as to how this could be done.

Ground vibration from railways was the much more concrete subject presented by our third speaker A. Lightstone (Valcoustics Can. Ltd.). Alfred started his exposition by explaining some basics of vibrations, before describing measurement techniques and different criteria regarding effects on people and structures. During the second part of his presentation he showed results from a survey of ground vibrations in different parts of houses in a variety of situations and distances from railroads.

The session was closed by our Honorary President, John Manuel, who among other considerations, reminded the audience that the 12th ICA is fast approaching (only 39 months left!).

A. Behar

THE NOISE-CON 83 PROCEEDINGS ARE AVAILABLE

"Quieting the Noise Source" was the theme of NOISE-CON 83 which was held at the Massachusetts Institute of Technology on 21-23 March 1983.

The 512-page Proceedings volume for NOISE-CON 83 was edited by Robert Lotz, Digital Equipment Corporation. The Proceedings contains the texts of 56 papers devoted to the understanding and control of the emissions of noise sources. The papers in the Proceedings focus on source noise control - diagnosing and understanding the generation of noise, predicting it, and controlling it at its origin. There are three aspects of source noise control which receive approximately equal emphasis: Basic theory, design and problem-solving. Approximately one-third of the papers in the NOISE-CON 83 Proceedings deals with understanding the basic causes of noise generation by various sources. Another third focuses on noise control as an integrated aspect of product or process design. The remaining papers are concerned with the diagnosis and noise control modification of already-existing sources that emit excessive noise.

A limited number of copies of the NOISE-CON 83 Proceedings are available for those who were not able to attend the Conference. Copies may be ordered from Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, N.Y., 12603, U.S.A. The 512-page volume is $42.00, shipped postpaid within the United States. Overseas orders should be accompanied by check in U.S. funds. There is no extra charge for surface mail shipment, but $12.50 per volume must be added for shipment overseas by air mail.

DIRECTORY OF GRADUATE EDUCATION IN ACOUSTICS TO BE REVISED

One of the responsibilities taken on by the ASA Committee on Education in Acoustics has been the gathering of data on the status of acoustics education in America. This activity has resulted in publication of the "Directory of Graduate Education in Acoustics". (J. Acoust. Soc. Am., 48, 469-476 (1970); 55, 1105-1115 (1974); 64, 1224-1239 (1978)). A revision of the Directory is planned for the fall of 1983, and requests for corrections have been sent to institutions that are currently listed. Contributions are hereby solicited for active acoustics programs that were not included previously. Information corresponding to that presented in past Directories should be sent to Dr. Wayne M. Wright, Kalamazoo College, Kalamazoo, MI 49007, USA.

THE LATEST IN NOISE NUISANCE IN UK

Nottingham's Environmental Health Department received a complaint recently from the occupier of a house, regarding the nuisance emanating from the garden of one house in the centre of the block.

The nuisance complained of was caused by people shouting in the garden to a prisoner carrying out a demonstration on the roof of Nottingham Prison for a period of three weeks.

Possible action to be taken - it was considered that a notice could be served on the prisoner requesting him to remove himself from the roof. Delivery to be executed by wrapping the notice around the shaft of an arrow and fired onto the roof by one of the Robin Hood Archery Club members.

This action, however, was not taken as the person upon whom the notice was to be served was on Crown property and probably classed as a servant of the Crown.

The problem was resolved when the prisoner came down after 42 days.

The incident was just one more in a series of extraordinary complaints which come to the department, especially under the heading of noise nuisance. Although the incident caused some amusement, the amount of disturbance caused to neighbours was considerable. (From November 1982 Environmental Health, U.K., article submitted by J.Manuel).

ASTM-COMMITTEE E-33 NEWS

New task groups on calibration and sound intensity measurement were formed at the meetings of American Society for Testing and Materials (ASTM) Committee E-33 on Environmental Acoustics in Columbus, Ohio, April 11-13, 1983.

The Task Group on Calibration will examine calibration requirements for instruments and apparatus used in various test methods developed by Committee E-33. The Task Group will recommend calibration intervals, procedures, and programs to guide laboratories that perform the tests.

The Task Group on Sound Intensity Measurement Techniques will evaluate new techniques to measure sound intensity that may be used with existing or new test methods. As the state of the art develops, it is expected that sound intensity measurements will become increasingly applicable to the kinds of measurements that are of interest to Committee E-33.

During the meetings the Task Group on Precision began work to make Committee members aware of the importance of precision statements in Standard Test Methods. ASTM policy requires that a precision statement be included in every Standard Test Method. Precision statements inform the user of the amount of variability expected in the results of a test according to the method in question.

The Task Group on Impedance Tube Measurements is preparing revisions to ASTM C 384, "Standard Test Method for Impedance and Absorption by the Impedance Tube Method". The revisions will include a new section on measuring the normal incidence sound absorption of anechoic wedges in an impedance tube and new sections on impedance tube measurements by the two-microphone method.

The Task Group on Reference Specimens for Sound Transmission Loss Tests will investigate the feasibility of a reference specimen made from galvanized steel sheet. It appears that the transmission loss of steel sheet follows the mass law over a wide frequency range. A laboratory could determine whether its measurements agree with the mass law by testing a well defined reference specimen.

Round-robin test series are being organized by the Task Groups on Interzone Attenuation for Ceiling Assemblies and Partial Height Space Dividers. The test series will provide precision data for proposed test methods for ceiling systems and office screens used in open plan offices.

The next meeting of Committee E-33 will be in Philadelphia, Pennsylvania, 3-5 October 1983. Further information about Committee E-33 and its activities can be obtained from David R. Bradley, ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103; Telephone (215) 229-5560.

NEW RESEARCH CONTRACTS

To International Submarine Engineering Limited, Port Moody, B.C., $38,064, for "Selection and acquisition of a two-axis doppler sonar velocity measuring equipment for the Autonomous Remotely Controlled Submersible Program". Awarded by the Dept. of Fisheries and Oceans.

To Bell Northern Research Limited, Ottawa, Ont., $240,333, for "Design of a surface acoustic wave transducer and light coupler for an integrated optics spectrum analyser - phase III". Awarded by the Dept. of National Defence.

To Acres Consulting Services Limited, Niagara Falls, Ont., $78,597, for "Study of sound radiation of ships' hulls". Awarded by the Dept. of National Defence.

To Canadian Astronautics Limited, Ottawa, Ont., $20,301, to "Conduct a synthetic aperture sonar study - phase II". Awarded by the Dept. of National Defence.

To Huntec ('70) Limited, Dartmouth, N.S., $24,960, for "Analysis of seabed acoustic data". Awarded by the Dept. of National Defence.

To Spectrum Computers, Winnipeg, Man., $15,914, for "Design and construction of five synthetic spelled speech computer terminal attachments". Awarded by the National Research Council.

To Nova, An Alberta Corporation, Calgary, Alta., $78,400, for "Development and evaluation of suitable methods for choosing ultrasonic transducers to inspect pipeline girth welds made by the gas metal arc process". Awarded by the Dept. of Energy, Mines & Resources.

To Techno Scientific Incorporated, Downsview, Ont., $165,039, for "Design, development, assembly and testing of an automated ultrasonic testing system for the characterization of defects in weldments". Awarded by the Dept. of Energy, Mines & Resources.

To Queen's University, Kingston, Ont., (Dr. D.A. Hutchins, Dept. of Physics), $53,760, for "Investigation into electromagnetic acoustic transducers". Awarded by the Dept. of Energy, Mines & Resources.

To Acres Consulting Services Limited, Niagara Falls, Ont., $69,780, for "Dynamic and static analysis of electro acoustic transducer model - refinement additions 1982/83". Awarded by the Dept. of Energy, Mines & Resources.

JOURNAL OF GUITAR ACOUSTICS

A one year subscription to this journal costs $35.00 U.S. For further information write to: Timothy P. White (Ed.), P.O. Box 128, Grass Lake, Michigan, USA 49240. Telephone enquiries may be made to (313) 665-7808.

INTERNATIONAL STANDARDS MEETINGS

ISO/TC43 "Acoustics", ISO/TC43/SC1 "Noise" and IEC/TC29 "Electro-Acoustics", are holding Plenary Sessions and associated Working Group meetings in Paris, France, July 28 - August 6, 1983, at AFNOR Headquarters. For further information contact Mr. C. Ender (ISO) or Mr. S. Buchowski (IEC), Standards Council of Canada, Suite 2-401, 2000 Argentia Road, Mississauga, Ontario, L5N 1V8.

APPLIED ACOUSTICS

This journal may be obtained from Applied Science Publishers Ltd., Ripple Road, Barking, Essex, U.K. The subscription for 1983 (6 issues) is $91.00 to Canada including airmail delivery. Ed. Professor Peter Lord.

NONLINEAR ACOUSTICS SYMPOSIUM - Japan - 1984

The 10th International Symposium on Nonlinear Acoustics will be held at the International Conference Center, Kobe, Japan, 25-28 July 1984. The main theme of the symposium will be "Basic and applied developments in nonlinear acoustics". Four major sessions are planned on nonlinear phenomena, underwater applications, applications to other acoustics fields, and miscellaneous (cavitation, radiation pressure, streaming, and other nonlinear problems). Applications for attendance should be received by 31 January 1984 and manuscripts for abstracts are due by 31 March 1984. Further information can be obtained from the symposium chairman, A. Nakamura, Institute of Scientific and Industrial Research, Osaska University, 8-1 Mighogaoka, Ibaraki, Osaka 567, Japan.

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

P.O. Box 3651, Station "C"
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Montreal March 23, 1983

Mr. H. Gordon Pollard
No.221 -4815, 48th Avenue
Delta, British Columbia
V4K 1V2

Dear Mr. Pollard,

I received your letter on February 28, 1983. The Canadian Acoustical Association of which I am presently the president was started in the early 1960's as an informal group of acousticians who wished to talk to others about acoustics. This informal group has grown so that it now includes individuals with interests in just about all the disciplines of acoustics from music, noise, hearing conservation, under water communication, to the components of speech. Within the group are a few architectural acousticians who deal with the types of questions you raise. Since this group has no professional standing (anyone with an interest in acoustics may join by paying our very modest annual fee) it has never tried or been asked to comment on engineering standards or codes. I do not believe it would ever want to either.

There is another Canadian group that is better equipped to answer many of your questions. This group is the Canadian Standards Association which has a committee Z107 called Acoustics and Noise Control. This committee is responsible for most of the acoustical standards in Canada. It in turn has a subcommittee on acoustical building standards and it is this group that can be of the most use to you. (It happens that I am a member of this subcommittee). The chairman of the subcommittee is Dr. David Quirt of the National Research Council of Canada.

To answer some of your questions:

1- The value given in the National Building Code for party walls was established many years ago when peoples expectations were not as high. It may well be time that this figure, which is a minimum, should be reconsidered and uppraded. There is an element of politics in this decision because this will result most likely in more expensive construction. Can and is the Canadian population ready to pay? (I believe the ansere is yes).

.../2

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2- None of the three engineering organizations speak on behalf of the Canadian Acoustical Association.

3- Dr. Northwood has never represented the CAA on the Associate Committee on the National Building Code or any of its related committees.

4- I am not in any position to answer your question about whether or not any of our member firms are represented on the building code committees. It is my understanding that only individuals serve on these committees.

5- The CAA has never been consulted by the Associate Committee on the National Building Code. Nor in my opinion will it ever be because of the very diverse nature of CAA.

6- CAA does not endorse any companies trade literature nor does it support any political or subjective criteria.

7- I can understand your frustration in trying to obtain a rating on a given building assembly of the type you describe. No laboratory in the world to the best of my knowledge has the capability of evaluating an 8" slab 8'X26'. The only evaluation possible would be a field test with all its limitations.

8- With respect to the use of concrete slabs I know of no special restrictions other than those normally followed.

I have tried my best to answer your questions but perhaps somethings are not clear. Please feel free to write again and do write to Dr. Quirt.

Yours truly,

Cameron W. Sherry
President
CWS/rmg

#221 4815 - 48th Avenue,
Delta, B.C.
V4K 1V2

February 17, 1983.

Mr. Cameron W. Sherry, President,
The Canadian Acoustical Association,
c/o Domtar Research Centre,
Senneville, Quebec.

Dear Mr. Sherry:

By way of introduction, I am one of many condominium owners (within multi-family dwellings) in various cities and municipalities in British Columbia, who are experiencing 'sound' problems in their respective units.

Over the past eighteen months, I have been engaged in a series of discussions and arguments (both written and oral), with federal, provincial, civic and municipal authorities, concerning the Associate Committee on the National Building Code (National Research Council - Canada).

It is my contention, that there are inadequacies, deficiencies and omissions in the present Code (which, in turn, are reflected in various Provincial, Civic and Municipal Building Codes), specifically with respect to Sound Control, Sound Transmission Class ratings, etc., etc., which should be amended, added to and clarified. What is your opinion?

Frankly speaking, from the lack of interest, understanding or cooperation, exhibited over the past two years by the regulatory authorities concerned, coupled with the determined opposition of private interests, my progress can be likened to that of "an ant trying to climb Mount Everest."

I have already been in communication with Ms. Deirdre Benwell, Editor-in-Chief, Canadian Acoustics, who referred me to John Manuel, Executive Secretary, CAA. It was the latter who informed me of your name and address.

Among the organizations commending use of the 1980 Building Code of Canada, three Engineering organizations are listed, namely: (i) Association of Consulting Engineers of Canada, (ii) Canadian Council of Professional Engineers and (iii) Engineering Institute of Canada.

Do any of the above organizations (or any of their members) speak for the CAA? Did T.D. Northwood, while President of the CAA, represent that organization on (i) The Associate Committee on the National Building Code - Canada, or on (ii) the appropriate Standing Committee, or on (iii) the appropriate Revision Sub Committee? Is or has a member firm of the Canadian Acoustical Association ever been represented on one of the foregoing Committees?

.... 2

Alternatively, is the CAA consulted on either a regular or ad hoc basis by the Associate Committee on the National Building Code, or requested to provide input criticisms and recommendations concerning SECTION 9.11 - SOUND CONTROL - pages 255 - 259 of the Code?

Another question, concerns a specification sheet issued presumably by Fiberglas Canada Inc., which states:

QUOTE As a general guide the following should be remembered:

STC				
38	or	below	-	POOR
38	-	46	-	MARGINAL
47	-	52	-	GOOD
Over	-	52	-	EXCELLENT

UNQUOTE

Based upon your experience and knowledge, does or would the CAA endorse the above assessments and qualifications?

