OCTOBER, 1979
Vol. 7, No. 4

acoustics and noise control in canada

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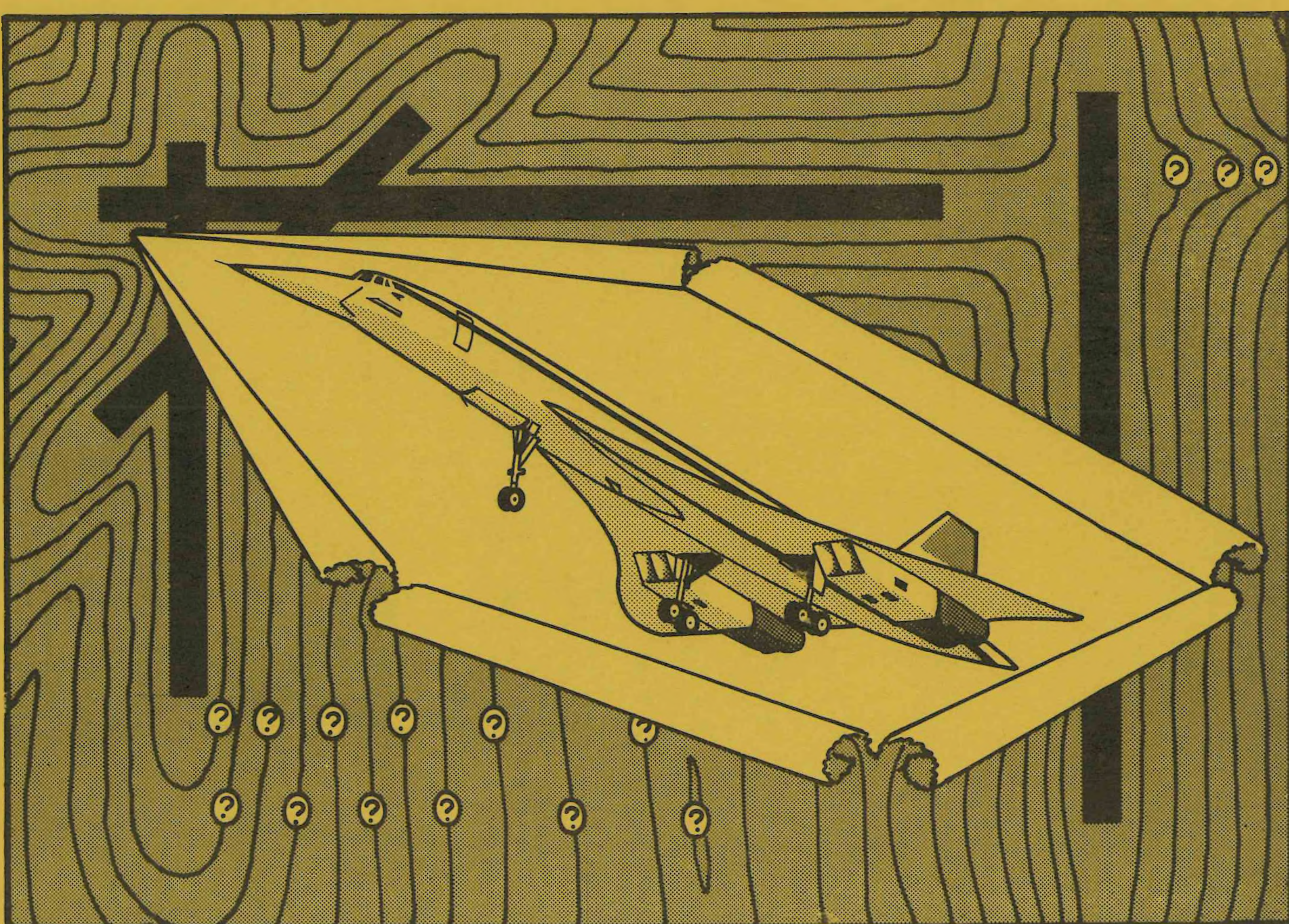
l'acoustique et la lutte antibruit au canada

Our cover illustrates the articles on pages 4 and 11-15.



Simon Tuckett

acoustics and noise control in canada

l'acoustique et la lutte antibruit au canada

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NEW RESEARCH CONTRACTS

To McMaster University, Hamilton (Dr. F. L. Hall and Dr. S. M. Taylor), $9,487 for "Assessment of guidelines for sound level limits in residential areas." Awarded by National Research Council.

To University of British Columbia (Dr. S. G. Hutton), $11,013 to "Determine the vibratory characteristics of mining equipment and assess the effects of direct vibration on workers." Awarded by Dept. of Energy, Mines and Resources.

To D-G Instruments, Kanata, Ontario, $371,500 for "Development of a helicopter ultrasonic air data system." Awarded by Dept. of Industry, Trade and Commerce.

To University of Western Ontario, London (Dr. I. MacNeil), $350 for "Examination of transducer directivity effects in acoustic fish stock assessment surveys." Awarded by Dept. of Fisheries and Environment.

To Brown, Strachan & Associates, Vancouver, $1,100 for "Examination of elimination of vibration of Lions Gate Bridge TV camera." Awarded by Dept. of Transport.

To Independent Acoustic Laboratories, Toronto, $112,716 for "Design and conduct of a noise study in and around the Canadian Pacific rail Agincourt marshalling yard." Awarded by Dept. of Transport.

To Renewable Resources Consulting Services, Sidney, B.C., $1,400 for "Review of noise impacts on birds associated with the proposed reactivation of Boundary Bay airport." Awarded by the Federal Dept. of the Environment.

To L. J. Hutchison, Orleans, Ontario, $22,436 for "Acousto-optics system integration of the CCD (Charge Coupled Device) detector." Awarded by the Dept. of National Defence.

To Baynes Communications Inc., Ottawa, Ontario, $4,900 for "Scientific provision of consulting services to Speech Program, Fisheries and Oceans." Awarded by Dept. of Fisheries and Oceans.

APPEL AUX ARTICLES EN FRANÇAIS

Notre journal est publié en français et anglais - mais il manque des nouvelles et articles en français. Auteurs francophones: Rappelez vous de notre journal quand vous envisagez publier. Nous aimerions entendre plus de vous.

Canadian Standards Association

ACOUSTICS & NOISE CONTROL COMMITTEE

The Acoustics and Noise Control Committee (Z107) of the Canadian Standards Association met at the Wandlyn Viscount Hotel in Windsor, Ontario on 23 October 1979. Three of its Subcommittees (on Noise from Transport Vehicles, on Noise from Small Appliances, and on Noise from Industry) met the previous morning, the Canadian Advisory Committee of ISO/TC 43 on Acoustics met the previous afternoon, and its Task Force on Community Noise met the previous evening. These two days of Standards' meetings immediately preceeded the Annual Meeting of the Canadian Acoustical Association in the same city - a practice that has been followed for several years with minor variations and which is of considerable benefit in minimizing travel costs for the many people involved in both meetings.

Highlights of the CSA meeting included the following items.

a) A new draft standard Z107.51 "Procedure for in-site measurement of noise from industrial equipment" has been approved by the Acoustics and Noise Control Committee, and now passes further up the chain of CSA for approval. A few other draft standards are nearly ready for Committee approval, including a revision of CSA Z107.4 "Pure tone audiometers for limited measurement of hearing and for screening".

b) The Canadian Advisory Committee of ISO/TC 43 on Acoustics will in future report periodically to the CSA Acoustics and Noise Control Committee, essentially as if it were one of its Subcommittees. The CAC will retain its present designation and its direct connection with the Standards Council of Canada for technical matters. The CAC will be expanded to include the Chairman of CSA Z107 and each of its subcommittees, and will thus be more closely in touch with standards activities under the auspices of CSA.

c) A task force has been set up, with John McEwen of the Ontario Ministry of Labour as Coordinator, to advise CSA Z107 of the need for new standards as revisions to existing standards in the area of occupational noise.

