ACOUSTICS AND NOISE CONTROL IN CANADA

THE CANADIAN ACOUSTICAL ASSOCIATION

L'ACOUSTIQUE ET LA LUTTE ANTIBRUIT AU CANADA

L'ASSOCIATION CANADIENNE DE L'ACOUSTIQUE

Janvier 1977
Vol. 5, N° 1

January, 1977
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CONTRIBUTIONS

Articles in English or French are welcome. They should be addressed to a regional correspondent or to a member of the editorial board.

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CONTRIBUTION

Vous êtes invités à faire parvenir des articles en anglais ou en français. Prière de les adresser à un correspondant régional ou à un membre de la rédaction.

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(suite au recto de la couverture inférieure)

Contents/Table Des Matieres

Notice Board

Acoustics Letters

Acoustics Letters will begin publication in 1977. It will be a monthly journal for the rapid publication of preliminary reports, new results and brief communications in all field of acoustics. Publication of work may normally be expected not more than 6 weeks after receipt.

Material for publication will normally be accepted in English; authors who submit in French or German are asked to provide a title and summary in English.

Authors are asked to restrict their contributions to 1000 words; illustrations should be in line drawing form only.

Contributions should be sent to: -

Dr. J.C. Scott
Fluid Mechanics Research Institute
University of Essex
Colchester CO4 3SQ
England

Sound in Architecture

Walter Barss at the University of Victoria is coordinating a series of 10 lectures on "Sound in Architecture" beginning January 25 and for the nine following Tuesday evenings. Helping with the lectures are Ken Barron and Ken Harford from Vancouver.

June 30, 1976

Honourable Robert Andras
Minister of Manpower and Immigration
Ottawa

Dear Minister:

I am writing to you on behalf of the Canadian Acoustical Association to seek your assistance in regard to a situation concerning Consulting Acoustical Engineers. Briefly, these engineers are concerned with architectural and building acoustics, industrial noise control and environmental noise abatement relating to urban planning.

Frequently, in fact all too frequently, Canadians find themselves in competition with foreign consultants for work being contracted by various governemt departments (both Federal and Provincial). Competition as such is not objected to; if this were all we would welcome it. Two factors, however, have to be taken into account. First there should be competition on equal terms and this does not apply particularly in regard to U. S. consultants. They are given much more favorable terms to obtain work in Canada than are Canadians in the U. S. To demonstrate this contention I enclose an abstract from one of your offices Mr. L.C. Hawkins (your reference: 5425 7 A-E) which indicates how easy it is for a U.S. consultant to operate in Canada. I enclose a second abstract from a letter from the U. S. Borax Company, which illustrates the problems for those who would operate in the U. S. from Canada.

My second point which relates to noise abatement, particularly in the urban environment. The National Research Council has introduced standards which it is hoped will be accepted and used across Canada. ISO R1996 is an example of such a standard. This particular standard is not accepted in the U. S. or the U. K. but it is accepted widely elsewhere. The standards accepted in the U. S. are sometimes more permissive and it would be our advice that they should not be accepted for use in Canada. This Association has, on occasion, had to write to Provincial Government advising them against accepting recommendations of U. S. consultants and pressing for the use of Canadian standards. It is inconceivable that such a equivalent situation could arise in the U. S.

Finally, I note, that Canada has some extremely eminent and able people in the field of acoustics. These people give of their time voluntarily to assist and advise government. This Association, for example, is presently occupied in preparing a substantial and detailed report for the advice of a Provincial Government; this an unpaid activity of the senior membership.

I would ask you to consider what assistance you could give to the Canadian acoustical engineer and scientist so that he can compete on an equal footing with his foreign counterparts.

Yours sincerely,

H. W. Jones

HWJ:lsp
Enclosure

ABSTRACT 1

We have been attempting to determine ways and means by which we could continue to avail ourselves of your services for our noise problems.

We have been informed that we must submit proof that you are of distinguished merit and ability, that you will perform work of a temporary nature, and that similar services are not available in the States.

Your work has been more than satisfactory, but we feel that the red tape is too voluminous and entangling to warrant further efforts to continue our association.

We appreciate sincerely the very fine report you made on our operation and regret that such severe restrictions are placed on international cooperation.

ABSTRACT 2

Consultants from foreign countries may be allowed entry to Canada if they otherwise meet requirements, such as evidence of citizenship, are of good health and good character.

They must be in possession of a letter from the Canadian client detailing the request for their services and a letter from the foreign employer identifying their connection with the firm, the qualifications for the job specified, its approximate duration, and assurance that the employee will not serve any other Canadian client during his stay without written permission from an Immigration officer.

Minister
Manpower and Immigration

Ministre
Main-d'œuvre et Immigration

August 9, 1976.

Dr. H.W. Jones,
President,
Canadian Acoustical Association,
c/o Physics Department,
University of Calgary,
Calgary, Alberta.

Dear Dr. Jones:

This is in reference to your letter of June 30, 1976, requesting our assistance in enabling Canadian acoustical engineers to compete on a reciprocal basis with their foreign counterparts who are working in Canada.

The selection and admission of foreign workers to Canada is governed by the Immigration Act and Regulations. It is the policy of the Federal Government that foreign workers will not be admitted on employment visas for temporary employment nor, in the case of potential landed immigrants, given credit for arranged employment, if a qualified Canadian or a permanent resident of this country is available and willing to take the employment. Canada Manpower Centres have the responsibility to ascertain if qualified Canadian or permanent residents are available.