I have also been trying, without success, to ascertain the STC rating (not an IMPACT rating) of hollow-core concrete slabs (beams) 8" x 8' x 26', each containing 6 hollow-cores lengthwise. Do you know if they have been rated and if so, what the rating is?

Also, with respect to the interior transmission of sound in building structures, would the use of these beams, as floors and ceilings in multi-family dwelling units, such as: hotels, apartment houses, townhouses and condominium units, be a liability or an asset? Are you aware of any precautions or restrictions, governing their use or non-use, which should/must be observed?

My apologies for the length of this letter Mr. Sherry, plus the questions, but I do need the advice of a knowledgeable and experienced Acoustician. This, because my knowledge and experience is totally unrelated to matters of Sound Control, STC ratings, NIC and NNIC, etc., or building construction.

Yours sincerely,

H. Gordon Pollard

HGP/ef

P.S. I presume you are aware, that in August 1974, California adopted Noise Insulation Standards, which were applicable to all new multi-family dwelling units, such as: hotels, apartment houses, townhouses and condominium units. Furthermore, that under the Standards, a new discipline was added, i.e., Acoustic Engineering. Also dealt with, was the matter of field testing of completed structures, including all flanking paths, and emphasis on the distinction between isolation and insulation.

Toronto Regional Chapter of CAA

Advance Notice of Meetings Planned for 1983/84

September 13,	1983	Hearing Conservation Program Convenors: S. Abel & M. Barman
November 29,	1983	Acoustics in Architecture Convenors: A. Behar & S. Abel
January 10,	1984	Student Evening & Lab. Tour Institute for Aerospace Research, U of T Convenors: G. Johnston, W. Richarz & M. Barman
February 14,	1984	Social Evening (St. Valentine's Day) Convenors: J. Manuel & J. Kowalewski
March 13,	1984	Research in Hearing Convenors: A. McKee & A. Behar
May 29,	1984	Transportation Noise Convenors: C. Krajewski & W. Sydenborgh

With the exception of the visit to U of T, Aerospace Research, and the social evening planned for St. Valentine's day, all Chapter meetings will be held in the Ontario Hydro Auditorium, Toronto, commencing at 7:00 p.m.

International Symposium on Acoustics and the Quality of Life, Cape Town, October 1982.

Copies of single papers published in the 1982 Proceedings of the International Symposium on Acoustics and the Quality of Life are available from the CAA Executive Secretary, John Manuel. Those interested should request a four page listing of the papers presented at the International Symposium. The speakers include Malcolm Crocker, C. J. Johnston, C. G. Van Niekerk, C. L. Wicht, H. Schmidt, H. E. Hanrahan, R. W. Guelke, D. J. H. Wagenfeld, S. Shaer, C. J. du Toit, W. de V. Keet, R. Temmingh, and Per Bruel.

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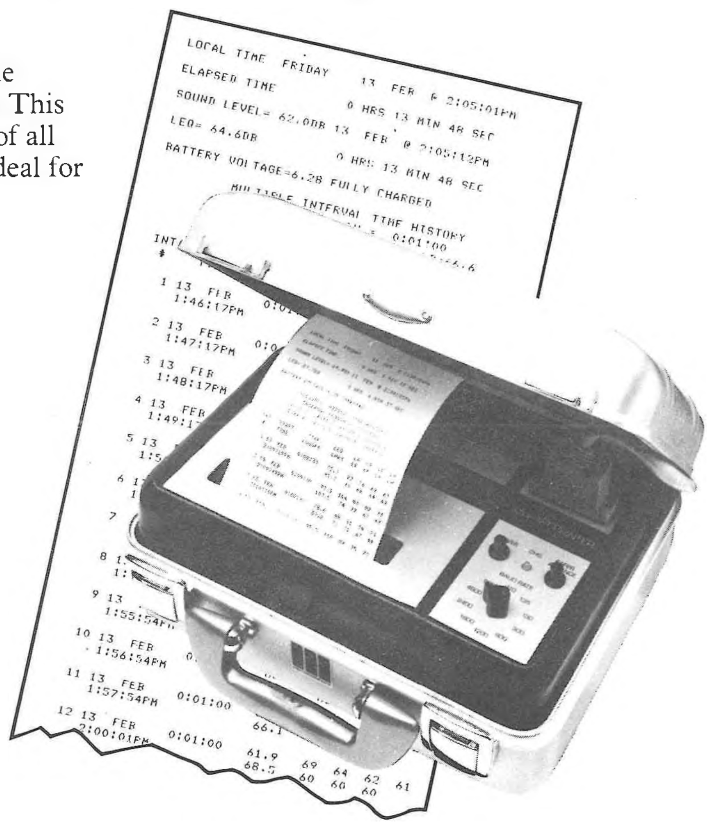

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Seminar: MACHINE HEALTH MONITORING

One of the seminars to be offered during Acoustics week in Vancouver is entitled "Machine Health Monitoring". The CAA feels priviledged to announce that by special arrangement with Bruel & Kjaer Canada Ltd., the services of Mr. Bob Randall and Mr. Roger Upton from B & K Denmark have been secured as seminar leaders.

Mr. Randall and Mr. Upton will be familiar to Canadians working in the fields of acoustics and vibration, both gentlemen being notable seminar leaders and authors of many excellent technical papers. This particular seminar, however, may not be so familiar as it has been presented only once before in Canada, and since has been considerably updated.

The measurement of vibration and selection of transducers will be covered on the first day of the seminar along with frequency analysis, fault detection and diagnosis. On the second day dual channel FFT analysis will be introduced, and its application to response of structures, mechanical impedence, mobility, and modal analysis. Balancing of machinery in single, two and multi-planes will be discussed, as will detection and diagnosis of faults in rolling element bearings and gears. The final day of the seminar will introduce cepstrum analysis and its application to machine diagnosis, along with a discussion of special problems including shaft cracks, turbo machinery, reciprocating machinery and machine tools.

The seminar will be supported through a full set of lecture notes and a wide range of instrumentation. For further information, contact the Canadian Acoustical Association, 1983 Committee, P.O. Box 46256, Postal Station G, Vancouver, B.C., Canada.

Seminar SEISMIC RESTRAINT OF ISOLA
MECHANICAL EQUIPMENT

A third seminar proposed for Acous week in Vancouver on October 18 & 1983 deals with the subject of sei restraint of isolated mechanical eq ment. The status of this seminar still tentative, but it is propose cover the subject of earthquakes, t effect on building mechanical ro and especially on spring isolated chanical equipment. The seminar deal with the need for vibration is tion of mechanical equipment and application of currently avail seismic restraint technology inclu snubbing, and slack cables. The for dynamic analysis will be a t that will be reviewed, as will the rent code regulations. For fur information, contact the Cana Acoustical Association, 1983 Commit P.O. Box 46256, Postal Station G, couver, B.C., Canada.

Seminar: ELECTROACOUSTICS FOR THE
PERFORMING ARTS

A seminar on ELECTROACOUSTICS FOR PERFORMING ARTS will be held 17 - October 1983, and will emphasize practical and artistic application audio in performance spaces. This inar, taking place in conjunction the Symposium of the Canadian Acou cal Association in Vancouver, will clude sessions on sound control both legitimate theatres and multi pose spaces, loudspeaker cluster des touring sound for both popular m drama, electronically enhanced re beration, microphone design and appl tion, and the art of theatre sound sign. The sessions will be held in theatre of Douglas College, a flex auditorium which will accommodate extensive demonstrations being plann

Confirmed speakers thus far include Jeff Burnett (Washington State University, Pullman), Randy Cormack (Artec Consultants Inc., NYC), Charlie Richmond (Richmond Sound Design and Mushroom Studios, Vancouver) Greg Silsby (E-V, Buchanan, MI), and Ted Uzzle (Altec, Anaheim, CA). For further information, contact the Canadian Acoustical Association, 1983 Committee, P.O. Box 46256, Postal Station G, Vancouver, B.C., Canada.

CALL FOR PAPERS

The annual meeting of the Association will be held Thursday and Friday, 20 and 21 October, 1983 at the Georgia Hotel, Vancouver, B.C.

Contributions on all aspects of acoustics are welcome. The following special sessions have been planned:

Transportation Noise / Architectural Acoustics / Underwater Acoustics / Psychoacoustics and Physiological Acoustics / *Sound Intensity Measurement / Vibration / *Hearing Conservation: Noise Control, Audiometry, and Personal Hearing Protection

Send all abstracts to:

Dr. David Y. Chung, Hearing Branch, WCB
10551 Shellbridge Way, Richmond, B.C. V6X 2X1.

Deadline for receipt of abstracts is: August 15, 1983*.

*Changes from last issue.

APPEL AUX COMMUNICATIONS

La réunion annuelle de l'Association Canadienne de l'Acoustique aura lieu les jeudi et vendredi, 20 et 21 octobre 1983, à l'Hôtel Georgia de Vancouver, C.B.

Des communications sur tous les aspects de l'acoustique peuvent être présentées. Des séances spéciales sur les thèmes suivants seront organisées:

Bruit des transports / Acoustique architecturale / Acoustique sous-marine / Acoustique physiologique et psychoacoustique / *Mesure de l'intensité sonore / Vibration / *Lutte antibruit, audiométrie et protection personnelle de l'audition

Veuillez faire parvenir votre résumé à:

Dr. David Y. Chung, Hearing Branch, WCB,
10551 Shellbridge Way, Richmond, B.C. V6X 2X1.

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MODELISATION DE L'IMPACT ACOUSTIQUE
DES POSTES DE TRANSFORMATION

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SOMMAIRE

Les recherches présentées ici se poursuivent depuis 1980, initialement subventionnées par l'Hydro-Québec, elles sont actuellement soutenues par le ministère Fédéral de l'Energie, des Mines et des Ressources. Le projet original comprenait deux volets principaux: soit le développement d'un modèle mathématique pour simuler la propagation du bruit autour des postes de transformation et la mise au point en laboratoire des différents dispositifs et matériaux absorbants susceptibles de réduire efficacement le bruit des transformateurs. Le présent article est consacré à la première partie de la recherche, alors que les matériaux absorbants seront décrits dans une prochaine publication. Le modèle mathématique a d'abord été développé en APL, suite à de nombreuses mesures sur des transformateurs et des postes existants, il tient compte des réflexions, des diffractions et de l'effet de sol sur la propagation; de plus, des relevés sont actuellement poursuivis pour établir les effets de la topographie et des conditions climatiques sur la propagation à grande distance. Enfin, la version FORTRAN du programme est en cours de développement, avec alternativement la possibilité d'une définition très simplifiée des postes, en fonction de la tension nominale et de la puissance totale installée.

ABSTRACT

The research described in this article has been underway since 1980. It was initially subsidized by Hydro-Quebec and is now being supported by Energy, Mines and Resources Canada. The original project comprised two parts: elaboration of a mathematical model for simulating noise propagation around transformer stations, and testing in a reverberant room of various devices and materials which could be used to effectively reduce transformer noise. The present article covers the first part of the project; the research on absorbent materials will be presented in a later publication. The mathematical model was first elaborated in APL on the basis of a large number of noise measurements of existing transformers and transformer stations. It takes into account noise reflection, noise diffraction and ground effects on propagation. In addition, further readings are presently being taken in

order to determine the effects of topography and climatic conditions on long-distance noise propagation. At the present time, the FORTRAN version of the program is being worked out, with the alternative possibility of a much more simplified version of the stations in terms of nominal voltage and total electric power.

INTRODUCTION

Les recherches présentées ici se poursuivent depuis 1980, initialement subventionnées par l'Hydro-Québec via la firme d'ingénieurs conseils L.G.L. de Montréal, elles sont actuellement soutenues par le ministère fédéral de l'Energie, des Mines et des Ressources. Le projet original confié au Centre de recherches en aménagement et au Laboratoire d'acoustique de l'Ecole d'architecture comprenait deux volets principaux:

- le développement d'un modèle mathématique pour simuler la propagation du bruit autour des postes de transformation;
- une recherche en laboratoire sur différents matériaux absorbants et dispositifs pouvant réduire de façon efficace le bruit des transformateurs (1).

Le professeur T. Nakajima de l'Ecole d'architecture a dirigé le traitement informatique initial du modèle expérimental alors que MM. R. Paquet et A. Esteve travaillent maintenant respectivement sur le développement du modèle en FORTRAN et sur les mesures acoustiques relatives à la propagation.

1. REFERENCES POUR LA MODELISATION DE L'IMPACT ACOUSTIQUE DES TRANSFORMATEURS

Avant de développer notre propre modèle nous avons pris connaissance de trois modèles existants relatifs au bruit des transformateurs: E.D.F., 1980 (2), TSUCHIYA, OOGI, NODA et HORI, 1974 (3) et surtout GIAO TRINH, 1975 (4). Ce dernier modèle, développé à l'Institut de recherche en électricité du Québec, a déjà été utilisé par l'Hydro-Québec, malheureusement il ne comporte pas de calcul de diffraction; nous avons néanmoins utilisé sa procédure de reconnaissance des surfaces réfléchissantes au voisinage des transformateurs. Le second modèle mentionné a été publié par la compagnie Hitachi, il considère les réflexions sur les bâtiments, la "directivité des transformateurs" et les "caractéristiques de phase des sources sonores". Les équations présentées sont incomplètes, de telle manière qu'il est impossible d'en faire une analyse très détaillée. Quant au document E.D.F., il s'agit d'une plaquette de synthèse qui présente à la fois la politique française de contrôle du bruit des transformateurs et les éléments mathématiques nécessaires au calcul sommaire de l'impact acoustique et des dispositifs de protection. Nous nous sommes en partie inspirés de cette démarche pour la préparation de notre propre modèle. Concernant la relation entre la puissance électrique nominale ou la masse du noyau magnétique et le niveau de bruit produit, ainsi que l'effet de la tension de fonctionnement sur ce même niveau de bruit (suivant l'induction), nous nous sommes référés à REIPLINGER, 1977 (5) pour la théorie et à GALLAY et DENIS, 1978 (6) pour les équations pratiques.

La première version de notre modèle, dont quelques exemples de résultats seront présentés par la suite, a été développée initialement en langage APL à titre de démonstration, nous terminons actuellement une version FORTRAN beaucoup plus élaborée et surtout moins coûteuse en temps machine.