T. F. W. Embleton
Committee Chairman

CHANGE OF ADDRESS

Two of the editorial staff have changed address. Please see the inside front cover for the current addresses of (1) the Editor, (2) the Associate Editor - Advertising and Translation.

Third of a Series

We, at Vibron, would like to share the results of some interesting problems which have come our way.

CN TOWER TUNED MASS DAMPERS

CN Tower is a 330' steel antenna mast on a 1500' concrete tower. The steel is enclosed in a circular glass fibre radome leaving an annular space for the antennae. The circular radome gives rise to vortex-shedding and wind tunnel studies indicated resonant frequencies of 0.1, .26, .48, and .81 Hz. Predicted amplitudes in the second and fourth modes would induce fatigue failures in the structure. The study showed that tuned mass dampers, TMD's, would limit amplitudes.

Vibron designed and supervised construction and installation of two TMD's, each of 20,000 lb active weight. Located in the annular space and at the antinodes of the second and fourth modes, the damping was set high so that the two dampers would provide broad-band damping and be effective in the third mode.

The dampers were ring masses on three pendulum arms, on an inverted pendulum giving a natural frequency of .26 Hz. Steel springs acting against the pendulum arms provided the restoring force, and were adjustable, giving a tuned frequency range of 30%. Damping also was adjustable up to 30% of critical, and was provided by hydraulic cylinders in a passive hydraulic circuit-- this allowed simple adjustment of damping with orifice valves, and gave damping which was almost independent of temperature.

Next: Industrial noise control

Transport Canada's Aviation Noise Monitoring Vehicle

Transport Canada has developed a program to monitor aviation noise to help reduce its impact on communities near airports.

There have been significiant changes in aviation-related noise in recent years. Noise abatement measures have become more common at airports and newer jet aircraft are quieter than their predecessors. But at the same time, the number of jet flights has increased.

It is impossible to eliminate all aviation-related noise as long as we rely on air transportation. But the impact of such noise may be reduced.

The noise monitoring program at airports in Transport Canada's Pacific Region will assess the noise levels associated with various aviation activities and the parts of neighbouring communities which are most affected. The results will provide scientific data for airport planning and development. The program is starting in communities served by larger, busy airports.

The program includes analysis of aircraft noise abatement procedures to recommend needed changes consistent with safe operating practices. It is to be used to identify trends in the impact of aviation-related noise on the community as well as monitoring noise sensitive areas during peak traffic and quiet hour periods.

Noise monitoring sites are chosen in the surrounding community to collect noise data. After this "baseline" data is compiled initial actions can be taken, as required, to control or regulate aircraft noise or to plan land use in the vicinity of airports. Follow-up monitoring is done as required to detect changes in "baseline" noise levels.

Some of the noise monitoring projects recently completed or now underway include:

a) up-dating previous noise monitoring data for Vancouver International Airport;
b) monitoring night operations at Vancouver International Airport;
c) providing baseline and comparative noise data for Transport Canada's Environmental Impact Statement on the reactivation of Boundary Bay; and
d) expanding our community noise data base.

The noise monitoring vehicle enables Transport Canada to conduct several specific monitoring projects simultaneously. The customized 3.6 metre van is fully equipped to make it habitable for an operator for lengthy periods of working hours.

Four separate power systems for the electronic monitoring equipment make the van a very mobile and reliable piece of equipment. A roof-mounted microphone picks up sound, converts it to electrical signals and feeds them into a mini computer. This noise level analyzer makes more than 35,000 separate readings an hour. At the same time the computer is analyzing the sounds, it produces a continuous graph of noise levels. Once each hour, the computer also prints an accurate summary of various noise levels (in decibles) and their duration (in seconds).

All ground to air communications are monitored to correlate air traffic control instructions and the operations of individual aircraft with the recorded sound levels. Such communications can themselves be recorded to serve as a double check on the operator's manual record of aircraft activity.

Don't be surprised to see the van parked on your street, in a nearby park, schoolyard, community centre, or even in your neighbour's driveway.

When we can, we'll put the van on display and show you how we are monitoring community noise levels. We may be able to come out at the request of your group or community association, if the van's work schedule permits.

While we've got our electronic ear to the sky we have another ear ready to hear your complaints about aviation noise in the greater Vancouver area. Transport Canada's noise complaint telephone has been in operation since 1974. Your complaints will be investigated as they come in. If aviation-related noise is bothering you, don't hesitate to give us a call, 24 hours a day at 666-3477.

WINDSOR '79 - CONVENOR'S REPORT

The three-day meeting at the University of Windsor was successful although unfortunately not well supported. The Education Day morning activities included the demonstration of two draft Canadian Standards, an acoustics audiovisual festival supported by entries from Sound/Vibration, Bruel & Kjaer, Fisher Valve, and the Ontario Ministries of Environment and Transportation & Communications. There was also a display of community noise monitoring instrumentation. In the afternoon, after tours to the G. M. Transmission Plant and Diffracto Ltd., a reception was held at the University. The guest of honour was Dr. Cameron McInnes, Dean of the Faculty of Engineering, University of Windsor.

The technical sessions were officially opened on Thursday by the President of the University of Windsor, Dr. Mervin Franklin.

Fifty-one papers were read, many based around the theme of the meeting "The Automobile and Its Acoustical Environment". It is hoped that the papers will be made available to members in due course through the CAA Newsletter. The success of the technical session was, in a large measure, due to the cooperation of students and the session chairmen.

The annual dinner was well attended and the after dinner speaker, Mr. Hiliary Payne, presented an inspiring message on the potential for industrial growth in Windsor.

Z. Reif, Convenor

WINDSOR '79 - MINUTES

The following are the minutes of the CAA meeting held in the Wandlyn Viscount Hotel, Windsor, on October 26, 1979.

1. The meeting was called to order by the President, W. Bradley, at 6:05 p.m.

2. The minutes were read by the Secretary and on a motion by T. D. Northwood seconded by A. Behar were accepted as read.

3. J. Piercy tabled the Auditor's report signed by R. J. Donato and the Treasurer presented his report (which follows - Ed). L. Russell moved and D. Whicker seconded the motion that the Treasurer's report must be accepted as read. Carried unanimously.

4. C. Sherry moved and D. Whicker seconded the motion that "the annual membership fees by $10.00".

5. After some discussion, an amendment moved by F. Hall and seconded by A. Behar that "the annual membership fee for students be $0" was adopted. A question from the floor regarding the application of the student fee was answered by L. Russell who said that students should write to him requesting exemption.

6. The main motion was voted on and carried.

7. C. Sherry moved and Dr. Whicker seconded the motion that "a subscription fee of $10.00 annually be applied to any organization." Motion carried.

8. The Secretary read the correspondence received during the year. Details of upcoming meetings may be obtained directly from the Secretary.

9. J. R. Hemingway and D. Quirt seconded a motion of appreciation for the years of service given to CAA by the outgoing President, W. Bradley. Acclamation.

10. J. Piercy tabled a letter from E. A. G. Shaw regarding the possibility of Canada sponsoring an I.C.A. meeting in 1986. It was moved by J. Piercy and seconded by C. Sherry that "the President of CAA form a study group to look into the opportunity offered (by NRC) to consider holding the 1986 ICA meeting in Canada and the Directors shall have a mandate to decide a course of action before the Sydney Congress in July, 1980". Carried unanimously.

11. The President noted that two Directors, W. Bradley and J. Manuel, retire this year. He also noted that the President and Executive are to be elected.