However, in spite of this general rule, special circumstances sometimes exist when it is advisable, for the general good of Canada, to issue employment visas in order to permit designated persons to take temporary work regardless of the availability of Canadians or permanent residents. Until recently "specialists" being transferred into Canada by their employers were in this category. We have found that many engineers were being admitted under this provision and, consequently, I now require our Canada Manpower Centres to ascertain the availability of Canadians in regard to such persons. In ascertaining the availability of qualified Canadians, our officers check appropriate sources and in cases such as acoustical engineers, professional associations would be among our contacts.

.../2

While I fully appreciate your comments concerning the use of U.S. standards related to noise abatement, this is a matter which is outside of my terms of reference as Minister of Manpower and Immigration. However, copies of your letter will be sent to my colleagues, the Honourable C.M. Drury, Minister of Public Works and the Honourable Roméo Leblanc, Acting Minister of the Environment, so that they will be aware of your concerns in this area.

I would like to emphasize that our policy is to ensure that persons from this country have the first opportunity of engaging in available employment and trust that Canadian acoustical engineers will profit from it.

I appreciate you writing to me on this matter.

Yours sincerely,

R Andras

Robert Andras.

Now we have to see that the policy is in effect by enquiring into individual cases of employment of foreign consultants

Hugh J.

C--- paper

76-09-22

The Honourable Robert Andras
House of Commons
Ottawa, Ontario

Sir:

I thank you for your letter of August 9th concerning the employment of non-Canadian acoustical engineers in Canada. We regard your reply as most helpful and I wish to express our appreciation for the assistance you have given us.

I also wish to thank you for the action you took in circulating my letter to the then Minister of Public Works and Acting Minister of Environment.

Yours truly,

HWJ:jw

H. W. Jones,
President

c.c. The Honourable "Bud" Cullen
Minister of Manpower and Immigration

Minister
Environment Canada

Ministre
Environnement Canada

Ottawa, Ontario
K1A 0H3

NOV 3 1976

Dr. H.W. Jones
President
Canadian Acoustical Association
c/o Physics Department
University of Calgary
Calgary, Alberta

Dear Dr. Jones:

Your letter of June 30, 1976, addressed to the Minister of Manpower and Immigration, has been referred to me for further reply.

You raised two points which regard my Department. The first of these was that Canadian consultants in the field of acoustics should be in a position which will enable them to compete with foreign consultants on equal terms. Mr. Andras referred to federal government immigration policy on this in his reply to you of August 9.

I believe that agencies at various levels of government may make use of foreign consultant services because of a lack of information concerning the existence or the capabilities of Canadian consulting firms. My Department is trying to rectify this situation by arranging or facilitating the dissemination in Canada of information on Canadian acoustics activities.

The second point expressed in your letter is that Canadian government agencies may adopt recommendations of foreign consultants that are inconsistent with Canadian recommendations or practice. I agree with your contention that this is not always appropriate. We consider that here again is an instance where one of the problems is a lack of information on the part of various government agencies, and I hope that expanded dissemination of noise control information to federal, provincial and local government agencies will help to contribute to a solution.

In conclusion, I should like to thank you for drawing your concerns in this matter to the attention of the federal government. This will be helpful to us in deciding upon the nature of our future environmental noise control activities.

Yours sincerely,

Roméo LeBlanc

Roméo LeBlanc

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

January 10, 1977

The Honourable Roméo LeBlanc
Minister
Environment Canada
OTTAWA, Ontario
K1A 0H3

Dear Minister:

Thank you for your letter of November 3, 1976, concerning the employment of Canadian consultants in the field of acoustics.

Concerning the point relating to the adoption by Canadian government agencies of the recommendation of foreign consultants, I note the following. First, the Alberta Government has sought the assistance of The Canadian Acoustical Association in its attempts to frame a policy on environmental noise. We hope that the employment of the expertise of the senior membership of the association will result in a document being produced which will be useful to government agencies generally. Very great care has been taken in choosing the authorship of this report; it should, therefore, be authoritative and complete. I should perhaps note that it is being produced by the voluntary participation of many individuals including some from your ministry.

Second, I would like to express a personal opinion concerning the lack of a coherent policy on the matter of environmental noise in Canada. I believe that it is possible to show that there is a very definite need to develop standards and codes of practice for the production and employment of a wide range of industrial and commercial products. The need arises from two considerations - the need to manufacture items acceptable to the standards of foreign countries and also to protect the Canadian market against the dumping of noisier "end of line" products. There are, of course, more major and basic reasons for pusuing policies on environmental noise control, but the points which I have made suggest reasons for fairly prompt action.

I thank you, once again, for your letter and for the interest which you and your colleagues have shown. If there is any way in which The Canadian Acoustical Association can be of service, then I am sure that we can be relied on to do our best to assist.

Yours sincerely,

H.W. Jones

HWJ/rm

cc: Dr. C.W. Bradley, President

PREDICTING L_{10}, L_{50} AND L_{eq} FOR URBAN TRAFFIC NOISE

J. S. Bradley
Faculty of Engineering Science
The University of Western Ontario
London Canada

The work reported here is a small part of a larger project that has been carried out over the past two summers with the aid of students working on Ontario Experience '75 and '76 grants. The problem of predicting urban traffic noise levels breaks down naturally into two parts: (a) the prediction of levels close to the road and (b) the complex propagation of the traffic noise in an urban environment. Work on the propagation part of the problem has shown that simple methods such as "so many dB per row of houses" are inadequate, and point by point diffraction calculations for both the vertical and horizontal edges of buildings have been combined with the results of a computer ray tracing programme to predict attenuations due to arrays of apartments and townhouses. Results seem very promising, but are not yet complete. Therefore, the work reported here is limited to the problem of predicting levels close to the road.