2. MESURES PREALABLES SUR DES POSTES DE TRANSFORMATION EXISTANTS

De nombreuses mesures acoustiques préalables à l'élaboration du modèle nous ont permis de préciser plusieurs aspects du problème, notamment les difficultés soulevées par la comparaison entre les normes NEMA et CEI (7, 8)*, la définition de la surface émettrice optimale pour le calcul de la puissance acoustique et l'importance du rayonnement acoustique en provenance du dessus de la cuve des transformateurs de puissance (malheureusement inaccessible aux mesures).

Nous avons également pu statuer sur la hauteur du point source à considérer pour les calculs d'impact et sur la fréquence recommandable pour les calculs de diffraction. En ce qui concerne la hauteur du point source nous avons mesuré des transformateurs de 20 à 550 MVA selon trois hauteurs différentes sur le périmètre de mesure; c'est d'ailleurs ce genre de résultats de mesure que l'on peut voir sur la Figure no 1, concernant un transformateur de 66 MVA. Il apparaît dans de

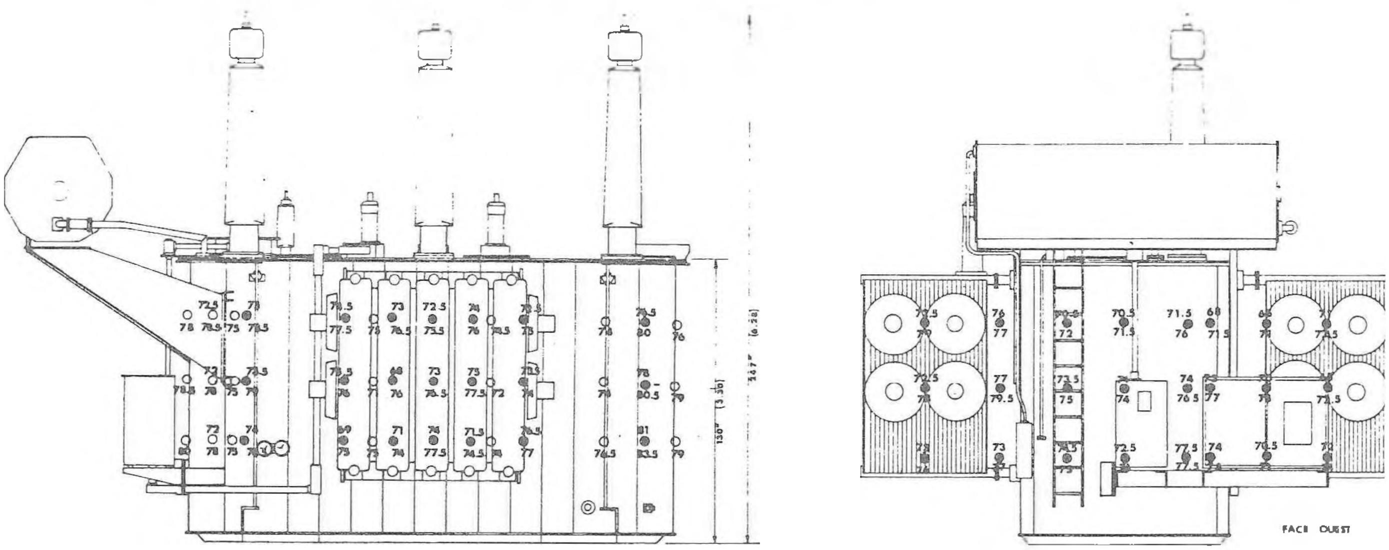


FIGURE NO 1 : *Exemple de relevés du niveau de bruit en dB(A) selon la norme NEMA, effectués à 3 hauteurs différentes autour d'un transformateur 66 MVA.*

---

* *On peut rappeler ici que la procédure CEI pour le calcul de la puissance acoustique en dB(A) suit arbitrairement les équations:*

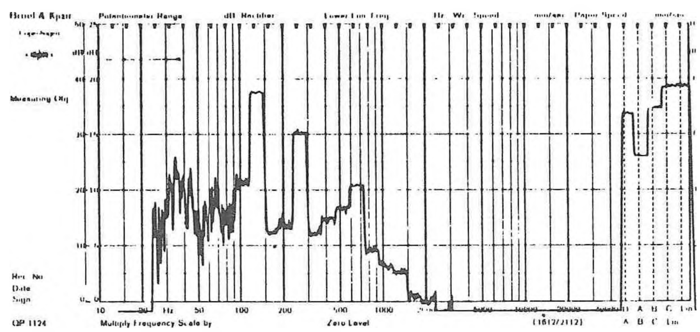
$$P_{W(A)} = \overline{N}_{(A)} + 10 \log S/So$$

$$\text{avec } S = 1.25\ h\ p_m \quad \text{ou} \quad S = 3/4\ \pi\ p_m^2$$

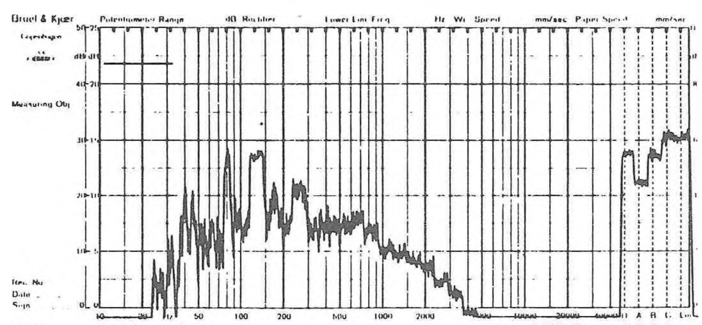
Formules pour lesquelles S est la surface émettrice, So la surface de référence égale à 1 m^2, p_m la longueur du contour de mesure, h la hauteur de la cuve et $\overline{N}_{(A)}$ le niveau de bruit moyen tel que mesuré en dB(A). La première de ces formules s'applique au cas des ventilateurs hors service, le contour de mesure étant distant de 0,3 m (similaire à la norme NEMA), et la seconde au cas des ventilateurs en fonctionnement, le contour de mesure étant distant de 2 m des équipement à l'essai (dans ce cas la procédure diffère de la norme NEMA qui recommande 6 pieds ou 1,8 mètres).

nombreux cas une très légère élévation dans le bas de la cuve (là où repose l'armature des enroulements); néanmoins, en partie pour tenir compte du rayonnement du couvercle, nous avons suivi la recommandation de REIPLINGER, 1972 (9) pour le calcul des effets d'écran, soit un point source équivalent au 2/3 de la hauteur.

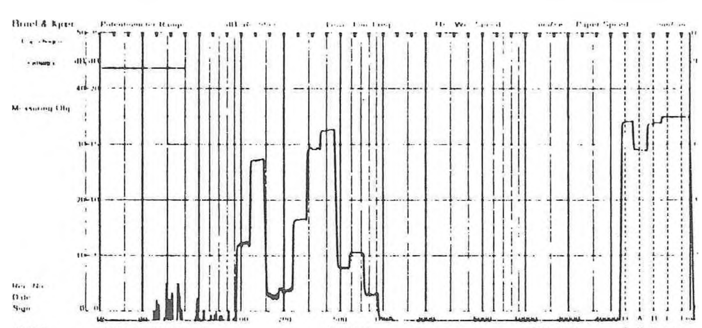
Au point de vue de la fréquence recommandable pour les calculs de diffraction, nous avons procédé à des analyses de composition spectrale sur les 4 faces de différents transformateurs. L'application de la correction physiologique (A), ainsi que l'atténuation relative des différentes bandes de fréquence par la diffraction d'un écran type, nous ont finalement amenés à ne retenir que la bande de fréquence la plus basse (soit 120 Hz); même si, comme le montre la Figure no 2, pour certains transformateurs le niveau de pression des premières harmoniques (240 ou 360 Hz) peut dépasser celui de la fréquence de base, ou bien dans d'autres cas le bruit de la ventilation couvre un large spectre, jusque vers 1 500 Hz.



a) spectre d'un transformateur 20 MVA, sans ventilation (bande principale à 120 Hz)



b) même spectre que le précédent, ventilateurs en fonctionnement



c) spectre d'un transformateur 66 MVA, sans ventilation (bande principale 360 Hz, exceptionnel)

FIGURE NO 2 : *Exemples de quelques analyses de composition spectrale au 1/3 d'octave relevées à 1 mètre de la cuve d'un transformateur.*

Enfin, nous avons procédé à de nombreuses cartographies des niveaux de bruit autour de postes existants d'importances variées (de 2 à 30 transformateurs ou inductances shunt), ainsi qu'à des mesures de bruit communautaire pour les résidences les plus proches, ceci afin de pouvoir vérifier l'efficacité du modèle par rapport à des situations réelles. A ce propos, la Figure no 3 montre deux exemples de postes d'importance différente, cartographiés lorsque les ventilateurs étaient en fonctionnement.

3. GRANDES LIGNES DU MODELE EXPERIMENTAL DEVELOPPE

Nous voulions obtenir un modèle susceptible de fournir le niveau de bruit résultant pour un point de coordonnées X, Y, Z (fenêtre d'une habitation par

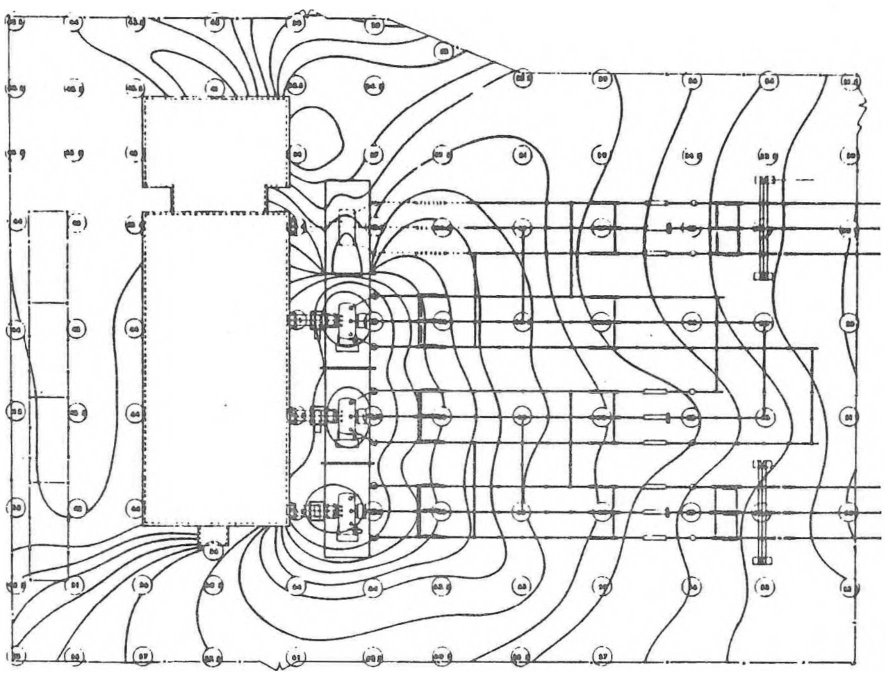
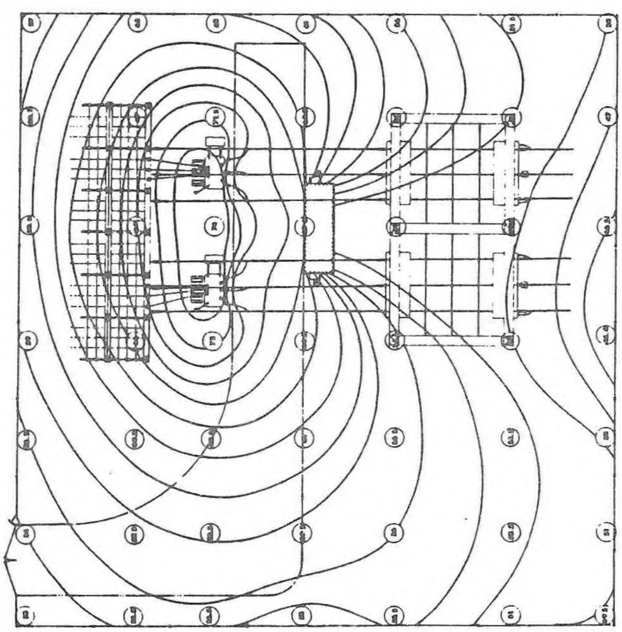


FIGURE NO 3 : *Exemple de cartographie des niveaux de bruit de fond, tels que mesurés pour un poste à 3 transformateurs 230/25 KV (avec murs coupe-feu) et pour un poste à 2 transformateurs 120/25 KV (1980).*



exemple), mais également une grille de valeurs en X, Y, interpolable sous forme d'une carte de bruit, ou bien encore des lignes de valeurs (entre deux bornes de propriété par exemple). L'ordonnancement logique du modèle expérimental finalement mis au point est la suivante:

- description des sources;
- calcul de la puissance acoustique;
- description des murs et bâtiments présents sur le poste;
- choix des points de calcul (isolés ou matrice pour cartographie);
- description complémentaire des lieux (limites, clôtures, édifices, etc.);
- calcul de la propagation hémisphérique;
- calcul de l'effet de sol (gradiant de température, etc.);

- calcul des éventuelles réflexions;
- calcul des éventuelles diffractions;
- itération et sommation des niveaux de bruit résultants;
- sortie, imprimée ou graphique suivant la demande.

4. ASPECTS ORIGINAUX DU MODELE EXPERIMENTAL

Tout d'abord, comme le montre la Figure no 4, le calcul de la puissance acoustique d'un transformateur a été limité à 5 cas dans le modèle expérimental (du transformateur sans radiateur au transformateur avec deux batteries de radiateurs accolées et ventilateurs); il sera élargi par la suite, notamment au cas des batteries d'aéroréfrigérants indépendantes.