12. H. W. Jones presented the Nominating Committee Report nominating the following:

T. D. Northwood	President
R. Cyr	Director - 4 year term
J. R. Hemingway	Director - 4 year term
D. Whicker	Director - 3 year term
J. Piercy	Director - 3 year term
C. Sherry	Director - 2 year term
E. Bolstad	Director - 2 year term
H. Jones	Director - 1 year term
G. Faulkner	Director - 1 year term

Closure was moved by B. Dunn and seconded by C. Sherry. Nominees were elected by acclamation.

13. T. D. Northwood in accepting the congratulations of members noted that the CAA had evolved slowly and deliberately over the past 17 years since he has helped to form the original Canadian Committee on Acoustics. Indeed, CAA could boast that it had all been done without the need for an office. He said that he was overwhelmed by being elected President. Acclamation.

14. W. Bradley confirmed that the 1980 CAA meeting will be held in Montreal and he agreed to act as coordinator.

15. D. Whicker on behalf of acousticians in Alberta invited CAA to hold the 1981 meeting in Edmonton. This was accepted.

16. The meeting adjourned at 7:20 p.m.

John Manuel, Secretary

WINDSOR '79 - TREASURER'S REPORT

The Treasurer's report consists of the following parts: (a) Statement of Cash Receipts and Expenditures for the Period of September 1, 1978 to August 31, 1979 together with a Balance Sheet to August 31, 1979; and (b) a breakdown of these figures reflecting our major income and expenses up to October 15, 1979, and a financial report for the 1978 Symposium held in Halifax, November 1-3, 1978.

This year has been a much more active year financially than has been experienced in the past. This results from our assumption of the full responsibility for publishing the Newsletter. I wish to commend the members of the Editorial Committee for their effort and dedication for without such an effort our books would reveal a negative rather than positive balance. Our present balance of $658.59 is not something to be complacent about since only one unforeseen added expense of reasonable magnitude could put us in the red. I, therefore, encourage all members to support, via contributions, the Newsletter. For the next year, I suggest that we continue without dues, but remind the members that depending on the finances of the Newsletter over the next year and other expenses, it may be necessary to recommend annual dues for the year beginning September 1, 1980.

I respectfully move that the financial statement as attached* be adopted.

Leslie T. Russell, Treasurer

CAA ACCOUNTS: SEPT. 1, 1978 - OCT. 15, 1979

I have examined the accounts of the Canadian Acoustical Association for the above period and found them to be correct.

Signed, Robert J. Donato

*Accounts follow on next three pages - Ed.

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS FOR PERIOD SEPT. 1, 1978 TO AUG. 31, 1979.

Receipts

Conference registration fees	$ 2,232.02
Interest	120.00
Newsletter advertising and contributions from sustaining members	1,820.00
	$ 4,172.02

Disbursements

Bank Charges	$ 2.00
Conference Expenses	1,464.41
I/INCE fees	220.55
Receiver General of Canada	30.00
P.O. Box Rental	10.00
Printing of Newsletter	1,634.74
	$ 3,361.70

Excess Receipts Over Disbursements	$ 810.70

BALANCE SHEET AS OF AUG. 31, 1979

Assets

Cash on hand	$ 1,096.82
Bank of Montreal Term Deposit	1,600.00
	$ 2,696.82

Liabilities

Surplus Balance Forward, Aug. 31, 1978	$ 1,886.50
Add: Excess Receipts over Disbursements	810.32
	$ 2,696.82

SUMMARY - INCOME TO OCT. 15, 1979

Opening balance, Sept. 1, 1978			$ 286.50	
Interest on TDR	- Oct. 31, 78	$ 60.49		
	- April 30, 79	23.01		
	- May 1, 79	36.50	120.00	
Conference Registration Fees:				
	Nov. 22, 78	$ 2,199.52		
Late Receipt:	Feb. 2, 78	32.50	2,232.02	
Newsletter:	Advertising	$ 1,290.00		
	Sustaining Subscriber	555.00		
	Mailing Lists	320.00		
TOTAL =			2,165.00	
			$ 4,803.52	$ 4,803.52

DISBURSEMENTS SEPT. 1, 78 to OCT. 15, 1979

Conference Expenses		$ 1,464.41	
I/INCE Fees:	Feb. 28, 79	220.55	
P.O. Box:	Jan. 5, 79	10.00	
Incorporation Fees:	May 8, 79	30.00	
Bank Service Charge:	Aug. 15, 79	2.00	
Newsletter		2,417.97	
TOTAL =		$ 4,144,93	$ 4,144.93
	NET BALANCE =		$ 658.59

STATEMENT OF RECEIPTS AND DISBURSEMENTS, CAA SYMPOSIUM AND ANNUAL MEETING, NOVEMBER 1 - 3, 1978

Receipts:

Pre-registrations			
(1)	Symposium only 21 at $20.00	$ 420,00	
(2)	Symposium and Introduction to Acoustics 17 at $27.00	467.50	
(3)	Students 5 at $7.50	37.50	
Registrations at Symposium			
(4)	Symposium only, 26 at $25.00	650.00	
(5)	Symposium and Introduction to Acoustics 14 at $32.50	455.00	
(6)	Introduction to Acoustics 1 at $7.50	7.50	
(7)	Students 3 at $10.00	30.00	
(8)	Banquet guests 7 at $10.00	70.00	
(9)	Professional Card Advertisements 3 at $30	90.00	
(10)	Miscellaneous receipts	4.52	
	TOTAL =	$ 2,232.02	$ 2,232.02

Disbursements:

Printing	162.68	
Signs	15.00	
Expenses - projectionists and registration assistants, name tags, etc.	21.54	
Honorarium - Guest Speaker	50.00	
Hotel expenses	1,180.19	
Coffee at Introduction to Acoustics sessions	35.00	
TOTAL =	$ 1,464.41	$ 1,464.41
Excess receipts over disbursements =		$ 767.61

A METHODOLOGY FOR DETERMINING ERRORS IN AIRCRAFT NOISE EXPOSURE MODELS

Robert K. Leong

Aeronautical Environment Technology Section
Civil Aeronautics, Transport Canada, Ottawa

ABSTRACT

This paper describes a technique for estimating the error in predicting noise exposure indexes due to inaccuracy in the input data required in their calculation.

1. INTRODUCTION

The extent of aircraft noise exposure is generally expressed by the noise index derived from a noise exposure model. A number of aircraft noise exposure models have been developed over the years - namely the CNR, NEF, L_{DN}, CNEL and L_{eq} system. The accuracy of these models is determined by (1) the underlying assumptions used in the development of these models and (2) the accuracy of the input data. Some aspects of the first category, more specifically, the effects of tone and duration corrections, temperature and relative humidity on the size and shape of the noise exposure contours, have been determined in two recent sensitivity studies (1 and 2). However, little or no effort has been made on the effects of errors in aircraft noise levels and operations on the size and shape of the contour. The intention here is to develop a methodology to determine the magnitude of the noise index error given the inaccuracies of the input data.

2. FORMULATION

The total noise exposure at a point due to a cumulative sum of each flight's contribution is given as:

$$NE = 10 \log \left\{ \sum_{i=1}^{n} (aD_i + bE_i + cN_i) 10^{EL_i/10} \right\} - A \qquad \ldots\ldots \quad (1)$$

where n = Number of distinct flights (unique combinations of track, profile and aircraft type)

a, b, c = Respectively; the Day, Evening and Night weighting factors

D, E, N = The actual number of Day, Evening and Night (respectively) operations for the flight in question.

EL = The single event exposure level (i.e. EPNL for NEF, SEL for L_{DN}, CNEL or L_{eq}) for exactly one such operation as the flight in question with all correction factors applied.

A = (88.0 for NEF
(49.4 for L_{DN}, CNEL and L_{eq}

To obtain the error of the model, Equation (1), due to inaccuracies of D_i, E_i, N_i and EL_i, consider the general expression Y as a function of m independent variables, such that:

$$Y = \sum_i g_i \left({}^1X_i,\ {}^2X_i,\ {}^3X_i,\ \ldots\ldots\ldots\ldots\ {}^mX_i \right)$$

where ${}^jX_i$, j = 1, m are the independent variables and i subscript denotes the i similar items to be summed.