PHASE I REVIEW

Results of the first phase of the work reported at the Toronto CAA Meeting examined methods for predicting various noise indices.(1) It was seen that in view of its simplicity, the empirical equations of Hajek's Ontario MT&C(2) method were about the best of the existing methods.

By refitting the empirical equations, using multiple linear regression analysis, new equations were obtained that produced even better results. This was not surprising in the case of the Delany equations which were derived originally from British data.

The first phase of the work thus showed that the Ontario equations were good but that the newly derived empirical equations were better. Both sets of equations were limited by the fact that they were empirical and hence were very much a product of the data base from which they were derived. There was a definite need to test the better equations with a larger amount of data, and to consider analytical equations that would better allow a fuller understanding of the noise generating process.

ANALYTICAL EQUATIONS FOR L_{eq}

An analytical equation was derived for predicting L_{eq} values. Although derived in a little different manner, it has subsequently been discovered to be essentially the same as an equation produced recently by BBN.[3] The equation was obtained by first calculating the L_{eq} for one vehicle by integrating over one complete pass by using an appropriate source level. Additional vehicles were then considered by adding the effects of each single vehicle.

Differences occurred between the present work and that of BBN in the use of vehicle source levels. After finding that their method overpredicted by about 4dBA, BBN arbitrarily subtracted 4dBA from all vehicle levels with some arguments about the shielding of one vehicle by another. It is interesting to note that when 4dBA is subtracted from the BBN expression for car source levels, it gives results almost identical to those of Olson at NRC.[4] As there is quite good agreement in the literature for car source levels at urban speeds, both the Olson and BBN-4dBA results were used for cars in this work. There is much less agreement in the literature for truck noise levels, due largely to the many types of trucks. The appropriate truck source levels were therefore determined by choosing values that minimized the error in the L_{eq} predictions at each speed. As an example, the value was 80.0 dBA for heavy vehicles at 30 mph and at a distance of 50 feet.

Analytical expressions for L_{10} and L_{50} were not attempted because their derivation is not such a clear cut problem. One must first make assumptions about the type of distribution of noise levels. These assumptions are approximations which must immediately be questioned, and it seems equally acceptable to consider empirical equations.

EVALUATION OF THE EQUATIONS

The more promising prediction methods have now been evaluated using 160, thirty-minute traffic noise recordings. The methods that were evaluated were: the Ontario MT&C method for L_{10}, L_{50}, and L_{eq}, the BBN equation for L_{eq}, and the new version of this equation. In addition, coefficients for the new empirical equations of the Delany form have been obtained by multiple linear regression analysis of the complete 160 data points.

Table 1 shows the standard deviations of the measured values about the predicted values.

All methods were reasonably accurate, but the Ontario equations for L_{10}, L_{50} and L_{eq} were inferior to the empirical equations developed in this work. This is probably largely due to the fact that the Ontario method was developed to predict highway noise, whereas the present data is strictly urban traffic noise. Of the four methods of predicting L_{eq}, the new empirical equation was the most accurate predictor followed very closely by the new version of the BBN analytical equation.

Figure 1 plots a range of predictions for three L_{eq} predictions equations: The Ontario, the new empirical, and the new version of the BBN. This figure illustrates that in more extreme conditions the three predictions differ quite greatly. For the case of 10% heavy trucks, the three methods are all quite close, (within about 1dBA). For the case of 20% heavy trucks, differences of up to about 2dBA occur. For the case of no heavy trucks, differences of up to 6dBA occur. Thus, the small overall standard deviations of 2 and 3dBA hide the much larger possible prediction errors in particular cases. More consideration must be given to the basic form of empirical equations and the range of the data base.

NON FREE FLOW TRAFFIC

It is frequently questioned whether prediction schemes are as accurate for non free flow traffic. Ten recordings were made for the extreme case of intersections with traffic lights. The results showed a small tendency for most methods to overpredict, but with only 10 points and such small effects, it can only be concluded that all of the methods are reasonably suitable for predicting noise levels at intersections with traffic lights.

GRAPHICAL PREDICTION METHODS

In many applications, simple graphical prediction methods can be extremely useful. Consideration was given to presenting the BBW type equation graphically. Because the effects of the three main variables (Cars/hour, Trucks/hour, and Speed) are not readily separable, a simple easy to use graphical prediction scheme is most easily obtained from the new empirical equation for L_{eq} as illustrated in Figure 2. Here, L_{eq} is plotted versus total vehicle flow rate for a range of values of percentage of heavy vehicles. Finally, a small correction is added for speeds over 30 mph.

USES OF THE ANALYTICAL EQUATION

One very valuable use of the analytical prediction equation concerns determining the effects of reduced vehicle noise levels. The resulting reduction in L_{eq} values is very easily calculated for various combinations of reduced car and truck levels. Several examples were calculated and showed that the commonly proposed case of reducing only truck levels would provide satisfactory reductions in overall traffic noise levels only at sufficiently high percentages of heavy trucks.