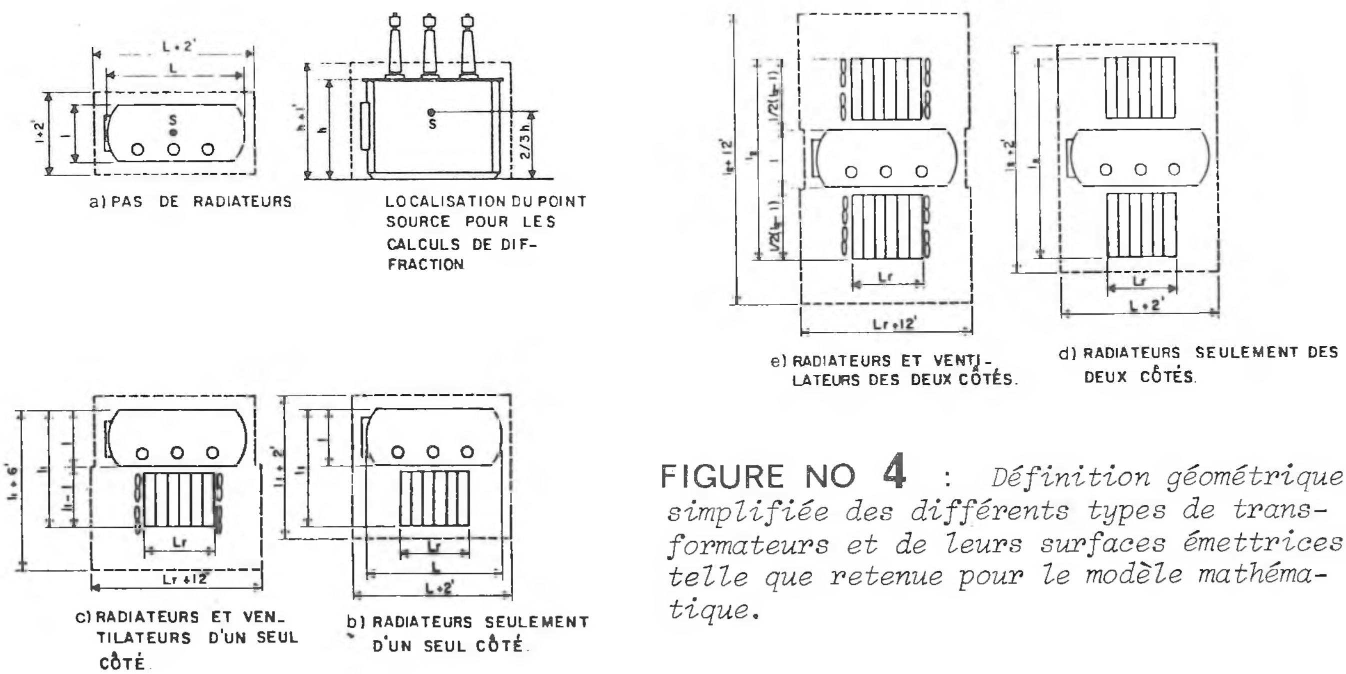


FIGURE NO **4** : *Définition géométrique simplifiée des différents types de transformateurs et de leurs surfaces émettrices, telle que retenue pour le modèle mathématique.*

La Figure no 5 regroupe ensuite la plupart des aspects originaux du modèle, sans pour autant rentrer dans le détail de tous les algorithmes. La propagation hémisphérique, complétée par l'effet de sol,est initialement calculée suivant l'équation:

$$N_{(A)} = P_{W(A)} - 20 \log d + 5 \log (3Z + 2h)/d - 8$$

dans laquelle d est la distance réelle entre le point d'écoute (X, Y, Z) et le point source placé tel que mentionné au 2/3 de la hauteur de la cuve h. De cette formule, purement expérimentale, il découle qu'au-dessus de la droite d'équation $Z = d/3 - 2/3h$ il n'existe aucun effet de sol. Cette partie du modèle s'inspire des principes énoncés par WHITE et McNALLY, 1974 (10) et des équations proposées en 1976 par le Greater London Council pour l'impact des autoroutes. La propagation est donc considérée comme hémisphérique autour du transformateur jusqu'à un cercle de rayon égal à 2h.

Ensuite, les réflexions sont définies en trois dimensions avec un certain nombre de conditions visant à la simplification des calculs; la propagation du son réfléchi fournissant un niveau résultant conforme à l'équation:

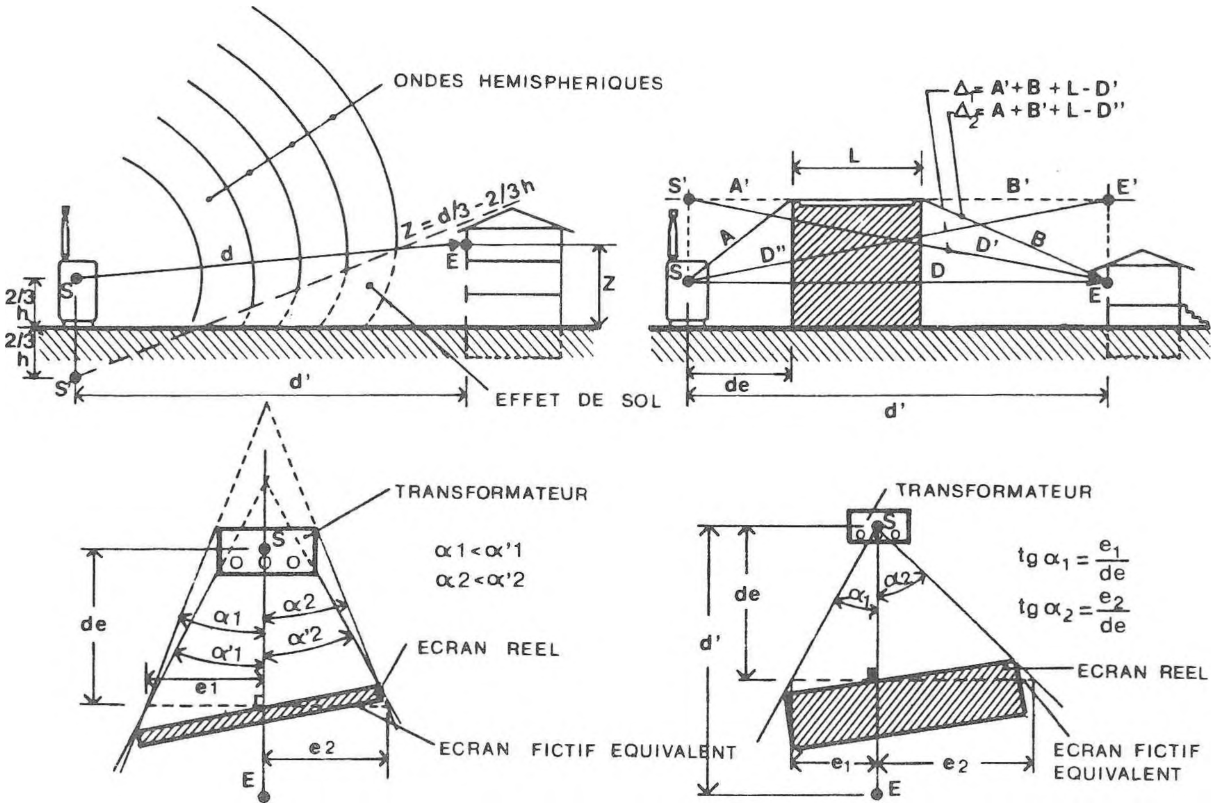


FIGURE NO 5 : *Principaux aspects de la propagation du bruit des transformateurs abordés dans le modèle expérimental.*

$$N_R = P_{W(A)} - 20 \log (r_1 + r_2) + 20 \log (1 - \alpha) - 8$$

relation dans laquelle r_1 et r_2 sont les deux portions du cheminement réfléchi et α le coefficient d'absorption de la surface réfléchissante. Pour le calcul de l'atténuation théorique par la diffraction la Figure no 5 fait également référence au cas d'un bâtiment écran (double diffraction); cette propagation est comparée à deux diffractions simples résolues à l'aide de la théorie de MAEKAWA telle que formulée par KURZE (11) avec quelques modifications après essai, suivant l'équation:

$$A_{TB} = 10 \log 40\ \Delta_1/\lambda + 10 \log 40\ \Delta_2/\lambda + 20 \log (A + B + L)/D$$

Les notations sont celles de la figure, Δ_1 et Δ_2 sont les différences de parcours acoustiques et λ la longueur d'onde est prise égale à 2,83 m.

Pour les pertes d'atténuation aux deux extrémités d'un écran, les deux droites de propagation limites définissent autour du point source les angles α_1 et α_2 ainsi que les segments e_1 et e_2 sur la perpendiculaire élevée sur le cheminement direct, à la distance de du point source ($tg\ \alpha_1 = e_1/de$). Les longueurs d' et de sont toujours respectivement la projection de la distance du point source au point d'écoute et la distance du point source à l'écran. Nous avons mis au point la formule simple suivante, qui donne finalement l'atténuation réelle d'un écran à partir de son atténuation théorique A_T:

$$A_R = A_T/2 \log (10\ tg\alpha_1) \quad \text{ou} \quad A_T/2 \log (10\ tg\alpha_2)$$

avec comme condition $0,1 \leq tg\alpha \leq 10$ (en fait il s'agit simplement de retenir le calcul correspondant au plus petit des angles α_1 ou α_2). Le modèle tient également compte du cas où les dimensions de la source sont très grandes par rapport à la longueur de l'écran en définissant plutôt 4 angles α_1, α_1' et α_2, α_2' et en choisissant le plus petit d'entre eux pour le calcul de l'atténuation réelle A_R. Le modèle tient compte ensuite de la continuité des écrans, jusqu'à 3 éléments différents (murs ou bâtiments), mais possédant au moins un point commun entre eux.

Finalement, il procède à toutes les sommations des niveaux sonores résultants et à toutes les itérations nécessaires, par ailleurs fort nombreuses.

5. RESULTATS ET PERSPECTIVES DE DEVELOPPEMENT

La Figure no 6 présente deux exemples de résultats, tels que fournis par l'ordinateur, pour un poste de 120 KV à 2 transformateurs et pour un poste de 230 KV à 3 transformateurs, avec murs coupe-feu et bâtiment de contrôle basse-tension; en fait il s'agit des deux mêmes postes que ceux qui sont cartographiés sur la Figure no 3.

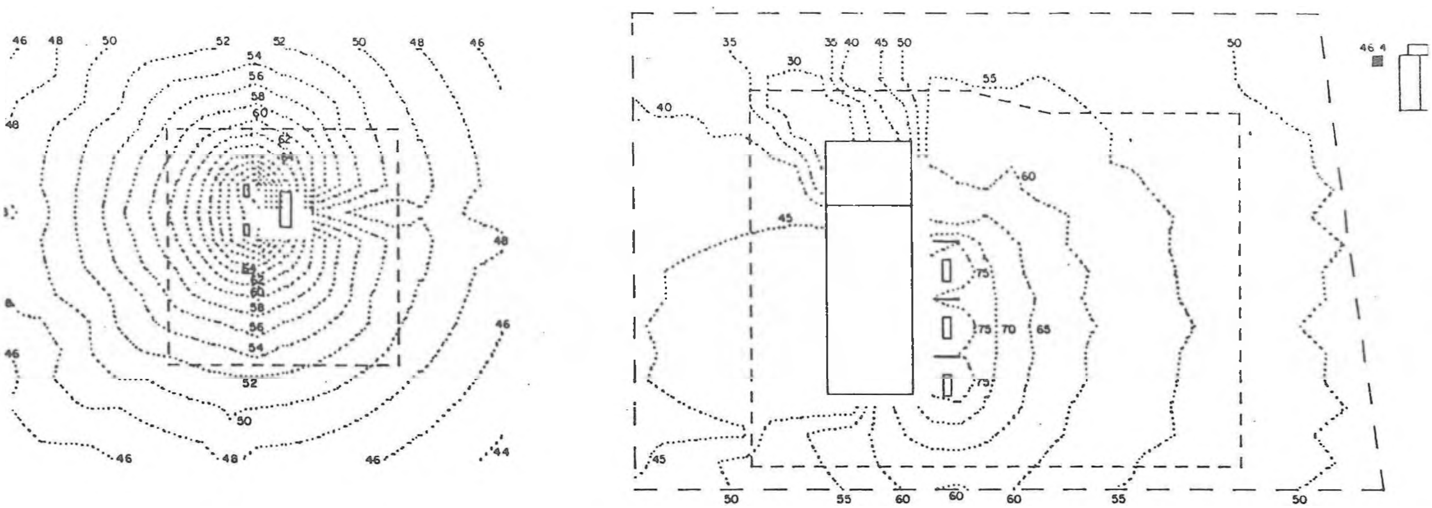


FIGURE NO 6 : *Exemples de résultats cartographiques obtenus par simulation, par classe de 2 ou de 5 dB(A) (ces deux exemples correspondent aux postes de la figure No 21).*

Au point de vue du développement du modèle, nous poursuivons actuellement nos travaux et nos mesures, de façon à intégrer dans les algorithmes les problèmes de propagation à grande distance (de 2 à 3 km), suivant les conditions climatiques et la topographie du site. Pour ce faire, nous avons entrepris un programme de relevés portant sur douze mois consécutifs, en périodes diurne et nocturne. Ces problèmes ont d'ailleurs été abordés d'un point de vue théorique par YING et McGAUCHEY, 1981 (12). D'autre part, nous avons intégré une entrée de données simplifiées (tension nominale, puissance totale installée, nombre et qualité des transformateurs), de façon à permettre la résolution rapide de certains problèmes de planification environnementale.

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Regulating Occupational Exposure to Noise - A Review
(Revised September 1982)

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Abstract

A brief historical background to occupational noise regulations is provided with a description of the "dose-relationships" used today. A summary of the regulations (existing and proposed) in Canada is presented outlining noise limits and various alternative noise protection measures. The benefits of hearing conservation programmes and education, and the limitations of present regulations are discussed. Methods of assessment of compensation for occupational noise-induced hearing loss are also described.

Sommaire

Cet article est un résumé historique de la réglementation concernant l'exposition au bruit en milieu de travail et description des relations dose-effet utilisées aujourd'hui. Un sommaire des règlements canadiens (en vigueur et proposés) est présenté incluant les niveaux sonores limites ainsi que diverses mesures possibles de protection contre le bruit. Il est également question des avantages que présentent les programmes de protection de l'ouïe et d'éducation en la matière, et des limites des règlements actuels. On trouve en outre une description des méthodes de calcul des indemnités à verser en cas de troubles de l'audition résultant de l'exposition au bruit en milieu de travail.