Define the function:

$$Y_i = g_i \left({}^1X_i,\ {}^2X_i,\ {}^3X_i,\ \ldots\ldots\ldots\ {}^mX_i \right)$$

such that: $Y_i + \varepsilon_i = g_i \left({}^1X_i + {}^1\delta_i,\ {}^2X_i + {}^2\delta_i,\ \ldots\ldots {}^mX_i + {}^m\delta_i \right)$

where ε_i is the error of Y_i due to errors ${}^j\delta_i$ of the independent variables. By taking the Taylor Series expansion around the mean, ${}^jX_i^*$, we have

$$g_i \left({}^1X_i,\ {}^2X_i,\ \ldots\ {}^mX_i \right) = g_i + \left({}^1X_i - {}^1X_i^* \right) \frac{\partial g_i}{\partial\, {}^1X_i} + \left({}^2X_i - {}^2X_i^* \right) \frac{\partial g_i}{\partial^2 X_i} + \ldots\ldots$$

$$\ldots\ \frac{\left({}^1X_i - {}^1X_i^* \right)^2}{2\,!} \frac{\partial^2 g_i}{\partial\, {}^1X_i^2} + \frac{\left({}^2X_i - {}^2X_i^* \right)}{2\,!} \frac{\partial^2 g_i}{\partial\, {}^2X_i^2} + R_n$$

If the second and higher order terms and remainder are small, then the first approximation gives:

$$\varepsilon_i = \sum_{\ell=1}^{m} \left\{ \left. \frac{\partial g_i}{\partial\, {}^\ell X_i} \right|_{\ell\ *} \right\} {}^\ell\delta_i$$

The total error ε_in the aggregate Y is then given by: $\varepsilon = \sum_i \varepsilon_i$

Equation (1) can be expressed in another form, namely:

$$NE = 10 \log \sum_i 10^{NE_i/10} \qquad \ldots\ldots (3)$$

when $NE_i = EL_i + 10 \log (aD_i + bE_i + cN_i) - A \qquad \ldots\ldots (4)$

Now let $g_i = NE_i$ and $n_i = aD_i + bE_i + cN_i$

$$\frac{\partial g_i}{\partial NE_i} = 1 \qquad \frac{\partial^2 g_i}{\partial NE_i^2} = 0$$

$$\frac{\partial g_i}{\partial n_i} = \frac{10 \log e}{n_i} \quad , \quad \frac{\partial^2 g_i}{\partial n_i^2} = -\frac{10 \log e}{n_i^2}$$

For large values of $n_i = n_i^*$, $\left.\frac{\partial^2 g_i}{\partial n_i^2}\right|_{n_i^*}$ is small

$$R_n = \frac{(NE_i - NE_i^*)^n}{n\,!} \cdot \frac{\partial^n NE_i}{\partial n_i^n} = \frac{(NE_i - NE_i^*)^n}{n\,!} (-1)^{n+1} (n-1) \frac{10}{n_i^{*n}}$$

Again for large n and $n_{i_j}^*$, R_n is small. Therefore, the error in noise index NE_i is:

$$\delta NE_i = \delta EL_i + \log e. \frac{\delta n_i}{n_i^*}$$

Now, define $z_i = 10^{NE_i/10}$ and $Z = \sum_i z_i$, then $\frac{\partial z_i}{\partial NE_i} = \frac{\ell n\ 10}{10} \cdot 10^{NE_i/10}$. The error in z_i is $\delta z_i = \left\{ \frac{\ell n\ 10}{10} \cdot 10^{NE_i/10} \cdot \delta NE_i \right\}$ and the error in the aggregate Z is $\delta Z = \sum_i \delta z_i$, i.e. $\delta Z = \sum_i \left\{ \frac{\ell n 10}{10} \cdot 10^{NE_i/10} \cdot \delta NE_i \right\}$

Using the new definitions, the total noise exposure is then given as NE = 10 log Z. Now $\frac{\partial NE}{\partial Z} = \frac{10 \log e}{Z}$ and

$$\delta NE = \frac{10 \log e}{\sum_i 10^{NE_i/10}} \cdot \sum_i \left\{ \frac{\ell n 10}{10} \cdot 10^{NE_i/10} \ \delta NE_i \right\}$$

The above expression can be further simplified to:

$$\delta NE = \frac{\sum_i \{10^{NE_i/10} \cdot \delta NE_i\}}{\sum_i 10^{NE_i/10}} \quad \ldots\ldots \quad (6)$$

This error equation can be further simplified if the deviations in noise level and aircraft operations for each aircraft type are the same, i.e. $\delta EL = \delta EL_i$, $\frac{\delta n}{n^*} = \frac{\delta n_i}{n_i^*}$. Equation (5), under these conditions, becomes

$\delta NE = \delta EL + 10 \log e. \frac{\delta n}{n^*}$ and Equation (6) is simplified to

$$\delta NE = \frac{\sum_i \{10^{NE_i/10}\} \cdot \delta NE_i}{\sum_i \{10^{NE_i/10}\}} \quad \text{or } \delta NE = \delta NE = \delta EL + 10 \log e. \frac{\delta n}{n^*}.$$

3. <u>APPLICATION</u>

The derived error equation was used to determine the resultant NEF error due to errors in aircraft noise levels and forecasted movements. The airport being studied has two runways and 356 aircraft movements with ten aircraft types using four different flight paths. The aircraft noise level is assumed to be accurate to within ± 3 EPNdB and the inaccuracy in aircraft movement is assumed to be within ± 10%. The total deviation in NEF at any ground position obtained from the NEF computer program is ± 3.4 units of NEF. The total inaccuracy as computed from equation (6) is ± 3.434 units of NEF. Within the accuracy of computations, the results compare very well.

4. REFERENCES

1.0 D.E. Bishop and T.C. Dunderdale, 1976, Army Medical Research Laboratory AMRL-TR-75-115, "Sensitivity Studies of Community - Aircraft Noise Exposure".

2.0 D.E. Bishop and T.C. Dunderdale, April 1977, Army Medical Research Laboratory AMRL-TR-76-116, "Further Sensitivity Studies of Community - Aircraft Noise Exposure".

NEW from BRUEL & KJAER:
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To obtain an absolute measurement of noise, it is not enough simply to measure the sound pressure level at a specified distance from the source because the acoustic environment adds its own parameters to the readings. The B & K Sound Power Calculator determines the total acoustical power output of the test object in pico-Watts — an absolute figure that is not affected by the acoustic environment.

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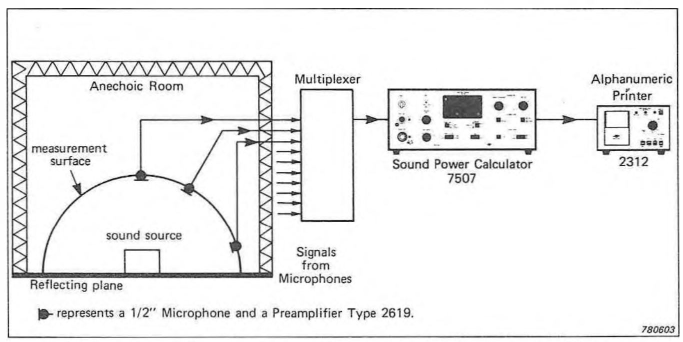
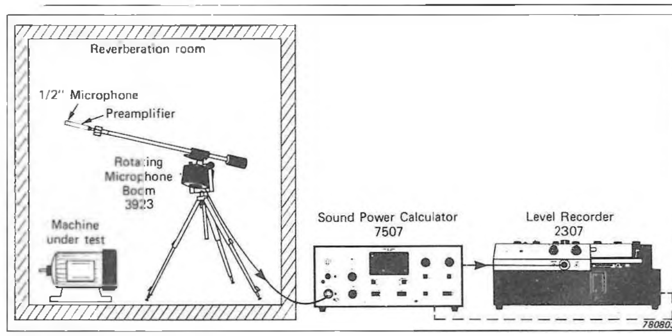


Determination of sound power employing an array of microphones and a multiplexer



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CALCULATION OF ENERGY EQUIVALENT NOISE LEVEL FROM TRUNCATED STATISTICAL NOISE LEVEL DISTRIBUTIONS

by

Robert Rackl*
Wyle Research
128 Maryland Street
El Segundo, California 90245

ABSTRACT

Formulas for calculating the ensemble energy equivalent noise level for a population of sources are given for truncated uniform, normal, and Gamma distributions.