CONCLUSIONS

To conclude, several methods of predicting traffic noise levels have been evaluated, using a large number of urban traffic noise recordings. New empirical equations have been found to be more accurate than the Ontario MT&C methods. An analytical equation for predicting L_{eq} values similar to that derived by BBN has been found to be quite accurate when vehicles were considered only in two type groups, and using suitable vehicle source levels. A definite need is seen for more vehicle noise data under various real operating conditions to use with such analytical prediction equations. Intersection noise levels were found to be predictable with almost the same accuracy as free flow traffic noise, and a simple graphical prediction method for L_{10}, L_{50} and L_{eq} was obtained from the new empirical equations.

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(3) "Highway Noise Propagation and Traffic Noise Models". B. A. Kugler, G. S. Anderson, D. E. Commins, A. Piersol, NCHRP 3-7/3 (1974).

(4) "Survey of Motor Vehicle Noise". N. Olson, J. Acoust. Soc. Am., Vol. 52, N. 5 (Part 1), pp. 1291, (1972).

TABLE 1 STANDARD DEVIATIONS ABOUT PREDICTED VALUES (dBA)

	L_{10}	L_{50}	L_{EQ}
ONTARIO	3.39	3.86	3.17
NEW EMPIRICAL	2.05	2.12	1.92
BBN	-	-	2.87
COBB/BBN	-	-	2.02

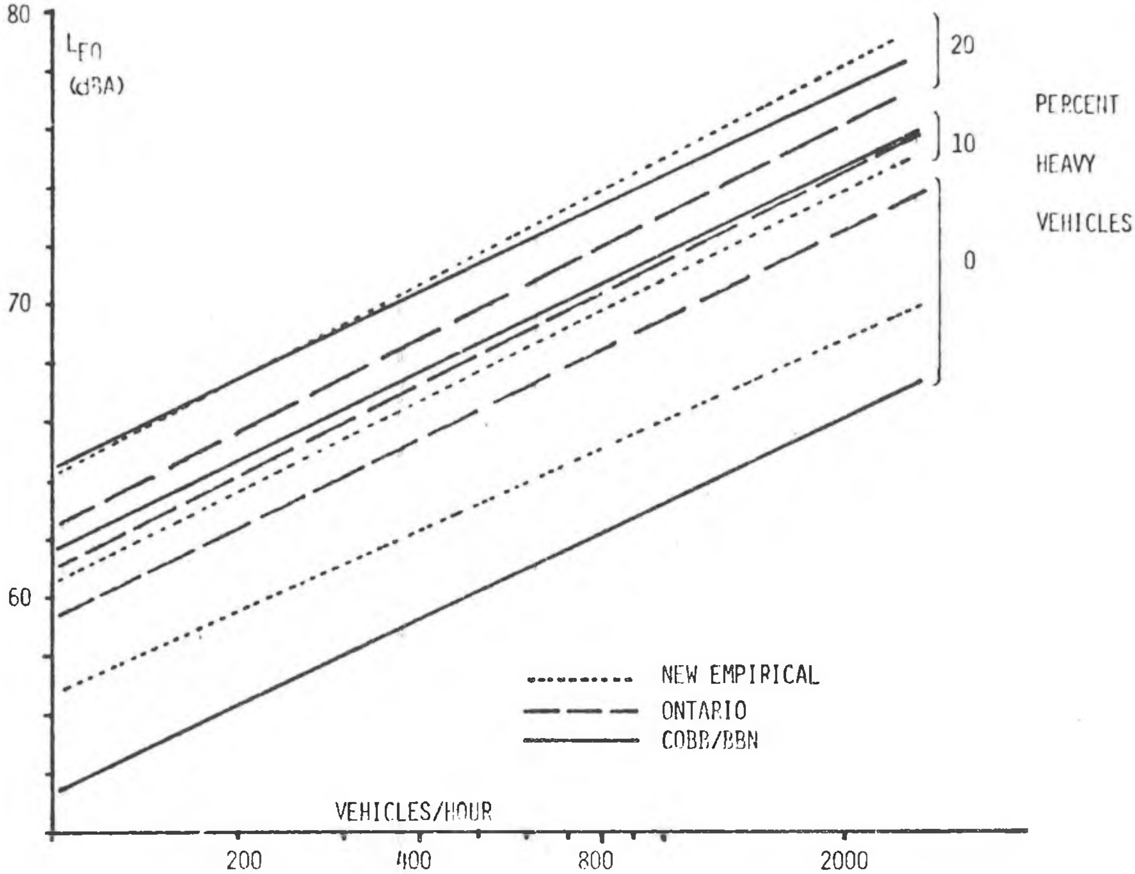

FIGURE 1 COMPARISON OF PREDICTION EQUATIONS

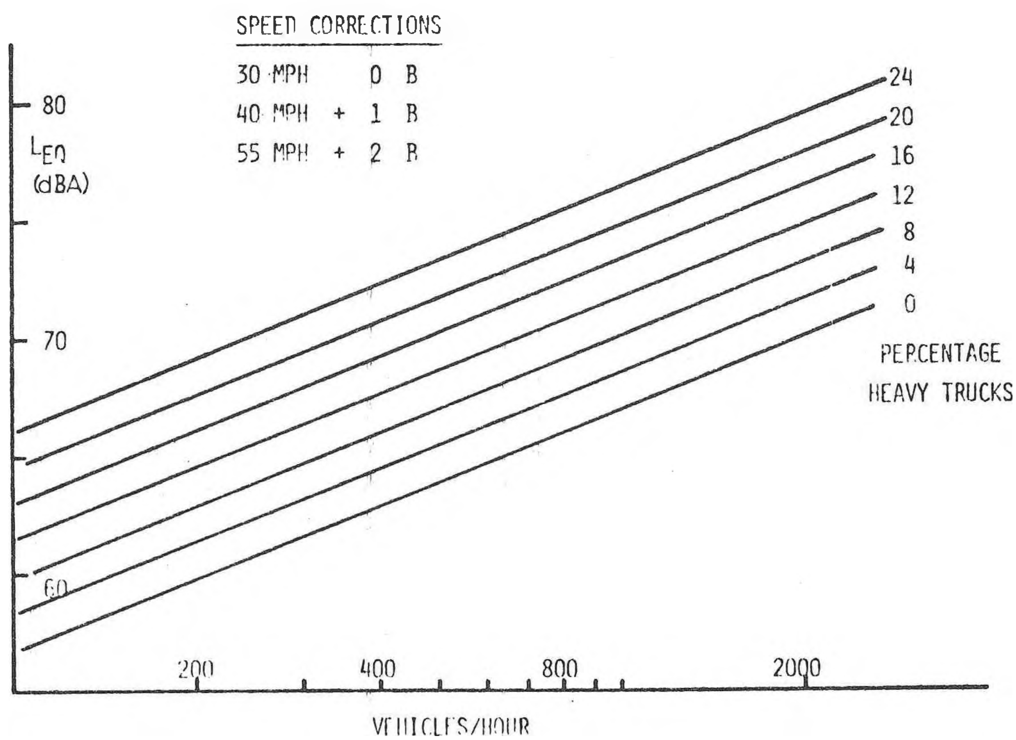

FIGURE 2 NEW GRAPHICAL L_{eq} PREDICTION METHOD

VISUAL DISPLAY OF SOUND WAVES IN TWO-DIMENSIONAL MODELS

W.M. Barss, J.E. Bernard, I.S. Graham
Department of Physics, University of Victoria

At the British Acoustical Society meeting in Loughborough, England, in 1972, there was a demonstration in which the passage of an ultrasonic pulse through water was made visible by a schlieren system using Ronchi grids. That system was used to display the effect of submerged sections of pipes or other shapes on the reflection and transmission of underwater sound.

The present project was devised to apply the same principles to display the reflection of sound from the surfaces of an auditorium, using either air or water as the propagation medium in the model. Such a display, which can illustrate focussing effects and excessive delays between arrivals of direct and reflected sound waves, was desired for demonstrations in connection with a proposed course in architectural acoustics and for testing models of halls designed by local architects for the University or other clients.

Basic Schlieren Principles

Optical inhomogeneities (*schlieren* in German) are usually made evident by the difficulty they cause: unstable density variations in the atmosphere make the stars twinkle and shift their apparent positions irregularly. Under some conditions the density variations are relatively stable, as in still air above a hot road surface, and distant objects may be seen clearly but displaced from their normal position by the gradual refraction of light rays.