1. Background

1.1 History

Loss of hearing from exposure to industrial noise was recognized as early as 1831 by J. Fasbrooke[1]. Since that time numerous surveys of the hearing of industrial workers have been made both in Europe and North America. Early investigators felt that a single value for the noise level at all frequencies would be adequate for defining a safe level. However, by the 1950's it was clear that proposed noise limits should consider other physical

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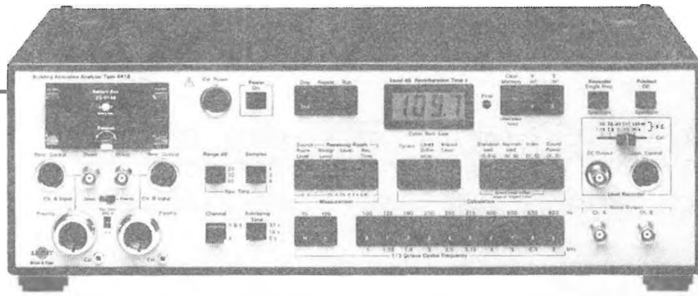

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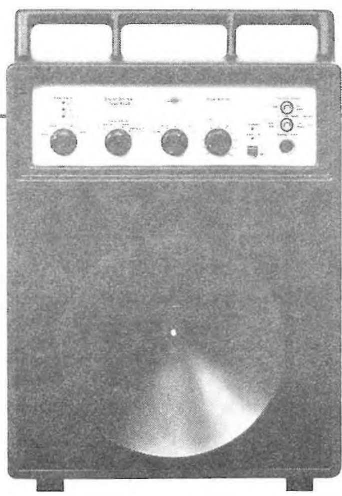

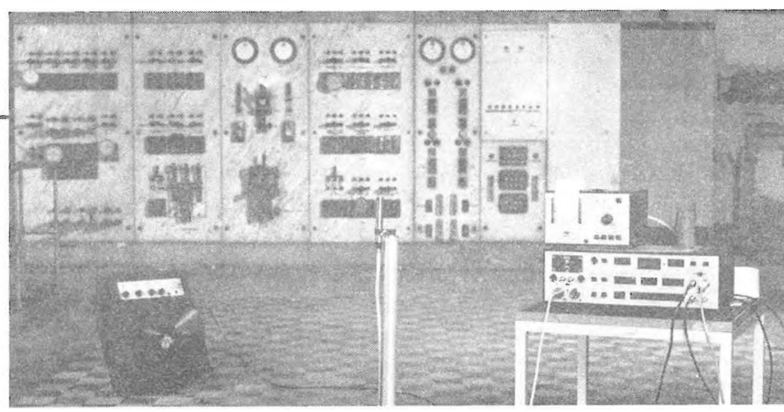

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Option Calculations

Opt. No.	Necessary Data		Standard	Result of Calculation		Range Hz
00				No Option Calculations		
12	Correction Spectrum in Backgr. Level'		DIN 52210	Correction of Normalized Impact Level		100–8000
12	Normalized Level Difference + Index		DIN 52210	LSM (Luftschallschutzmaß)		100–3150
12	Normalized Impact Level + Index		DIN 52210	TSM (Trittschallschutzmaß)		100–3150
20	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
21	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
22	Any Measurement	*	Circ. 29/6/72	Octave Conversion of all Measurements		100–8000
22	Any Calculated Level Difference	*	Circ. 29/6/72	D dB(A) (Octaves, Pink Source)		100–5000
22	Any Calculated Level	*	Circ. 29/6/72	dB(A) Calculation (Octaves)		100–5000
23	Any Measured or Calculated Level	*	NF S 31–052	dB(A) Calculation		100–5000
23	Any Level Difference	*	NF S 31–051	R dB(A) (Pink Source)		100–5000
30	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
31	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
32	Any Measurement	*		Octave Conversion of all Measurements		100–8000
32	Standardized Level Difference + index		NEN 1070	I(iu) (Octaves)		100–2500
32	Standardized Impact Level + Index		NEN 1070	I(co) (Octaves)		100–2500
40	Receiving Room and Background Levels	*	ASTM E492–73T	Removal of Backgr. Level Correction		100–8000
41	Receiving Room and Background Levels	*	ASTM E492–73T	Background Level Correction		100–8000
42	Level Difference + Index		ANSI E336–77	NIC (Noise Insulation Class)	3)	125–4000
42	Standardized Level Difference + Index		ANSI E336–77	NNIC (Norm. Noise Insulation Class)	3)	125–4000
42	Normalized Level Difference + Index		ANSI E336–77	FSTC, STC (Sound Transmission Class)	3)	125–4000
42	Normalized Impact Level + Index		ASTM E492–73T	IIC (Impact Insulation Class)	3)	100–3150
50	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
51	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
52	Any Measurement	*		Octave Conversion (1/3 Octave Step)		100–8000
52	Normalized Level Difference + Index		ÖNORM S 5100	LSM (Luftschallschutzmaß)		100–3150
52	Normalized Impact Level + Index		ÖNORM S 5100	TSM (Oct. Conversion, 1/3 Oct. Step)		100–4000
90	Receiving Room and Background Levels	*	ISO 140	Removal of Backgr. Level Correction		100–8000
91	Receiving Room and Background Levels	*	ISO 140	Background Level Correction		100–8000
92	Any Measurement	*		Octave Conversion of all Measurements		100–8000
93	Any Level	*		dB(A) Calculation		100–8000
94	Any Level or Level Difference	*		Rounding to nearest dB		100–8000
95	Any Measurement			'Run': Same Frequency		100–8000
96	Any Measurement			As above, 15 Measurements averaged		100–8000

Notes:
1) * means: Press 'Option' to perform Calculation.
2) For each group, Measurement in 'Run' stops after the underlined frequency, if Program Switch No.5 is Closed.
3) Program Switch No.1 must be open. (If closed, ANSI/ASTM Index Calculations are performed without 8dB Rule).

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characteristics of noise in addition to intensity. An example of earlier philosophy is reflected in Kryter's monograph on the "Effects of Noise of Man"[2]. This was a comprehensive review of all the literature on this subject up to that date, recognizing the need to consider the component frequencies and the bandwidth of frequencies that have common effects in evaluating the hazard of a given exposure to noise. For the next 15 or so years a number of damage-risk curves were produced by investigators, relating noise exposure level with duration of exposure and the frequency of the noise.

The use of A-weighted sound levels as a measure of hazard to hearing became common after 1967. The A-weighting network in a sound level meter electronically weights the amplitudes of sound in the various frequencies in the audible spectrum approximately in accordance with the average person's hearing sensitivity and sums the resulting weighted sound spectrum to obtain a single number (dBA).

Botsford[3], Passchier-Vermeer[4], Robinson[5], Cohen et al[6] found that A-weighted sound levels indicated hazard to hearing as well as octave-band sound pressure levels, noise rating numbers, etc. Because of its simplicity and accuracy in relating hazard to hearing, the A-weighted sound level was adopted as the measure for assessing noise exposure by the American Conference of Governmental Industrial Hygienists (ACGIH), in 1967.

The establishment of limits of noise exposure requires the consideration of many factors. These include: the results of surveys investigating noise-induced hearing loss and their applicability; methods of noise exposure control, their cost and feasibility; and of primary importance, the percentage of the group estimated to be protected by the established limits.

There has been a considerable controversy over the appropriate limits to be set, particularly in the United States. The development of regulations in the U.S. is of particular interest, as they most closely resemble the development of Canadian regulations.

The first Federal regulation in the U.S. limiting noise exposure, specifically to prevent hearing loss, was in the Health and Safety Regulations of the Public Contracts (Walsh-Healey) Act, May 1969[7]. This regulation incorporated the noise exposure limits adopted by the American Conference of Governmental Industrial Hygienists (ACGIH), shown in Table 1.1.

Scientific data at that time on noise-induced hearing loss indicated that a limit of 90 dBA for a 8-hour day, 40-h/week exposure over a working lifetime would protect about 90% of the people exposed to this level from a hearing loss substantial enough to interfere with speech communication. The ACGIH increased the limit 5 dB, for each halving of the exposure time, since there was evidence that the ear could tolerate higher levels for shorter periods of time. Further, if the noise is intermittent in nature (with rest periods between exposure), the ear could tolerate considerably more acoustical energy than for uninterrupted exposure to continuous noise. A limit of 140 dB peak sound pressure level was recommended at that time for impulsive noises.

In 1970 the Occupational Safety and Health Act (OSHA) was passed in the United Stated[9], and in 1971 the Walsh-Healey Safety Regulations were adopted under this Act. In 1972 the National Institute for Occupational Health and Safety (NIOSH), reviewed the published data available on noise-induced hearing loss along with data from their research studies, and made recommendations to OSHA for a noise health standard[10]. One of the principle changes recommended by NIOSH was the lowering of the basic standard from 90 dBA to 85 dBA. To this date this recomendation (1982) has not been adopted in its entirety by OSHA.

On January 16, 1981, OSHA published 29 CFR Part 1910, "Occupational Noise Exposure; Hearing Conservation Amendment",[10A] in the U.S. Federal Register as a final rule to become effective April 15, 1981. This was amended on August 21, 1981[10B]. The exposure criteria of this regulation have been hotly disputed by employer and employee representatives, and still are not finally settled. The regulation as printed, allows a maximum time-weighted average sound level (TWA) of 90 dBA for 8 hours, with a 5 dB dose-trading relation. It does, however, require noise-exposure monitoring to identify employees exposed to a 8 hour TWA of 85 dBA or greater; in which case a hearing conservation program must be implemented, including baseline and annual audiometric testing.

In addition there has been a move in recent years, lead by the U.S. Environmental Protection Agency (EPA), to use a dose-trading relation of 3 dB as opposed to 5 dB. Simply expressed, this means that the limit is increased 3 dB for each halving of the exposure time. A 3 dB dose-trading relation is used almost exclusively in Europe on the grounds of it being the best relationship for hearing conservation[13]. The 3 dB dose-trading relation may be simply measured by the Equivalent Sound Level (L_{EQ}). The Equivalent Sound Level is a single value of sound level for any desirable duration, which includes all of the time-varying sound energy in the measurement period[11,12]. In his report "Effects of Noise on Man", Thiessen states "a good deal of legislation aimed at hearing conservation has been passed that allows 5 dBA higher levels for each reduction in exposure time by a factor of two; the supporting data for this originated primarily from temporary threshold shift (TTS) experiments. This trading relation is not accepted by all authorities and is probably, in many cases, a practical compromise. There is at least as much evidence that the increase should be just 3 dB instead of 5 dB, which also has the merit of simplicity of concept as well as dosage measurement."[14] It has the additional advantage of giving a simple method of handling impulse noise - which can be included in the L_{EQ} measurement. Impulse noise has long been felt to be responsible for a higher risk of hearing loss than that given by the total noise-dose criteria now used. This view was supported by the World Health Organization who recommended research in this area[15,16].

1.2 Occupational Hearing Loss in Canada

There have been very few published studies on occupational noise-induced hearing loss in Canada[14,53]. A recent study, "Progression of Noise-Induced Hearing Loss in Specific industries in Canada"[54], was submitted to the Non-Ionizing Radiation Section of the Department of Health and Welfare, March 1982. It is anticipated that this report will be published in the Environmental Health Directorate publication series.

A major deterent to the study, from the outset, was the reluctance of industries with ongoing hearing conversation programmes to make their records available for the survey. To summarize the findings of the project as a whole: Serial audiograms from three industries taken over a 10 to 15 year period in relatively large samples of individuals, allowed the evaluation of the progression of hearing loss due to noise exposure within subject. This is in contrast to the traditional cross-sectional survey approach in which individuals each contribute one audiogram and the estimate of change in hearing is based on the average result for groups differing in age and/or years of exposure.

For each of the industries considered wide differences were noted across individuals in the rate of change with time. This might have been due to large variation in susceptibility. However, number of years of exposure at the start of the series of measurements could not be accurately estimated. Thus, a moderate change could mean either that the individual was resistant to noise and/or that he had already reached his asymptote for impairment. Significant differences due to job type were evident for the data of one company. These could not be related to noise levels, since precise measurements were not available. Even with these data, exact dosage would be unknown because of wide differences in complying with regulations for the wearing of hearing protectors. In general the greatest loss occurred at 4 kHz, and the number of frequencies at risk of exceeding the 25 dB HL fence increased with years of exposure. Across job types the rate of loss was roughly 1 to 2 dB per year, although younger subjects often showed rates in excess of 3 dB per year. By comparison control subjects were significantly less at risk and the slope in hearing loss with time was close to 0.0.

The major recommendations that might be made on the basis of this study are that there be closer monitoring and more complete record-keeping of both noise levels and noise dosage. These data might go with the individual as he transfers from job to job or across industries. Unless the usage of hearing protectors is strictly enforced, there appears to be little value in instituting a hearing conservation program. One encouraging bit of data garnered from one company was the greater compliance among younger employees, perhaps reflecting the success of relatively recent upgrading of teaching and advertising campaigns jointly by industry, union and Workman's Compensation Board.

2. Brief Description of Noise Dose Relations

One of the most critical decisions that legislators must make when formulating regulations to prevent occupational noise-induced hearing loss is to set limits of noise exposure. Since the amount of hearing loss incurred varies not only with noise level, but also with duration of exposure, noise-dose relations are equally important.

Early Canadian occupational noise regulations all used the 5 dB rule (a 5 dB increase in noise level allowed for a halving of exposure time). This rule was based on a limited number of studies, such as those by Kryter(17) and Sataloff(18), on temporary threshold shifts (TTS). These studies investigated the effect of intermittency and duration of noise exposure on the risk of hearing impairment. These works were used as a basis for the formulation of "Guidelines for Noise Exposure Control"(19) and the Walsh-Healey Act(7) in the United States (see Table 1.1). When the daily noise exposure is composed of two or more periods of noise exposure of different levels, the combined effect is calculated as follows. If the sum of the following fractions:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots \frac{Cn}{Tn} > 1$$

exceeds unity, then the mixed noise exposure should be considered to exceed the threshold limit value. C_1 indicates the total time of exposure at a specified noise level and T_1 indicates the total time of exposure permitted at that level.

For example, if a worker is exposed to 90 dBA for 6 hours and 95 dBA for 2 hours, according to Table 1.1, he is allowed 92 dBA for 6 hours and 100 dBA for 2 hours. The calculation is thus:

$$\frac{6}{8} + \frac{2}{6} = \frac{13}{12} = 1\frac{1}{12}$$

This sum is greater than 1 and therefore the worker has been overexposed.

Recently there has been a growing trend towards adopting the 3 dB rule. The 3 dB rule is based on the equal energy concept i.e. a noise level of 90 dB for 8 hours contains the same amount of energy as a noise level of 93 dB for 4 hours.

This concept may seem to be reasonable in terms of hearing conservation, but it does not take intermittency into account, i.e. that most exposure to hazardous noise levels is intermittent, thus reducing the hearing hazard. Unfortunatley there is increasing evidence that Temporary Threshold Shift (TTS), on which early intermittency studies were based, is not a good indicator of Permanent Threshold Shift (PTS), or permanent noise-induced hearing loss.