When assessing the effectiveness of a regulation limiting the noise emission of a certain product (say, trucks, for illustration), the following procedure is often followed. A statistical distribution of "current" (i.e., without regulation) noise levels is obtained (e.g., Figure 1(a)) for the population of that product. Its energy equivalent ensemble noise level is calculated and used in a noise impact computation. Then, assumptions are made on how the regulation will change the noise level distribution, and a new equivalent noise level is obtained and fed in turn into a noise impact model. The difference in noise impact may be regarded as the effect of the regulation.

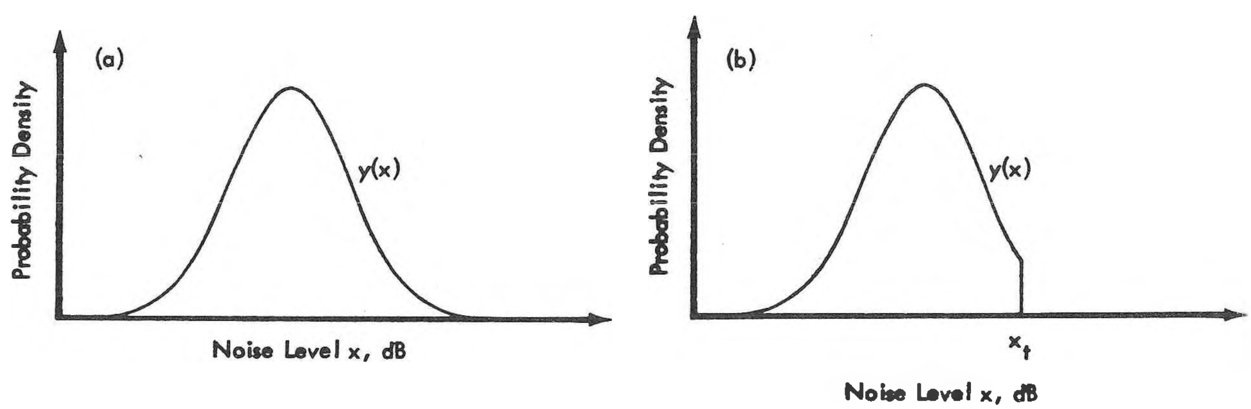

Figure 1. Statistical Distributions of Noise Levels: (a) Full, (b) Truncated

*Robert Rackl, a doctoral graduate of the University of British Columbia, worked for Environment Canada before joining Wyle Laboratories.

The simplest assumption about the effect of a noise level regulation on a statistical distribution of noise levels from a source population is that the upper tail is truncated from the distribution at a known noise level. It is assumed that the parameters of these distributions have been estimated and are known quantities. For the normal distribution, these estimations are well-known. For the Gamma distribution, estimation procedures may be found for instance in Bury 1975, page 311. Only uniform, normal and Gamma distributions are treated here since no other closed form solutions could be found which are readily computed with a programmable pocket calculator.

Denoting noise levels by the symbol x with units dB, and probability density by the symbol y, the energy equivalent ensemble noise level L_{ep} (in dB) is defined by

$$L_{ep} = 10 \log \left\{ \int_{-\infty}^{\infty} y(x)\, z^{x}\, dx \right\} \tag{1}$$

where z is a constant equal to $10^{0.1}$. The area under y(x) must, of course, equal unity for y to be a proper probability density function. The subscript "ep" is chosen to distinguish this statistical energy equivalent level of a noise source population, from the energy equivalent level computed over a time interval of a fluctuating noise level signal, usually denoted by L_{eq}.

(a) Uniform Distribution

The formulas for uniformly distributed noise levels are as follows:

$$y(x) = f_u(x; a, b) = \begin{cases} 0 & , \quad x < a \\ \dfrac{1}{b - a} & , \quad a \leq x \leq b \\ 0 & , \quad b < x \end{cases}$$

$$L_{ep} = 10 \log \frac{z^b - z^a}{(b - a)\, \ell n\, z} \tag{2}$$

When the upper portion is truncated above x_t, b is simply replaced by x_t. Figure 2 shows equation (2) in dimensionless form.

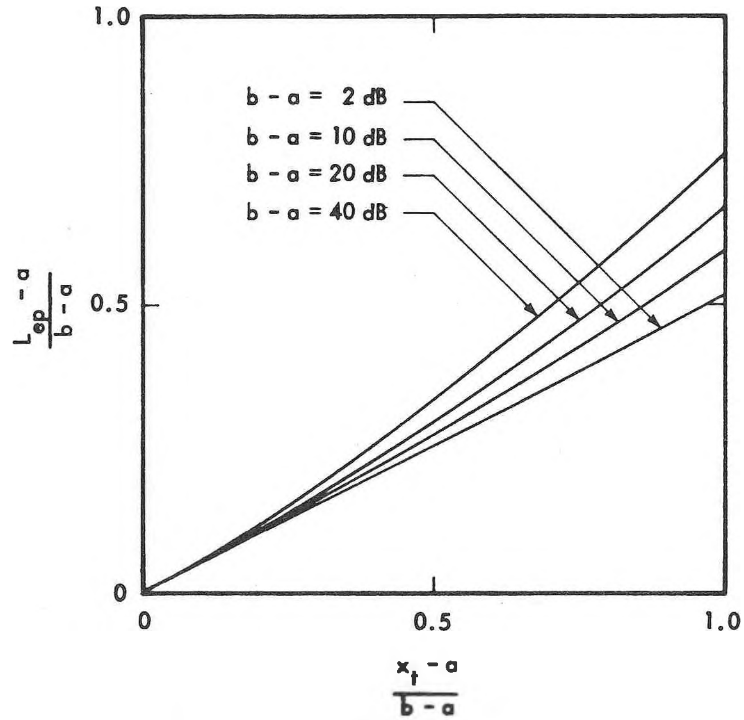

Figure 2. Dimensionless L_{ep} as a Function of Dimensionless Truncation Value (Uniform Distribution)

(b) Normal Distribution

The full normal probability density is

$$y(x) = f_N(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right] \tag{3}$$

where μ is the mean, and σ the standard deviation. The cumulative distribution function F_N is

$$F_N(x; \mu, \sigma) = \int_{-\infty}^{x} f_N(t; \mu, \sigma)\, dt \tag{4}$$

If the upper tail of f_N is truncated at x_t (Figure 1(b)), y(x) must be corrected such that the area under y remains equal to unity:

$$y(x) = f_{N,t}(x; \mu, \sigma, x_t) = \frac{1}{\sigma\sqrt{2\pi}\, F_N(x_t; \mu, \sigma)} \exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right] \qquad (5)$$

$$\text{for } -\infty < x < x_t, \qquad \text{zero elsewhere.}$$

Substituting equation (5) into equation (1) yields the following result after some algebra:

$$L_{ep} = \mu + \sigma^2 \frac{\ln z}{2} + 10 \log \left\{ \frac{F_N(x_t; \mu + \sigma^2 \ln z, \sigma)}{F_N(x_t; \mu, \sigma)} \right\} \qquad (6)$$

The second term is the familiar $0.115\,\sigma^2$ term in the expression for the energy equivalent level for a normal distribution of sound levels. The third term may be called a "truncation correction" which reduces to zero for $x_t \longrightarrow \infty$ as should be expected.