An optical system designed to observe such inhomogeneities is commonly called a schlieren system. A simple example is illustrated in Fig. 1. In the absence of inhomogeneities in the system the image of point source S is focussed by lens L onto a small opaque spot on a transparent screen. Thus no light passes beyond this point, except for light scattered by dust particles.

When optical inhomogeneities are present (in practice confined to a thin region called the schlieren field), light rays passing through the inhomogeneities are deflected and no longer are focussed on the opaque spot. The refraction which causes this deflection is proportional to the transverse component of the gradient in refractive index. The schlieren field effectively becomes an object which can be viewed directly from behind the spot or whose image can be focussed on a screen by lens L'.

To allow more light to enter the system, the pinhole can be replaced by a narrow slit. The image of the slit may be absorbed by a parallel opaque line on the transparent screen or, more commonly, the screen is replaced by a knife edge that is parallel to the image of the slit and can be adjusted to block all or part of the light reaching the image. If about half of the light is intercepted by the knife edge, areas of the schlieren field will appear either lighter or darker than average, depending on whether they refract light away from or toward the opaque blade. In this case the only effective component of the refractive index gradient is the one perpendicular to the slit and knife edge.

Use of Ronchi Grids

Ronchi grids, which consist of alternating opaque and transparent bands that are parallel and nearly equal in width can also be used to replace the point source and opaque spot combination. The system is arranged so that the image of the transparent bands of the first grid is focussed by the lens on the opaque lines of the second grid. The required grid positions may be found experimentally by observing the moiré fringes at the second grid and adjusting the positions of both grids along the axis of the lens so that a single moiré fringe covers the whole visual field. This arrangement may be considered as multiple slits and multiple knife edges, with the advantages that the first grid may be illuminated by an extended light source and that the position of the observer's eye beyond the second grid is not critical, as is the case with the opaque spot or knife edge.

Folded Schlieren Systems

The system used in the present work is shown in Fig. 2. A simple Ronchi grid is placed at the centre of curvature of a concave mirror of 305 mm diameter and 3.05 m radius of curvature. The fact that the folded systems pass the light twice through the schlieren field makes the folded systems more sensitive than the single-pass systems but it also decreases the resolution since only the light ray along the axis is reflected exactly along its original path. To minimize the loss of resolution, the schlieren field is placed as close to the mirror as possible.

The lower half of the grid is illuminated by a strobe lamp with a reflector and a ground glass diffusing screen, via a plane mirror inclined at about 45° to the vertical. The horizontal top edge of this mirror is parallel to the grid lines and as close as possible to them.