The variables in occupational noise-induced hearing-loss are numerous and include: differences in susceptibiity of the individual to noise, variation in noise exposure (duration and level), variations in audiometric testing, TTS, sociocusis (effect as hearing of noise from social as opposed to occupational activities), etc., making the analysis of these studies extremely complex.

In weighing the merits of the 3 dB and 5 dB trading relations, it would appear that the scientific arguments in favour of the 5 dB rule may not be as strong as appeared to be the case 10 years ago.

However, recent experiments have tended to confirm the protective benefits of intermittency[20,21]. On the other hand the 3 dB rule does enable impulse noise to be included in the measurement, possibly eliminating the need for a separate assessment of impulse noise to be made. Since many industrial operations contain high levels of impact (impulse) noise this could save a great deal of effort in the assessment of noise hazard. Further information on the effects of impulse noise on hearing is still required.

3. Summary of Canadian Legislation

Occupational noise legislation in Canada is for the most part covered by legislation having general health application and promulgated by the individual provinces and the Federal Government. In some provinces there is specific legislation for industries such as lumbering, mining, construction and forestry. A detailed description of Canadian legislation aiming particularly at the protection of workers against the harmful effects of noise exposure in the work-place is given in Labour Canada's publication "1977 Occupational Noise Legislation"[22], and its latest amendment (October 1981). Since occupational noise legislation is in a continuing state of change in Canada, latest draft regulations are given, where publicly available, and tables of information are dated.

The Federal Government has two occupational noise regulations: The Canada Labour Code, Noise Control Regulations proclaimed in 1971, modified in 1973[23], which cover federal works' undertakings and businesses, and Treasury Board Standards issued in 1972 and modified in 1978[24], which have requirements similar to the Labour Code, but apply to Public Service departments and agencies. Some 750,000 people are covered by these two standards. New draft Treasury Board Standards, April 14, 1982, have been circulated[24A] and it is anticipated that these standards will be so modified shortly.

Other occupational noise legislation in Canada[25-45] falls within provincial jurisdiction, and thus applies to the majority of working Canadians.

Recently the Federal/Provincial Advisory Committee on Environmental and Occupational Health established a Working Group on Occupational and Environmental Noise Exposure and Hearing Conservation. The present terms of reference of this group is to prepare guidelines on occupational noise and hearing conservation regulations. It is hoped, in this way, to encourage national agreement in this area, with a firm scientific rationale. This work is supported by the Canadian Standards Association CSA Z107 Committee on Acoustics and Noise Control, whose Task Force on Occupational Noise recommended such action. The Task Force position is supported by the results of a comprehensive survey on the subject mailed across Canada to some 150 users of standards on occupational noise. There were over 60 replies and a need for national guidelines on occupational noise and hearing conversation regulations in Canada was clearly demonstrated.

3.1 Noise Exposure Limits

Limits of noise exposure prescribed in Canadian occupational noise legislation are shown in Table 3.1. It is generally assumed to be implicit in these regulations that noise levels are measured in a diffuse sound field with an omnidirectional microphone. It can be seen that there are some differences between the various regulations. The three main differences are (1) the variation between 85 and 90 dBA for an 8 hour per day exposure, (2) the variation between a 5 dB increase for a halving of exposure time prescribed in most provinces and a 3 dB increase for a halving of exposure time prescribed in British Columbia, and (3) combined or separate assessment of impulse noise. A recent trend toward 3 dB is reflected in draft Manitoba and Ontario legislation and in draft Federal Treasury Board Guidelines. This enables a combined assessment of impulse and steady-state noise. Eight provinces specify a separate assessment for impulse/impact noises that varies with the number of impulses, as shown in Table 3.2. The Federal Government presently prohibits exposure to impact/impulse sound "the peak sound pressure level of which, measured by a method acceptable to the regional safety officer, exceeds 140 dB unless that employee is wearing (prescribed) hearing protectors"[23]. Impulse noise limits are not specified by 3 provinces. Impulse noise exposure level measurements are now incorporated with steady-state noise measurement in 1 regulation and 3 proposed regulations considerably simplifiying exposure calculations. Maximum impulse noise limits are also set for these 4 regulations.

At present Saskatchewan legislation specifies that noise levels in excess of 85 dBA be monitored and controlled, and aural protection of workers be required. Details of compliance, including an 85 dBA maximum daily 8 hour exposure level with a 3 dB increase for a halving of exposure time are given in a guide to compliance published by Saskatchewan Labour(44).

3.2 Alternative Noise Protection Measures

A summary of noise protection measures, other than noise exposure limits prescribed in Canadian Occupational Noise Regulations, is provided in Table 3.3.

Hearing Protectors

All provinces with occupational noise regulations prescribe hearing protectors under certain conditions. The majority (British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island and Quebec), state in general terms, that hearing protectors must be worn when employers are unable to reduce the noise below harmful levels (or the noise limit table indicated).

The Federal Government requires the use of hearing protection at noise levels over 90 dBA. Saskatchewan regulations, Manitoba and Ontario draft regulations, require hearing protection at noise levels over 85 dBA, as do Nova Scotia draft regulation guidelines(34A). Proposed new Federal Treasury Board Standards require hearing protection at noise levels over 84 dBA.

Certain legislation (Federal Government and Quebec) specify that hearing protectors must comply with Canadian Standards Association (C.S.A.), Standard Z.94.2.1965, although only the Federal Government specifies "as amended". New Brunswick legislation specifies that hearing protectors must comply with C.S.A. Standard Z.94.2-1974, as does British Columbia. However legislation in British Columbia also has a table giving the C.S.A. Standard Class of hearing protector that may be worn in prescribed sound levels as in Table 3.4. Alberta legislation contains a similar table to that in Table 3.4, as does Ontario draft legislation. Ontario and Federal Treasury Board proposed legislation also include Noise Reduction Rating (NRR) hearing protector requirements.

Audiometric Testing

Three provinces, Alberta, British Columbia, and Saskatchewan specify requirements for audiometric testing (Saskatchewan in the compliance code) as do 3 draft provincial regulations. In Quebec, medical examinations may be required periodically, while the Federal Government specifies that audiometric tests may be required in certain situations >84 dBA in Treasury Board Proposed Standard. Nova Scotia have draft guidelines respecting noise exposure which include audiometric test requirements. Manitoba, New Brunswick, Newfoundland, North West Territories, Ontario, Quebec, Prince Edward Island, and the Yukon, do not presently require audiometric tests.

Alberta legislation requires establishments with high noise levels to set up a hearing conservation programme which may include audiometric testing. When audiometric testing is required, it may only be conducted by qualified people. In this case the audiograms shall be made available to the Department of Health. Permissible background noise conditions for audiometric testing are specified in the regulations.

British Columbia legislation states that in any area where levels exceed the criteria, the employer is responsible for the establishment and maintenance of a hearing test program. The criteria are (1) 85 dBA steady noise and (2) an impact noise table as shown in Table 3.5. Details of when hearing testing should be conducted, by whom, and recording and keeping of the test results are also required.

Warning Signs

Although warning signs are prescribed in 6 of the present occupational noise laws in Canada, the requirements vary, particularly in the wording of the sign. The Federal Government, New Brunswick and Ontario, require warning signs where the level is greater than 90 dBA, Saskatchewan where the level is greater than 85 dBA. The Federal Government also requires signs where the impact noise is greater than 140 dB peak sound pressure level. British Columbia, requires signs where levels exceed the specified limits. Alberta, Manitoba, Newfoundland, Nova Scotia, Prince Edward Island, Quebec and Yukon, do not require warning signs.

The Federal Government and British Columbia require signs warning persons that a noise hazard exists and the type of hearing protection required. The Federal Government also requires the permissible exposure time to be stated. Saskatchewan requires the range of noise levels measured to be stated. New Brunswick requires signs which (1) warn individuals that hearing protectors are required, (2) are in contrasting letters at least 4" (102 mm) high and (3) are at least 18" x 24" (457 mm x 609 mm) in size.

Manitoba proposed legislation requires warning signs that not only clearly identify that a potential sound exposure hazard exists, but also specify the type of hearing protection required to be worn and used in that area. Draft Federal Treasury Board Standard requires clearly legible warning signs where employees may be exposed to an Leq of 90 dBA or above, indicating that the area is a high noise area and that hearing protectors are required.

Noise Surveys

Surveys of noisy places are only specifically required by the Federal Government, and Saskatchewan. In the proposed legislation they are also required in Ontario and Manitoba. The Federal Government states that noise surveys may be required where the safety officer believes levels are sufficient to impair employees hearing. Saskatchewan legislation states that all occupational establishments with noise levels >85 dBA must be surveyed and documented within 3 months of the promulgation of the regulation and thereafter when there is reason to believe that substantial changes in noise levels have occurred. Ontario proposed regulations contain a detailed code for noise measurement. In most provinces a noise survey comes under the powers of an inspector.

Noise and Vibration Control

Only Quebec mentions this subject. In their workplace regulations under the Quebec Environmental Quality Act[39] it is stated that noise and vibration capable of producing harmful effects on workers shall be reduced by one or all of the following means:

(a) isolation of noise sources;
(b) limitation of the intensity and duration of these noises; and
(c) installation of a soundproof device to isolate working areas from sources of noises or vibrations.

4. Hearing Conservation Programmes and Education

Whenever noise exposures are such that an unavoidable risk of permanent hearing loss exists, a hearing conservation programme should be provided[47]. Such programmes should contain 3 elements: education concerning the hazards of noise; education in the proper use and supervision of the wearing of hearing protection; and monitoring audiometry, including periodical medical examination, performed when necessary. Monitoring audiometry, if properly planned and executed, identifies workers at risk from incipient hearing impairment, so that they can be removed from the noisy workplace before excessive irreversible damage is caused. Since occupational noise regulations allow a certain risk of permanent hearing loss, a hearing conservation programme is highly desirable in addition to the specification of maximum exposure levels. Hearing conservation programmes are considered desirable when 8 hour daily exposures exceed 75 dBA[47]. Present concepts of acceptable risk and economic constraints limit the practical application of these programmes in most countries including Canada to levels around 85 dBA.

There is good evidence that well managed hearing conservation programs do protect the hearing of workmen[48]. Some aggressive hearing conservation programmes have been introduced into Canadian industry over the last 10 years and these should soon begin to bear fruit. More and more industries are becoming conscious of sound levels. Specifications for noise levels are being included when new machinery is ordered, and industries are becoming aware that very often the cost of engineering out noise is less than the cost of compensation paid for hearing loss. Awareness of the harmful effect of noise, both by labour and by management is probably the largest single incentive toward reducing occupational hearing loss.

Occupational noise regulations are beginning to recognize the importance of hearing conservation programs. Alberta regulations detail regular audiometric testing for noise exposed workers and a reporting system for those showing signs of hearing loss. British Columbia requires annual hearing tests for noise-exposed workers and records to be kept for the period of employment.

Draft Federal regulations specify audiometric tests for noise exposed workers and record keeping. The Ontario proposed regulation contains as Appendix Nb, January 19, 1982, a "Code for Medical Surveillance of Noise

Exposed Workers". The objective of the Ontario Medical Serveillance programme is to protect the health of workers by: (1) ensuring fitness for exposure to noise, (2) evaluating the effect of noise on workers, (3) enabling remedial action to be taken when necessary; and (4) providing health education. To achieve this the programme must consist of the following: (1) pre-employment and pre-placement examinations including audiometric tests, (2) periodical medical examinations, (3) health education, and (4) record keeping. The Manitoba proposed regulation is presented as a basic element of a hearing conservation programme. Other elements of the Manitoba programme will include development of educational materials for employers and workers, and a Code of Practice, which will contain detailed information to provide practical guidance with respect to provisions of the regulation. Exposure monitoring data, audiometric test results, health histories and associated reports must be maintained for the duration of a worker's exposure. The employer and workplace safety and health committee or worker representative are to be advised regarding the effectiveness of existing practices to control worker exposure to noise and the need for additional control measures.

5. Limitations of Present Regulations

Present Canadian occupational noise regulations are aimed primarily at protecting the hearing of the majority of workers in the speech frequencies. Protection of the hearing of acoustic frequencies outside this range, though even more noise sensitive, is only indirect and limited.

One of the major problems is lack of agreement on the appropriate methods of assessing both hearing loss and hearing disability and their relationship with each other. The question of what constitutes a hearing handicap and how it should be measured has not been resolved.

A successful method of assessing hearing handicap should take into account the economic and social handicap of the hard-of-hearing person and yet should be relatively quickly measured in a reproducible manner. At the present time evaluations of social and economic handicap are very time-consuming to undertake and are still in the experimental stage[49,50]. Current methods rely on the indirect relationship between hearing threshold as measured by pure tone threshold acuity and subjective complaints.

Another factor to be considered is that the effectiveness of any regulation relies heavily on its enforcement, voluntary or otherwise. Since most Canadian occupational noise regulations allow hearing protection to be used where the noise cannot be reduced to acceptable levels, the employer must not only provide hearing protection, but also ensure that it is worn properly to give adequate protection against hearing loss.

6. Worker's Compensation for Occupational Noise in Canada

In general industrial noise-induced hearing loss claims are accepted by the Workers' Compensation Boards if:

(a) there is an adequate history of exposure to hazardous noise in the workplace, and
(b) an otologist finds that the worker has a hearing loss that could have been caused by noise exposure.

It then has to be determined if the hearing loss is of sufficient magnitude to be considered pensionable.

Compensation for hearing loss due to occupational noise is dealt with very similarly in all provinces except British Columbia and Quebec, as shown in Figure 4.1. This figure shows that most provinces use a 35 dB low fence (the smallest amount of hearing loss that is compensated) and an 80 dB high fence (total deafness in one ear). The hearing loss calculation is an average of the 500, 1000, 2000 and 3000 Hz frequencies for each ear. The better ear is weighted by 5/1 which means that the disability rating for the better ear is five times as great as the rating for the poorer ear. The disability rating schedule used by these provinces is shown in Figure 4.2., Table A. Total deafness in one ear is thus rated at the equivalent of 5% total body impairment. Total deafness in both ears is rated at 30% total body impairment.

Slight differences in the way some of the provinces compensate hearing loss include (1) applying a presbycusis correction factor of 5 dB for each year over 60 (Newfoundland, Ontario and Alberta), (2) giving an additional 2% compensation for tinnitus (Ontario and Alberta), and (3) giving 60% disability for sudden complete bilateral deafness (New Brunswick and Alberta), who also have a schedule for unilateral deafness (see Figure 4.2, Table B).