The cumulative normal distribution F_N is tabulated in any textbook on statistics. Simple pocket calculator programs also exist to evaluate F_N.

Figure 3 shows equation (6) in dimensionless form. This graph can be used to evaluate equation (6), interpolating between curves when necessary.

(c) <u>Gamma Distribution</u>

The full, three-parameter Gamma probability density function is (Figure 4):

$$y(x) = f_G(x; \beta, \alpha, \lambda) = \frac{1}{\alpha\Gamma(\lambda)} \left(\frac{x-\beta}{\alpha}\right)^{\lambda - 1} \exp\left(-\frac{x-\beta}{\alpha}\right) \qquad (7)$$

$$\text{for } x > \beta, \qquad \text{zero elsewhere,}$$

where β is the location parameter, α the scale parameter, and λ the shape parameter. $\Gamma(\lambda)$ is the complete Gamma function defined by

$$\Gamma(\lambda) = \int_0^\infty t^{\lambda-1} e^{-t}\, dt$$

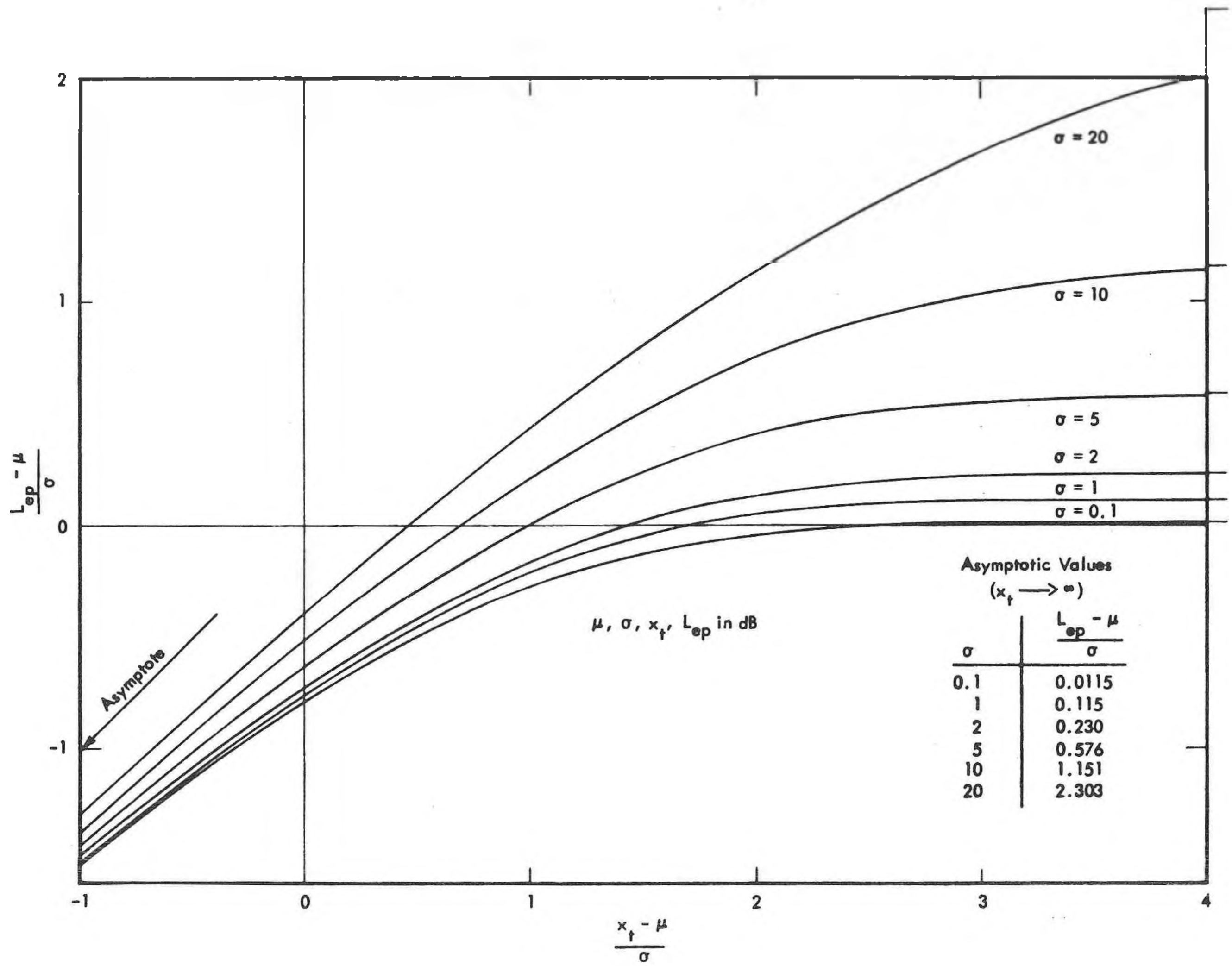

Figure 3. Dimensionless L_{ep} as a Function of Dimensionless Truncation Value (Normal Distribution). Tick Marks Outside Right Margin Indicate Asymptotes.

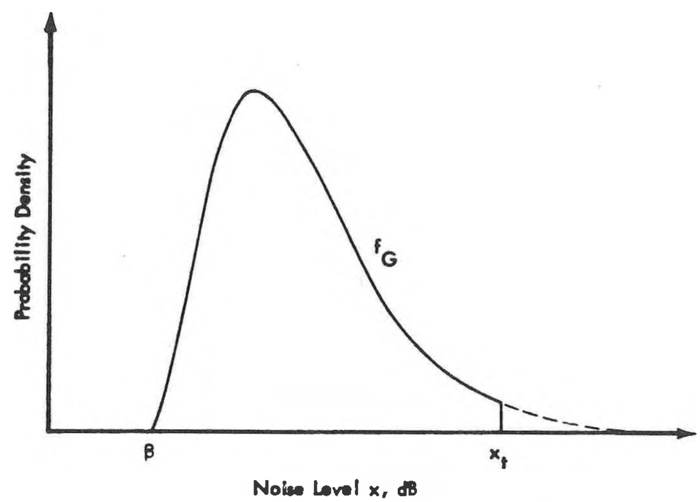

Figure 4. Gamma Distribution

Note that the arithmetic mean of the three-parameter Gamma distribution is $\beta + \alpha\lambda$, and the variance is $\alpha^2\lambda$.

The cumulative distribution function F_G is

$$F_G(x; \beta, \alpha, \lambda) = \frac{1}{\Gamma(\lambda)} \int_{\beta}^{x} \left(\frac{x - \beta}{\alpha}\right)^{\lambda - 1} \exp\left(-\frac{x - \beta}{\alpha}\right) \frac{dx}{\alpha} \tag{8}$$

which can be written

$$F_G(x; \beta, \alpha, \lambda) = \frac{\gamma_\lambda\left(\frac{x - \beta}{\alpha}\right)}{\Gamma(\lambda)} \tag{9}$$

where γ_λ is the "incomplete" Gamma function defined by

$$\gamma_\lambda(x) = \int_0^x t^{\lambda - 1} e^{-t} dt \tag{10}$$

This leads to the Gamma probability density with truncated upper tail at x_t:

$$y(x) = f_{G,t}(x; \beta, \alpha, \lambda, x_t) = \frac{1}{\alpha\gamma_\lambda\left(\frac{x_t - \beta}{\alpha}\right)} \left(\frac{x - \beta}{\alpha}\right)^{\lambda - 1} \exp\left(-\frac{x - \beta}{\alpha}\right) \tag{11}$$

for $\beta \leq x \leq x_t$, zero elsewhere.