In most of the work reported here, the Ronchi grid was produced photographically from a Letratone sheet LT 111 (available from Letraset Canada Ltd., of 24 Progress Avenue, Scarborough, Ontario) with the transparent bands 0.424 mm wide and the opaque ones 0.666 mm wide. The coarseness of the grid and the difference in width of the bands made it possible to obtain dark-field conditions in spite of imperfections in the glass windows. Tested samples of either plate or float glass were found to have inhomogeneities or thickness variations predominantly in one direction so they didn't contribute a schlieren pattern of their own if care was taken to assemble the cell so that both windows caused defocusing only in the direction parallel to the grid lines. With windows of better quality, a finer grid would be preferred for visual observation. For photography, any difficulty with the coarse grid can be avoided by using a camera with a long-focus lens and a lens aperture much larger than the grid spacing or by using an auxiliary lens near the grid to project a real image that can be photographed by a camera with a lens of shorter focal length.

Since the transition from dark-field to light-field conditions requires the grid to be moved in its own plane by only 1/4 of the distance between grid lines, a fine control for this motion is essential.

Sound Source in Air

The source of sound waves to be studied in a model auditorium must produce density gradients great enough for detection by the schlieren system and the disturbance should be of short duration so that a single wavefront and its various reflections can be clearly distinguished. An electric spark satisfies both of these requirements and is also small enough to simulate the production of sound by a single speaker or instrument in an auditorium.

A satisfactory spark was produced between two vertical wires projecting into the schlieren cell from the top, with their lower ends bent toward each other so as to leave a 10 mm gap parallel to the axis of the optical system. The long spark and cell thickness of only 5 cm (other dimensions 21 cm high and 22 cm wide) were chosen to make the shock waves in the two-dimensional model nearly cylindrical, rather than spherical, in order to improve sensitivity. Under these conditions, a wave could be followed for a path length of at least 40 cm.

Placing the spark near the top of the cell minimized the optical effect of heated air rising from the spark. To reduce electrical interference, a carefully shielded automotive ignition cable was used to connect the spark gap to the spark generator.

Light Source

Since the shock wave produced by the spark travels at a speed in excess of 330 $m \cdot s^{-1}$ it can be observed or photographed only if it can be illuminated by a light flash no more than a few tens of microseconds in duration. A General Radio Type 1531-AB Strobotac appeared to be a satisfactory light source although the light distribution from the reflector was uneven enough to require the use of a diffusing screen. A single flash would probably suffice for photographic recording but direct observation requires a flash repetition rate of at least 20 flashes per second.

Timing Controls

In order to observe a wave front at different positions as it expands within the model there must be a variable delay between the spark and the light flash which illuminates the resulting shockwave. This delay should be continuously variable between 0 and approximately 2 milliseconds.

The system described used a Tektronix type 162 waveform generator, synchronized to line frequency, to provide a triggering pulse to the spark, and also to provide a sawtooth signal to a Tektronix Type 161 Pulse Generator. The pulse generator produces a pulse of controllable amplitude and duration when the sawtooth signal voltage from the 162 matches a voltage set by the delay control potentiometer in the 161. The pulse from the 161 is used to fix the strobe light. Line synchronization was required because the high voltage spark power supply was powered by an unfiltered rectifier, and did not produce sparks of uniform intensity unless it was always triggered at the same phase of the alternating current cycle.

Modeling

Preliminary tests in a small test chamber have shown that good reflections are obtained from strips of metal, such as aluminum, approximately 50 mm wide and 1 mm thick, with which the contours of interior surfaces can easily be modeled. Figure 3 shows the results obtained using a camera with a 200 mm (zoom) lens directly through the grid.

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Schlieren Methods, by L.A. Vasil'ev, Israel Program for Scientific Translations, Jerusalem 1971.