Hearing loss compensation in the British Columbia regulation presently varies significantly from the above. However they apparently have proposed legislation to change the audiometric frequencies averaged to include 3000 Hz. Since this recommenation has been under consideration for several years now and immediate action is not anticipated[46], the low fence would also increase from 28 dB to 35 dB[46]. Their present disability rating schedule is shown in Figure 4.2, Table C. British Columbia awards a lower percentage compensation for total deafness, 3% for one ear and 15% for both ears, however their definition of total deafness in one ear is 68 dB rather than 80 dB, and thus the actual monetary compensation is claimed to be comparable with other provinces[51].

Only the province of Ontario includes guidelines to be taken for rehabilitation in its draft. These include authorization for hearing aids, lip-reading classes and vocational rehabilitation (the latter when employees are recommended for non-hazardous noise exposure employment).

Discrepancies exist in the relationship between percentage hearing loss and total pensional disability. In Canada total hearing loss is rated at between 15% and 50% of total pensionable disability. Blindness, on the other hand, is equated with 100% pensionable disability. It has been said that total hearing is one of the primary senses, and most jobs are impossible for the totally deaf and many are impossible for the hard of hearing[48].

Hearing loss produced by occupational exposure to noise has aroused increasing interest over the last decade[48]. One of the main reasons for this is the rise in the number of claims and the associated rise in the dollar cost of these. Figure 6.3, shows, as an example, the dramatic increases in Ontario over the last 30 years. It is likely, as the cost increases, and engineering technology improves, that high noise levels will be engineered out at source or masked. Until such time the cost of compensation is borne directly by industry and thus passed back to the consumer.

7. Health and Welfare Programme in Occupational Noise

In protecting the health of Canadians from noise exposure, the Non-Ionizing Radiation Section (NIRS) of the Radiation Protection Bureau, Environmental Health Directorate, Department of Health and Welfare began by concentrating on the most significant health effect of noise - hearing loss - and the noise exposure that causes this effect and thus occupational noise exposure in Canada has been studied. There are also plans to investigate noise levels causing other health effects such as sleep loss, stress and annoyance, and the masking of important warning signals.

A background document entitled "Noise Hazard and Control", was published in 1979[53]. This doucment summarizes known health effects of noise (both auditory and non-auditory) indicates the major sources of noise, and describes Canadian noise legislation. It also indicates areas of incomplete knowledge, mainly related to noise-induced hearing loss, which are:

(a) the effects of impulse noise and continuous noise in the 4 - 6 kHz frequency range
(b) the accuracy and effectiveness of screening audiometric testing and screening audiometers
(c) the assessment of the total noise exposure of Canadians and its relation to hearing loss, and
(d) the investigation of the effects of hearing loss by various noise exposure limits.

Since then, noise levels and the progression of noise-induced hearng loss in specific industries in Canada have been evaluated.[54] The method of testing hearing (audiometric testing), and the acoustic accuracy of audiometers have also been investigated.[55] Current work is under way in conjunction with the provinces, to move towards consistent regulations for occupational noise exposure and hearing conservation. This is presently being conducted through the Federal-Provincial Advisory Committee on Occupational and Environmental Health.

Further surveys are planned on the measurement of noise from various sources, including sources emitting high frequency sound and ultrasound. Limited surveys of hearing acuity of people of various ages and noise exposures have been conducted. The contribution to hearing loss that can be related to age and exposure to various noise levels has also been investigated.

There are thus many present and future challenging problems to be investigated in the area of protection of health from acoustics radiation.

8. Conclusions

The main conclusions reached are as follows:

(1) Education of both employers and employees is an important element of most successful programmes for reducing occupational hearing loss.
(2) It is unlikely that levels below 75 dBA are harmful to workers.

(3) Considerable improvement of Canadian occupational noise regulations can be achieved by expanding them to include all the possible aspects of hearing conservation.
(4) The dramatic increase in number of claims for occupational hearing loss in the past decade and the cost of compensation provides a strong incentive for effective hearing conservation programmes.
(5) It would appear that the scientific arguments in favour of the 5 dB dose-trading relationship are less strong now than they were 10 years ago, although recent experiments have tended to confirm the protective benefits of intermittency.
(6) Further research is required into appropriate methods of assessing hearing loss and hearing disability and their relationship with one another.

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Table 1.1. Permissible A-weighted Noise Exposure Levels, (ACGIH 1967)[8].

Duration per Day Hours	Sound Level dBA*
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
3/4	107
1/2	110
1/4	115-C**

* Sound level in decibels as measured on a standard sound level meter operating on the A-weighted network with slow meter response.

** Ceiling Value.

Table 3.1. Current and Proposed Occupational Noise Regulations of Wide Application in Canadian Provinces (August, 1982).

Jurisdiction / Agency	Regulation or Guidelines or Proposal	Steady-State Noise			Impulse Noise			Year
		8 hour/day Limit[1]	Exchange Rate (dB)[2]	Maximum (dBA)[3]	Separate (S) or Combined (C)	Maximum (peak)[4]	Daily limit on number of impulses	
Federal Labour Canada	Regulation	92	5	115	S	140	No	Jan. 31 1973
Federal Health & Welfare (Existing)	Guideline	92	5	115	S	140	No	1972
Federal Health & Welfare (Proposed)	Proposal	90	3	-	C	-	No	April 14 1982
Alberta	Regulation 314/81	85	5	115	S	140	Yes	Sept. 15 1981
British Columbia	Regulation	90	3	105	S	140	Yes	Oct. 1 1979
Manitoba (Existing)	Guideline MR204/77 Sec 11 & 12	85	5	115	S	140	Yes	1977
Manitoba (Proposed)	Proposal	90	3	115	C	140	No	May 1982
New Brunswick	Regulation	90	5	115	S	140	Yes	1977
Newfoundland	Regulation O.C.799/79 Section 31(5)	85	5	115	S	140	Yes	1979
North West Territories	Regulation 271-77	90	5	-	-	140	No	June 1977
Nova Scotia	Regulation	85	5	115	S	140	Yes	1967
Ontario (Existing)	Regulation	90	5	115	S	140	Yes	1978
Ontario (Proposed)	Proposal	90	3	115	C	135	No	June 1981
Quebec	Regulation 44	90	5	115	S	140	Yes	Jan. 1981
Saskatchewan	Regulation[5] 567/81 Part IX	85	3	-	C	-	No	April 15 1981
Prince Edward Island	Regulation	Note 6			-	-		1975
Yukon								

Notes

1. Maximum permissible daily 8 hour time weighted average exposure level Leq (dBA).
2. Time/intensity doubling rate.
3. Maximum permissible hearing level without hearing protection (dBA).
4. Maximum permissible level (dB peak SPL).
5. Details taken from "Noise Regulations - A guide to compliance for occupational health committees, employers and workers", 6M/09/81, Saskatchewan Labour.
6. In Prince Edward Island levels are not specified in the legislation. Federal Labour Canada regulations are followed.

Table 3.2. Impulse Noise Exposure

Peak Sound Pressure Level dB	Maximum Number of Impulses Per Day
120	10,000
130	1,000
140	100
Greater than 140	0

Table 3.3 Noise Protection in Present and Proposed Occupational Noise Regulations. (August 1982)

Jurisdiction / Agency	Noise Protection Measures: Hearing Protectors — Required when occupational exposure limits are exceeded	Meet CSA Std.	ERR Std.	Audiometric Testing Required	Warning Signs Required	Noise Survey Required	Noise & Vibration Control Specifications Required	Hearing Conservation Program
Federal Labour Canada	>90 dBA or >140 dB peak SPL	✓	-	✓Conditional	✓	✓	-	-
Federal Health & Welfare (Existing)	>90 dBA or >140 dB peak SPL	✓	-	✓Conditional	✓	✓	-	-
Federal Health & Welfare (Proposed)	>84 dBA	-	✓	✓ 84 dBA	✓	✓	-	✓
Alberta	✓	✓	-	✓	-	-	-	✓
British Columbia	Detailed level requirements	✓	-	✓	✓	-	-	✓
Manitoba (Existing)	✓	-	-	No	-	-	-	-
Manitoba (Proposed)	>85 dBA	-	-	✓	✓	✓	-	✓
New Brunswick	✓	✓		No	✓	-	-	-
Newfoundland	✓	-	-	No	-	-	-	-
North West Territories	✓	-	-	No	-	-	-	-
Nova Scotia	✓ At discretion of inspector	-	-	Specifications (included in guidelines)	-	-	-	-
Ontario (Existing)	✓	-	-	No	✓	-	-	-
Ontario (Proposed)	>85 dBA	✓	✓	✓ 85 dBA	✓	✓	-	✓
Quebec	✓	✓		No	-	-	✓	-
Saskatchewan	>85 dBA	-	-	✓Recommended	✓	✓	-	-
Prince Edward Island	✓	-	-	No	-	-	-	-
Yukon	-	-	-	No	-	-	-	-

Table 3.4. Hearing Protector Requirements in B.C. Legislation[28].

C.S.A. Standard Z94.2.-1974 Class	Sound Level dBA (Note 1)
C	85-93
B	94-99
A	Over 100
A	Impulse (Note 2)

Note 1: This is understood to mean steady level[46].

Note 2: This is understood to mean where Impulse Noise exceeds the B.C. Schedule for impact noise where the maximum number of impacts per 24 hour period are given for specified peak sound pressure levels[22,46].

Table 3.5.

British Columbia Schedule for Impact Noise Levels Above Which Audiometric Testing Routinely Required[28].

Peak Sound Pressure Level (dB)	Maximum Number of Impacts Per 24 Hour Period
Over 135	0
134	112
131	225
128	450
125	900
122	1800
119	3600
116	7200
113	14400

Table 6.1.

Workers Compensation for Occupational Hearing Loss in Canada

Audiometric Frequencies Used (Hz)	Method of Calculation	Low Fence (ANSI/ISO)	High Fence (ANSI/ISO)	Better Ear Correction	Presbycusis Correction	% Per Decibel loss		Maximum % for Total Deafness			% for Tinnitus	Provinces
						Partial (both ears)	Unilateral or Acute Traumatic Hearing Loss	One Ear	Both Ears	Sudden Complete Bilateral Deafness		
500, 1000, 2000	average	25 dB	65 dB	5/1	.5 dB each year over 60	not known	-	5	30	30 - 60	-	Quebec
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1	.5 dB each year over 60	A*	-	5	30	-	-	Newfoundland
500, 1000, 2000, 3000	average (rounded up to next 5 dB increment)	35 dB	80 dB	5/1	-	A*	B*	5	30	60	-	New Brunswick
500, 1000 2000, 3000	average	30 dB	80 dB	5/1	.5 dB each year over 60	A* extended down to .1% at 30 dB	-	5	30	60	-	Northwest Territories
C O N F I D E N T I A L - N O T D I S C L O S E D												Nova Scotia
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1	.5 dB each year over 60	A*	-	5	30	-	2	Ontario Manitoba P.E.I.
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1		A*	-	5	30	-	-	Saskatchewan
500, 1000, 2000, 3000	average	35 dB	80 dB	5/1	.5 dB each year over 60	A*	B*	5	30	60	2	Alberta
500, 1000, 2000	average	28 dB	68 dB	4/1	-	C*	-	3	15	30	-	British Columbia

* A, B, C, see Figure 4.2 Tables A, B, and C.

Table 6.2. Percent Disability For Varying Degrees of Hearing Loss.

Table A. Partial Hearing Loss Where Both Ears are Affected

dB Hearing Loss	% Disability
35 dB (ANSI/ISO)	.4
40	.7
45	1.0
50	1.4
55	1.8
60	2.3
65	2.8
70	3.4
75	4.0
80	5.0

Table B. Unilateral Deafness (Alberta) or Acute Traumatic Hearing Loss (New Brunswick)

dB Hearing Loss	% Disability
30 dB (ANSI/ISO)	1
40	2
50	3
60	4
70	5

Table C. Non-Traumatic Hearing Loss (British Columbia)

Loss of Hearing in dB	% of Total Disability	
	Ear Most Affected PLUS	Ear Least Affected
0 - 27 (ANSI/ISO)	0	0
28 - 32	0.3	1.2
33 - 37	0.5	2.0
38 - 42	0.7	2.8
43 - 47	1.0	4.0
48 - 52	1.3	5.2
53 - 57	1.7	6.8
58 - 62	2.1	8.4
63 - 67	2.6	10.4
68 or more	3.0	12.0

Table 6.3.

Province of Ontario: WCBO Industrial Hearing Loss Claims (48)

Years	No. Claims (c) +	No. Pensioned (p) +	% c/p	Aver. PD	New Annual Payments $ (estimated)*
1950-1960	130	39	30	3.96°	1,404
1961-1965	312	62	10.9	3.96	4,910
1966-1970	862	238	27.6	3.96	18,849
1971	370	130	35.1	3.96	51,480
1972	382	148	38.7	3.96	58,608
1973	582	208	35.7	7.02*	146,016
1974	986	483	50.0	7.02	339,066
1975	1519	639	42	7.02	448,578
1976	2463	1066	43	7.02	702,000
1977	2405	1364	57	7.02 est	957,528
1978	2091	1338	64	7.02 est	930,276

° from Alberti et al (53).
* computed from patients studied.
PD = pensionable disability.
Mean age of claimants between 1971 and 1975, 55.7 years.
Aver. PD includes presbycusis correction; as applied at time.
Assumption made that presbycusis correction and frequencies averaged changed January 1, 1973.
Until 1974 claimants pensioned only when out of noise.
From 1974 onwards claimants may receive pension and continue working in noise.
+ Courtesy Dr. Margaret Hayley, Hearing Consultant, Workmen's Compensation Board of Ontario.
* expressed in 1976 dollars.

A TECHNIQUE FOR ZOOM TRANSFORM AND LONG-TIME SIGNAL ANALYSIS

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ABSTRACT

This paper reviews a useful technique for performing zoom transform. The method involves recording a long-time signal and transforming it in parts, using a smaller transform. Its ability to handle long-time signals renders the method attractive to both acousticians and vibration engineers. Examples and the listing of a computer program are given to demonstrate the technique.

SOMMAIRE

Une technique pratique pour réaliser la transformation avec zoom nécessite l'enregistrement d'un signal de longue durée, pour ensuite le transposer en parties en utilisant une plus petite transformation. La possibilité de traiter des signaux de longue durée accroît l'intérêt de cette technique pour les spécialistes de l'acoustique et des vibrations. Des exemples ainsi qu'une liste imprimée d'un programme informatique sont donnés pour illustrer cette technique.