Inserting equation (11) into equation (1) yields the following result after some algebra:

$$L_{ep} = \beta - 10\lambda \log(1 - \alpha \ln z) + 10 \log\left\{\frac{\gamma_\lambda\left[\frac{x_t - \beta}{\alpha}(1 - \alpha \ln z)\right]}{\gamma_\lambda\left(\frac{x_t - \beta}{\alpha}\right)}\right\} \tag{12}$$

The third term is again the truncation correction term as similarly observed with the normal distribution (equation (6)) reducing to zero for $x_t \to \infty$. With one exception, L_{ep} should always exist for finite x_t. The exception is that the calculation method breaks down when values of the scale parameter $\alpha \geq 4.343$ ($= 1/\ell nz$), which is not considered a serious restriction. Values of α will usually range between 0.5 and 2.5 when operating on environmental noise data.

Appendix A gives an algorithm for calculating the incomplete Gamma function on a programmable pocket calculator or a computer.

Figure 5 shows curves representing equation (12) in dimensionless form using the Gamma standardized variable

$$\frac{\frac{x}{\alpha} - \lambda}{\sqrt{\lambda}}$$

One may note the basic similarity of Figure 5 with Figure 3. However, since the Gamma distribution has a finite lower tail, the curves stay finite on the left side.

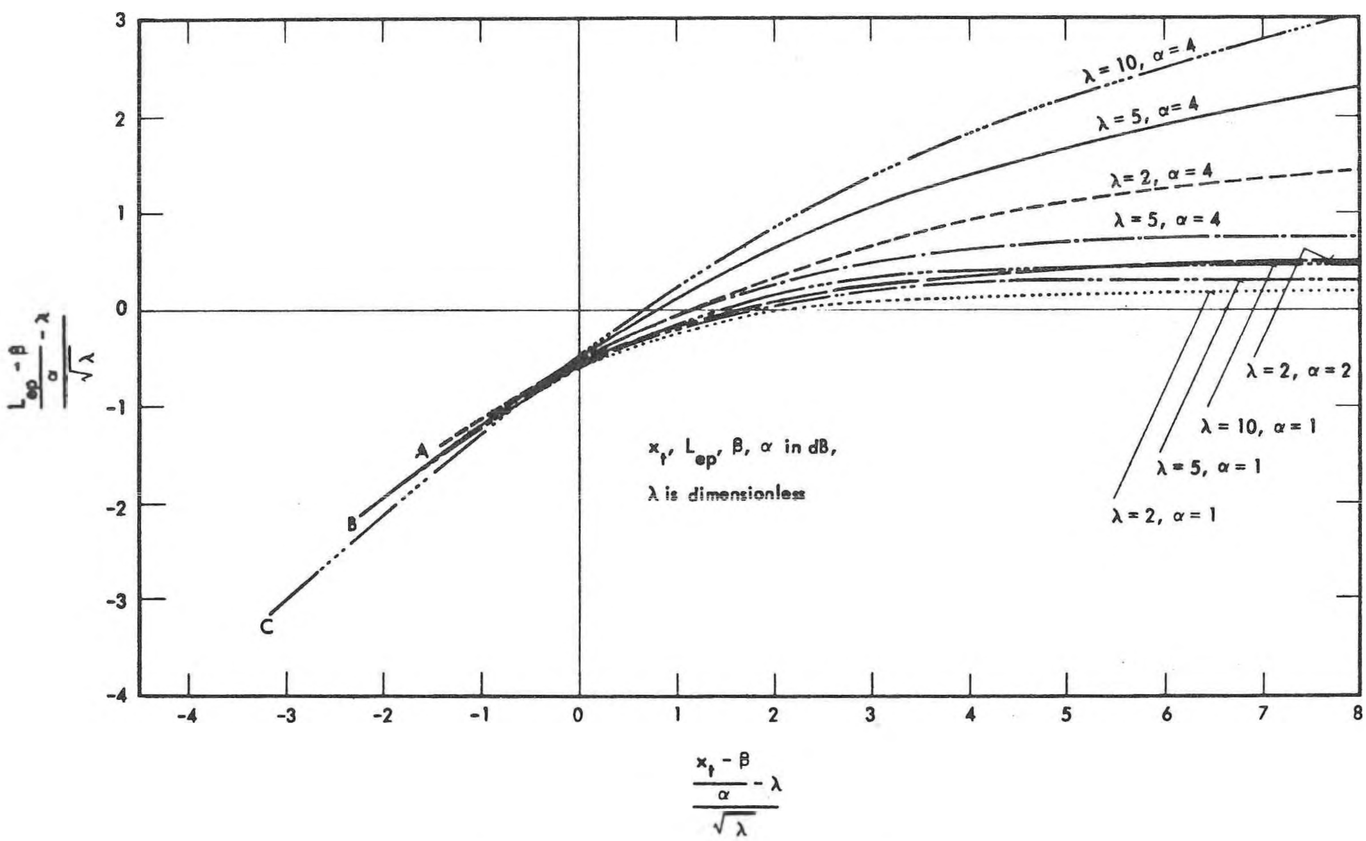

Figure 5. Dimensionless (Reduced) L_{ep} as a Function of Dimensionless (Reduced) Truncation Value (Gamma Distribution). A, B, C are Endpoints of Curves with Same Shape Parameter λ (A: $\lambda = 2$, B: $\lambda = 5$, C: $\lambda = 10$.)

The effectiveness of a regulation is best assessed by estimating its effect on a population of noise sources as a function of time. This has been examined in Plotkin 1974, Plotkin and Sharp 1974, and Plotkin 1977. These references either assume normal models, or they use measured noise level distributions without fitting them with a mathematical model which is a more accurate and also more time-consuming technique than the one discussed in this paper. The formulations developed in this paper are used in Wyle Research 1979 (see references), a document developed for use by local governments, whereas the previously mentioned references stress the use by a federal government.

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APPENDIX A

ALGORITHM FOR INCOMPLETE GAMMA FUNCTION EVALUATION

Definition of incomplete Gamma function:

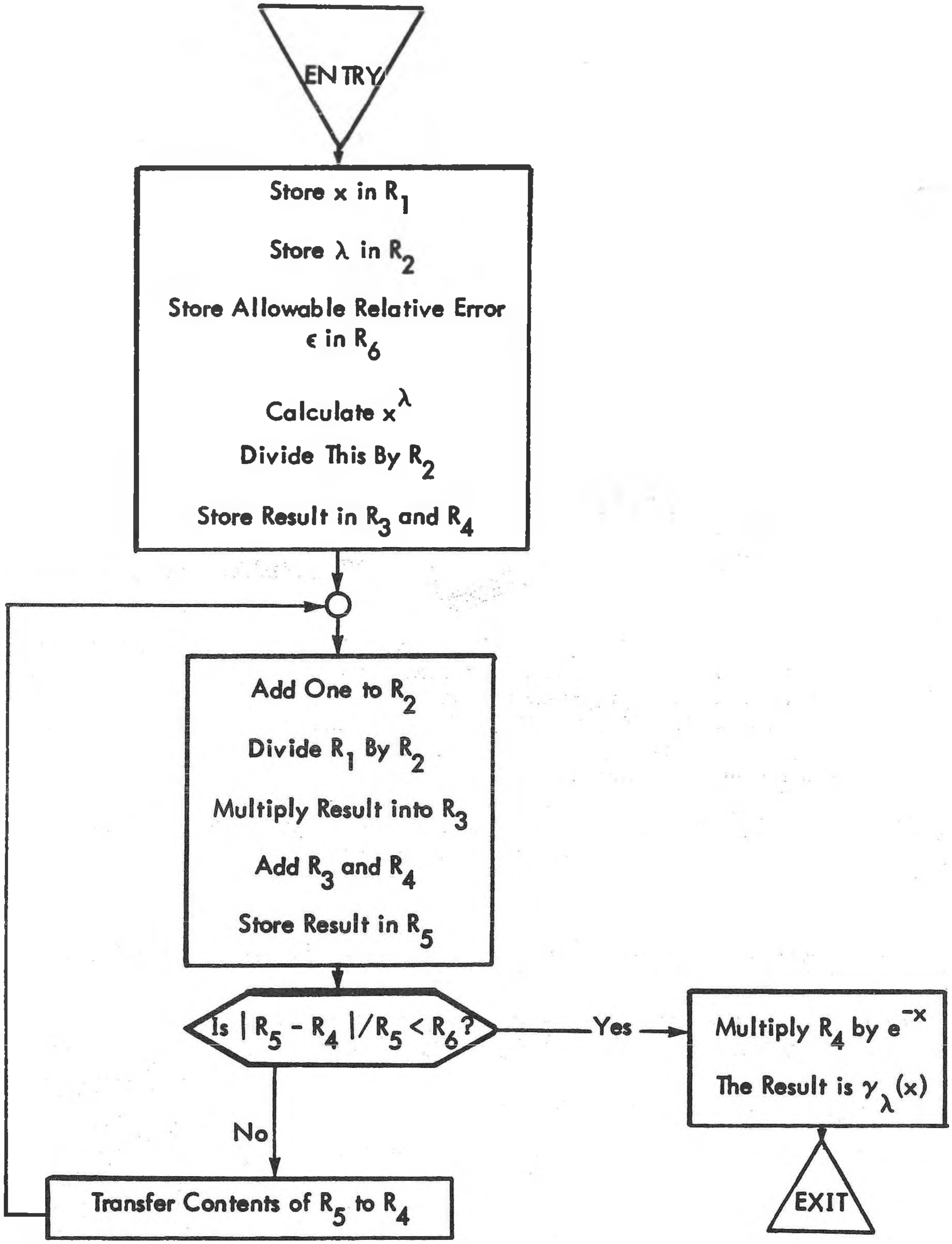
$$\gamma_\lambda(x) = \int_0^x t^{\lambda - 1} e^{-t} dt \tag{A1}$$

where $\lambda > 0$, $x > 0$. This is also equal to:

$$\gamma_\lambda(x) = x^\lambda e^{-x} \sum_{n=0}^{\infty} \frac{x^n}{\lambda(\lambda+1)\ldots(\lambda+n)} \tag{A2}$$

Algorithm for evaluating equation (A2):

$R_1, \ldots . R_6$ are storage registers.



Examples:

$\gamma_1(2) = 0.86466$

$\gamma_1(0.1) = 0.09516$

$\gamma_2(10) = 0.99950$

$\gamma_{10}(5) = 11549.8$

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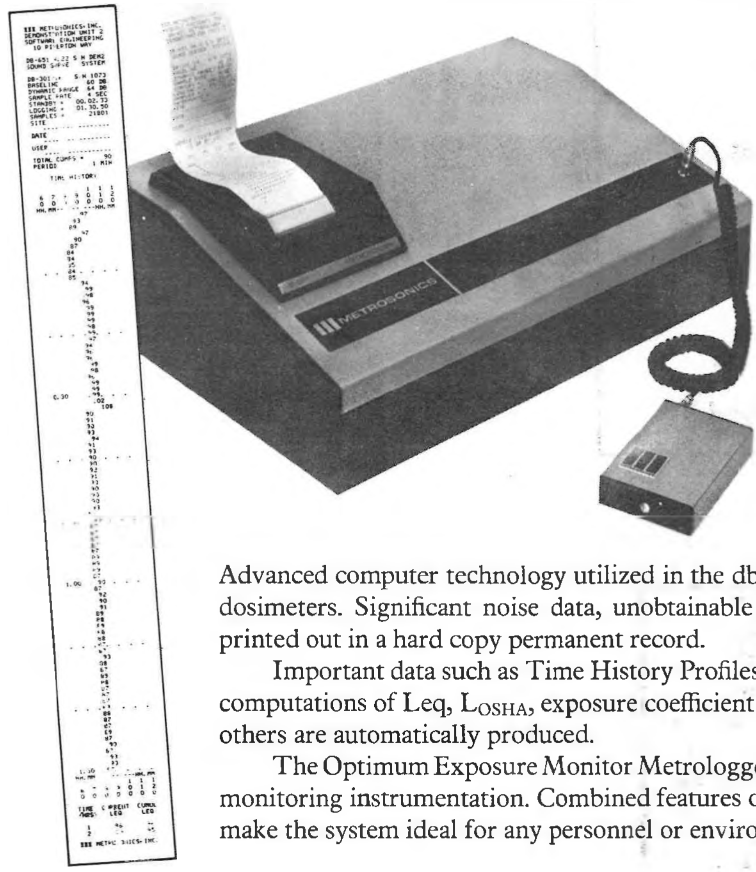

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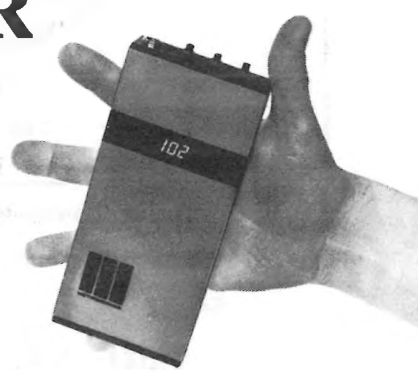

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NOISE HAZARD AND CONTROL

Prepared by D.A. Benwell and M.H. Repacholi, Environmental Health Directorate, Health Protection Branch, Ottawa, K1A 0L2. Published by Authority of the Minister of National Health and Welfare, 79-EHD-29, March 1979.

This document summarizes those aspects of noise related to health. It outlines the present state of knowledge on noise and provides a basis for developing specific health criteria that could be used in the development of regulations and by-laws.

A summary of known noise-induced bioeffects is presented. Major topics include noise-induced hearing loss and the effect of noise on sleep, since these are prominent and well-documented health effects of noise. Other topics include: non-auditory physiological responses to noise such as stress, leading to cardiovascular and neurophysiological illness; the reduction in work performance due to annoyance and speech interference caused by noise.

The document describes the various sources of noise in our living and working environment, discusses present noise control standards and regulations, and suggests areas in which further research is required. It is planned to follow this general document with specific criteria on each of the various health effects of noise.

RISQUES ASSOCIÉS AU BRUIT ET SURVEILLANCE

Rédigé par D.A. Benwell et M.H. Repacholi, Direction de l'Hygiène du milieu, direction générale de la Protection de la Santé nationale et du Bien-être social, 79-EHD-29, mars 1979.

Ce document contient un relevé des aspects du bruit qui ont trait à la santé. Il brosse un tableau de la situation présente de nos connaissances sur le bruit et est une base sur laquelle ont peut fonder des critères sanitaires précis pouvant servir à l'élaboration de règlements et de statuts.

Le document donne un relevé des effets biologiques connus du bruit. Entre autres points principaux, on signale les pertes auditives causées par le bruit et les effets du bruit sur le sommeil, puisque ces effets sont prépondérants et traités dans un grand nombre d'ouvrages. Voici d'autres points: les répercussions physiologiques du bruit autres qu'auditives, comme par exemple, le stress; la baisse de rendement au travail en raison des désagréments causés par le bruit et l'interférence au niveau des conversations.

Dans le document, on décrit les diverses sources sonores de notre milieu social et professionnel, on y discute des normes et des règlements régissant présentement la surveillance du bruit et on y fournit des recommandations sur les domaines devant faire l'objet de travaux de recherche plus approfondis. On prévoit donner suite à ce document général, en élaborant des critères précis se rapportant à chacun des effets du bruit sur la santé.

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