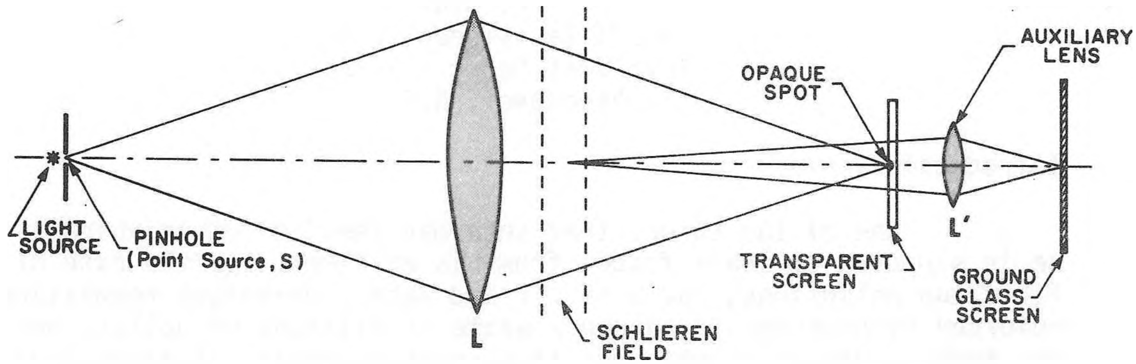


Fig. 1. Simple schlieren system using a pinhole and spot

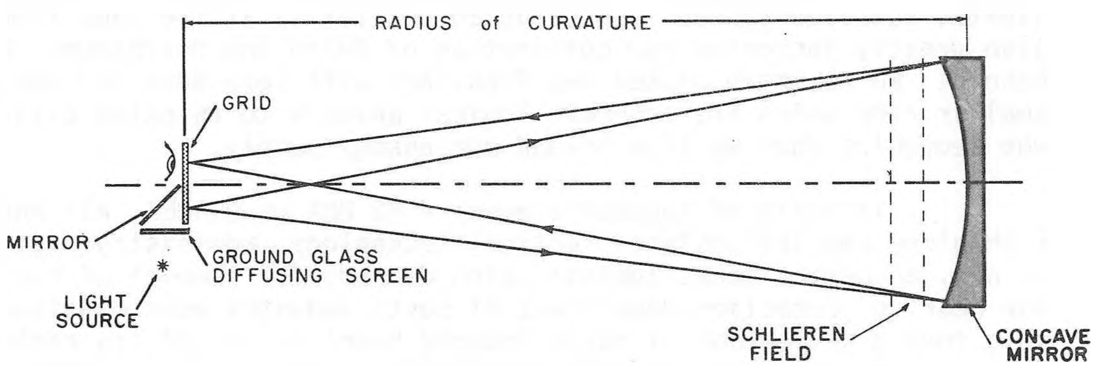


Fig. 2. Folded schlieren system with concave mirror and Ronchi grid

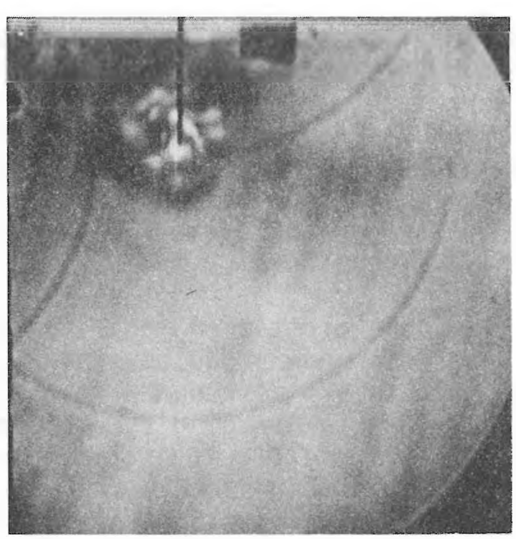


Fig. 3. Sound waves from spark gap, including portions reflected from wall and cover of schlieren cell.

Noise - The Third Pollution
Suggested Guidelines for Action Now

D.H.R. Blake
MacMillan Bloedel Ltd.
1075 West Georgia Street
Vancouver, B.C.

Introduction

One of the things that sets man ahead of other animals is that he is supposed to learn faster from his mistakes. In the case of the first two pollutions, those of air and water, premature regulations enforced by Governments caused a waste of millions of dollars because new technologies with more positive, more economic solutions were on the horizon. Perhaps in recognition of this, Governments in the United States and Canada appear bogged down in coming to grips with firm regulations on noise. None of us, I am sure, would like to repeat the classic errors of the automotive industry that: - reduced some pollutants to within limits, but simultaneously introduced new toxics at the same time, and also greatly increased our consumption of dwindling petroleum. Lo and behold! We now have broken new frontiers with lean-burn engines and smaller cars which are economic logical answers to thinking citizens who recognize that we live beyond our energy supply.

In spite of squabbles over: - 85 dBA vs 90 dBA, all known technology applied against practical technology, administrative controls or not, economic impact against union demands for removal of the need for hearing protection regardless of cost; industry must continue to move toward prevention of noise induced hearing loss of its employees by enforcement of hearing protectors and the elimination of noise in a logical economically feasible manner.

Suggested Guidelines for a Rational Approach

No matter what regulations Government bureaucracies of ever increasing size ultimately decide, the end point is to quieten our environment in the work place to below levels that cause hearing loss over and above that of natural aging. Does it not therefore appear rational to spend our hard earned dollars to reduce sound energy on a basis of maximum benefit to the most employees? Such a system can be instituted by a suggested "Rine" formula with "Rine" meaning the "Relative Importance of a Noise Expenditure".

Noise levels dBA plotted on logarithmatic paper with 90 dBA for 8 hours as a base reference produces a straight line. This plus the basics of the Rine formula are reproduced in the chart. To assess the energy being absorbed that is damaging to employees affected, noise dosimeters can be used or intelligent estimates made based on known time of the employee in a steady state noise. In the case of intermittent noise such as a whole log chipper which generates 110 dBA chipping a 30" log 30 feet long in 30 seconds, a recording sound level meter or watt meter on the motor gives a good positive measurement of intermittent noise.

The basic formula which is applied to each employee station affected by the noise source is:

$$\text{Rine} = \frac{(E_B - E_A)\ (h/_8)\ N}{M} + \frac{(E_{B_1} - E_{A_1})\ (h/_8)\ N_1}{M} + \text{---}$$

E_B = Energy equivalent before abatement (if sound level is continuous at 100 dBA E_B is 400% from graph)

E_A = Estimated energy equivalent after abatement (if we expect 93 dBA E_A would be 150%)

h = Estimated exposure of station for 8 hour shift (dividing by 8 hours puts it in ratio for time exposure)

N = Number of employees in station over 24 hours (i.e. three shift operation exposes 3 times as many people as a single shift)