The discrete Fourier transform (DFT) has become a very important tool for analysis because of the availability of efficient computer algorithms and low priced mini- and micro-computers with fast array processors. The efficient method for computing DFT is called the fast Fourier transform (FFT). Most machines, however, are usually limited to a 1 k or 2 k point transform (k = 1024). This limitation often presents problems to acousticians who have to analyse very long time signals and to vibration engineers who need fine resolution spectra for modal analysis. Although FFT instruments with zoom features are readily available, software can be difficult to find. For example, no such programs are listed in "Programs for Digital Signal Processing" by the IEEE Press.[1]

Techniques for zoom transform and for long-time signal analysis are available in the literature,[2-4] but they involve fairly complicated procedures. There is, however, a straightforward method used by the Bruel and Kjaer Type 2033 "High Resolution Signal Analyser" to solve both problems. Unfortunately, neither the Bruel and Kjaer manual nor Thrane[5] give enough information for other researchers to implement the technique with their own computers. The procedure involves taking smaller transforms on selected data points from different segments of a pre-recorded long-time signal. Although Yip[4] did not promote this procedure in his paper, the mathematical foundation can be gained from his analysis. This paper reviews this technique and presents some examples.

ANALYSIS

Although both the discrete and fast Fourier transform algorithms are, in general, considered for complex variables, the following discussion is restricted to real input data since all experimental time functions are real. Consider a time function $x(t)$ sampled at interval Δt and starting at $t = 0$. If N is the total number of contiguous data points, the finite discrete Fourier transform of $x(t)$ is given by the following equation:[6]

$$X(n\Delta f) = \sum_{k=0}^{N-1} x(k\Delta t)\, e^{-j2\pi nk/N} \tag{1}$$

where $n = 0, 1, \ldots N-1$, and $\Delta f = 1/N\Delta t$ is the spectral resolution.

In practice, the sampling frequency $f_s(= 1/\Delta t)$ is governed by the highest frequency of interest, f_m. The sampling theorem requires that $f_s = 2f_m$. Thus,

$$f_m = \frac{1}{2\Delta t} \tag{2}$$

As a result, N has to be large for fine resolution analysis at high frequencies. If the hardware limits N to 1 or 2 k, the usual zoom technique by frequency shift has to be used. This paper offers a different solution.

Suppose the computer is limited to a P (= 1 k for example) point transform and the requirement for N is M (= 10 for example) times P. For some machines these N data points have to be stored either in a disk or a tape file first. The proposed technique involves performing an ordinary 1 k transform ten times using data selected from different parts of the 10 k samples. After the results from the ten smaller transforms have been properly combined, the solution is equal to a 10 k transform. It is also possible to compute, with the same resolution, only a selected portion of the whole spectrum. Thus, this technique can be considered as a zoom transform also. The mathematical background is given in the following paragraphs.

Let the N data points be divided into P blocks of M points each, such that $N = MP$. Using the following index transformation,[4]

$$k = rM + s \tag{3}$$

where $r = 0, 1, \ldots, (P-1)$
$s = 0, 1, \ldots, (M-1)$.

Equation (1) can be rewritten as

$$\begin{aligned} X(n\Delta f) &= \sum_{r=0}^{P-1} \sum_{s=0}^{M-1} x\left[(rM + s)\Delta t\right] e^{-j2\pi n(rM+s)/N} \\ &= \sum_{s=0}^{M-1} e^{-j2\pi ns/N} \sum_{r=0}^{P-1} x\left[(rM + s)\Delta t\right] e^{-j2\pi nr/P} \end{aligned} \tag{4}$$

Another index transformation,

$$n = \alpha P + \beta \tag{5}$$

with $\alpha = 0, 1, \ldots, (M-1)$
$\beta = 0, 1, \ldots, (P-1)$

will recast Eq. (4) into

$$X[(\alpha P + \beta)\Delta f] = \sum_{s=0}^{M-1} e^{-j2\pi\alpha s/M} e^{-j2\pi\beta s/N} \sum_{r=0}^{P-1} e^{-j2\pi\beta r/P} x[(rM + s)\Delta t] \quad (6)$$

The first summation on the index r of Eq. (6) represents a DFT on the P sampled points, x(s), x(M+s), x(2M+s), etc., to give P complex spectral components. The DFT can be carried out by the usual FFT algorithm and this operation has to be repeated M times as s changes from 0 to M-1. These intermediate results are termed partial spectra. That is

$$X_s(\beta\Delta f) = \sum_{r=0}^{P-1} e^{-j2\pi\beta r/P} x[(rM+s)\Delta t] \quad (7)$$

where $\beta = 0, 1, \ldots, (P-1)$.

As pointed out by Thrane,[5] the term $\exp(-j2\pi\beta s/N)$ represents a phase shift correction to the frequency components of each of the M partial spectra. This is governed by the index s and is required to compensate for the time shift between the M sets of data used in the transform. Thus, Eq. (6) can be rewritten as

$$X[(\alpha P+\beta)\Delta f] = \sum_{s=0}^{M-1} e^{-j2\pi\alpha s/M} X'_s(\beta\Delta f) \quad (8)$$

where $X'_s(\beta\Delta f) = X_s(\beta\Delta f)\, e^{-j2\pi\beta s/N}$ are the M compensated partial spectra.

There is no mention of the other term, $\exp(-j2\pi\alpha s/M)$, in Thrane's paper, but it may be thought of as a weighting function of the M compensated partial spectra. For a given value of α, Eq. (8) generates up to P spectral lines. The number selected within the range $\alpha P\Delta f$ to $[(\alpha+1)P-1]\Delta f$ is determined by the choice of the range for β. This procedure provides a form of zoom transform. By allowing α and β to take on all values from 0 to M-1 and to P-1, respectively, the full spectrum of N lines can be generated if necessary.

To minimize storage space and computing time, Yip[4] chose to re-order the summation procedure so that data could be used in chronological order. He had to treat the phase shift factor $\exp(-j2\pi\beta s/N)$ as unity, however, and to correct the results after the zoom spectrum had been computed. As the correction factor depends on the type of signals being analysed, his zoom scheme is less attractive than the method presented here.

PROGRAMMING HINTS

The M partial spectra as defined by Eq. (7) can be performed with any available FFT program. It is important to note, however, that there are FFT programs for complex input data and other programs for real input data only. The two types will have different input and output format.

For real input data the frequency spectrum obtained is a conjugate even function; that is,

$$X_s[(P-\beta)\Delta f] = X_s^*(\beta\Delta f) \quad (9)$$

where * denotes complex conjugate. Some FFT programs intended for use only with real input may return only P/2 points. As Eq. (8) requires the complete P lines of the partial spectra, they must be recreated using Eq. (9). In general, P is set by the available software or hardware and is much larger than M. The second summation over the index s can be performed in the straightforward manner.

It is important to realize that the DFT is just an approximation of the continuous Fourier transform, and that there are problems associated with its usage, for example, aliasing, leakage and picket-fence effect. These problems have been dealt with in the literature.[7] If it is necessary to apply windowing such as Hanning to the data, it should be applied to the original N data points. For the full spectrum, only the first N/2 frequency lines are independent.

EXAMPLES

To verify the proposed technique, 512 data points are generated using an analytical function. First, an ordinary transform on the 512 data points was performed to give 256 complex frequency results. The same 512 data points were then divided into 128 blocks of four data points each to be used in the proposed transform procedure. No significant differences were found between the two results.

To illustrate the zoom capability, a test signal consisting of two sine waves (198 Hz and 200 Hz) and a band-limited random noise was used. The test signal was sampled at a rate of 1 kHz. Initially, an ordinary 512 point transform was used. As the spectral resolution for this transform was only 1.95 Hz, it would not be capable of resolving the two sine waves (see Fig. 1). Increasing the total number of data points to 5120 and using the proposed transform technique with P = 512 and M = 10, the spectral resolution became 0.195 Hz and it was possible to resolve the two sine waves, as indicated in Fig. 2. The listing of a sample program is given in the Appendix.

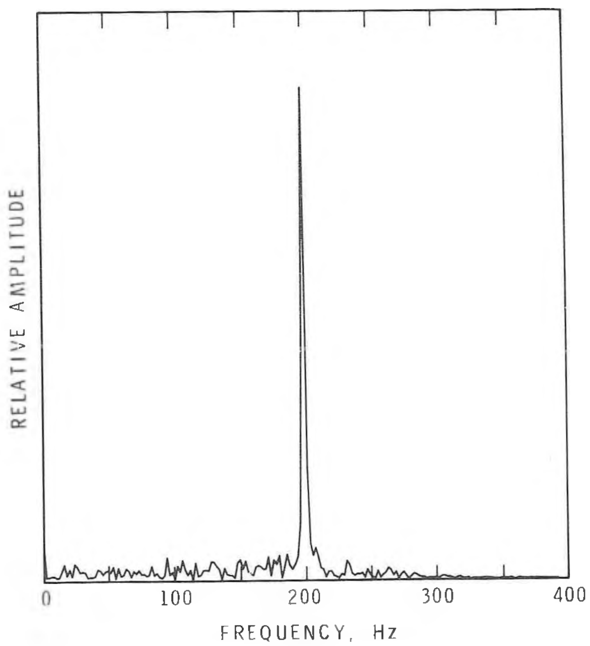

Figure 1. Overlapped spectrum obtained by the ordinary FFT method using 512 points. Spectral resolution = 1.95 Hz

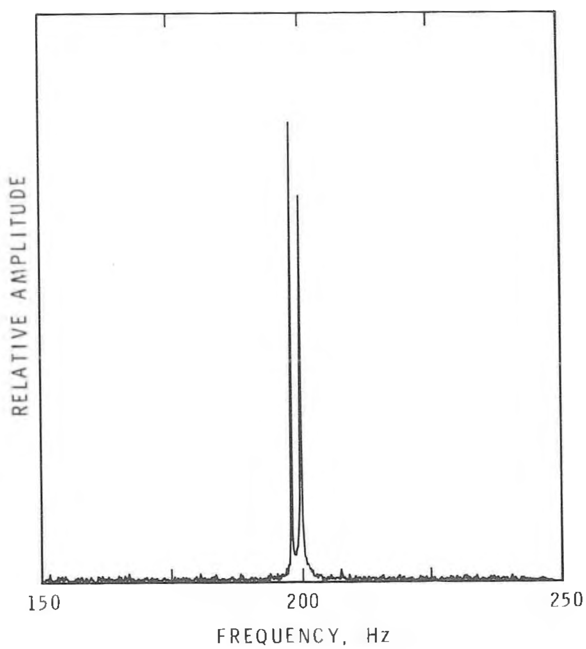

Figure 2. Fine resolution spectrum obtained by the proposed transform method using 5120 points. Spectral resolution = 0.195 Hz

CONCLUSION

A simple technique for zoom transform and long-time signal analysis has been reviewed and examples have been given to illustrate its applications. It is hoped that other acousticians and vibration engineers will find it useful.

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APPENDIX

```
C     SAMPLE PROGRAM FOR A 10 k POINT TRANSFORM USING A 1 k FFT
C     SUBROUTINE.  THE FFT SUBROUTINE CALLED FAST BY BERGLAND AND DOLAN
C     IS FOR REAL INPUT DATA ONLY AND IS LISTED IN THE IEEE BOOK ON
C     PROGRAMS FOR DIGITAL SIGNAL PROCESSING.
      COMPLEX C, F, CEXAF, CEXBA
      DIMENSION P(10240), PI(1026), C(1024), F(1024)
      COMMON/CONS/PII, P7, P7TWO, C22, S22, PI2
C     SPLIT THE 10240 POINTS INTO 1024 BLOCKS OF 10 DATA POINTS EACH.
      NP=1024; # OF BLOCKS GOVERNED BY THE FFT SIZE.
      NM=10; # OF POINTS PER BLOCK.
      NMH=NM/2
      NP1=NP+1
      NPH1=NP/2+1
      NPH2=NP/2+2
C     FOR 'ZOOM' TRANSFORM, ENTER PARTICULAR NAF VALUE FOR ALPHA.
C     EXAMPLE GIVEN IS FOR THE COMPLETE SPECTRUM.
C     NOTE, A 10 k TRANSFORM GIVES 5 k INDEPENDENT FREQUENCY COMPONENTS
C     ONLY.
      DO 20 NAF=1,NMH
      NAFO=NAF-1
      DO 25 NBE=1, NP
      F(NBE)=0.0
25    CONTINUE
      DO 30 NS=1, NM; SET UP EXPONENTIAL ALPHA-S TERM
      NSO=NS-1
      ARGAF=2.*3.14159*NAFO*NSO/NM
      EXAFR=COS(ARGAF)
      EXAFI=-SIN(ARGAF)
      CEXAF=CMPLX(EXAFR, EXAFI)
```

```
C     PERFORM 1 k POINT TRANSFORM WITH SELECTED DATA FROM EACH BLOCK
      DO 40 NR=1, NP
      NRO=NR-1
      J=NRO*NM+NS
      PI(NR)=P(J)
40    CONTINUE
      CALL FAST(PI, NP)
C     SINCE SUBROUTINE FAST GIVES (NP/2+1) FREQUENCY RESULTS ONLY, IT IS
C     NECESSARY TO GENERATE RESULTS FOR THE REST OF THE PARTIAL
C     SPECTRUM
      J=1
      DO 50 L=1, NP1, 2
      LC=L+1
      C(J)=CMPLX(PI(L), PI(LC))
      J=J+1
50    CONTINUE
      J1=1
      DO 60 J=NPH2, NP
      K=NPH1-J1
      C(J)=CONJG(C(K))
      J1=J1+1
60    CONTINUE
      DO 70 NBE=1, NP; SET UP EXPONENTIAL BETA-S TERM
      NBEO=NBE-1
      ARGBA=2.*3.14159*NBEO*NSO/N
      EXBAR=COS(ARGBA)
      EXBAI=-SIN(ARGBA)
      CEXBA=CMPLX(EXBAR, EXBAI)
      F(NBE)=F(NBE)+C(NBE)*CEXAF*CEXBA
70    CONTINUE
30    CONTINUE
      DO 80 I=1, NP
      TOR=REAL(F(I))
      TOI=AIMAG(F(I))
      TYPE TOR, TOI
80    CONTINUE
20    CONTINUE
      STOP
      END
```

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