M = Estimated cost in $1,000

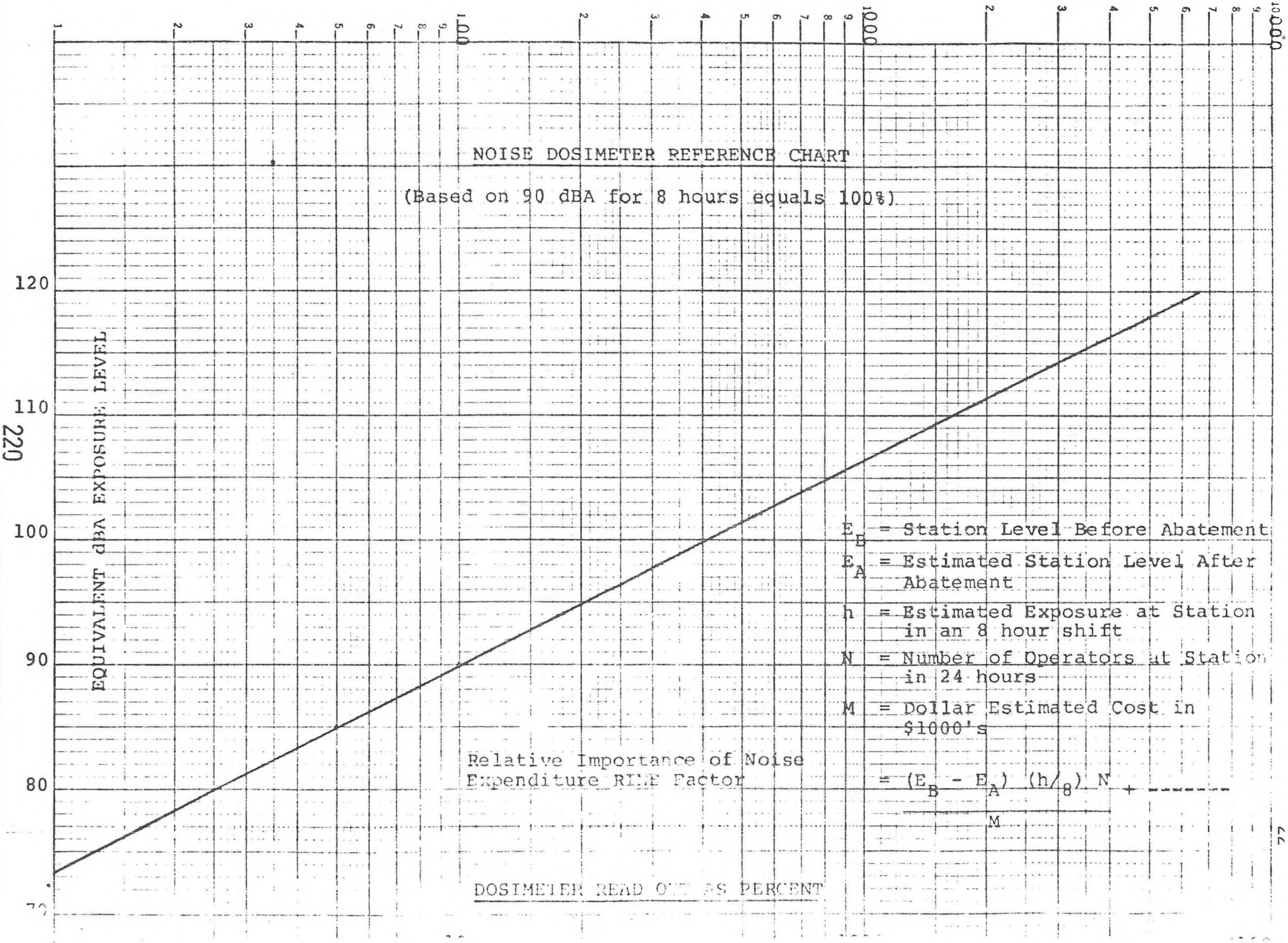
By summing these we get a factor which is positive identification of cost effectiveness of the abatement dollar. The higher the factor the higher the priority on reducing damaging noise energy for employees in the plant.

We do little these days successfully without full involvement. The Rine formula assists in convincing management that we spend our money wisely. It assists in assuring department managers that the choice is the best for overall noise abatement in the plant. It is a convincing argument to union presidents and the employees affected that the right course is charted.

DESIDERATA #1 states at the start:

> Go placidly
> Amid the noise and haste, and remember what
> peace there may be in silence.

Let us in the spirit of this code tackle our problems of noise and progress in what appears to the writer as a logical fashion to a most worthwhile goal - the progressive economically feasible elimination of noise from the work environment.


NOISE DOSIMETER REFERENCE CHART
(Based on 90 dBA for 8 hours equals 100%)
EQUIVALENT dBA EXPOSURE LEVEL
120
110
100
90
80
70
1
2
3
4
5
6
7
8
9
10
100
1000
E_B = Station Level Before Abatement
E_A = Estimated Station Level After Abatement
h = Estimated Exposure at Station in an 8 hour shift
N = Number of Operators at Station in 24 hours
M = Dollar Estimated Cost in $1000's
Relative Importance of Noise Expenditure RINE Factor
$= \frac{(E_B - E_A)\ (h/8)\ N}{M}$
DOSIMETER READ OUT AS PERCENT

A MULTI-CHANNEL DIGITAL NOISE MEASURING APPARATUS FOR THE MEASUREMENT OF NOISE PROPAGATION

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ABSTRACT

This paper describes a multi-channel system designed to make simultaneous measurements at up to six widely spaced points. The apparatus was used to determine the attenuation of traffic noise as it propagated over various forms of terrain in urban communities.

The method of data acquisition, digital coding, interfacing and subsequent computational treatment to obtain any of the A weighted statistical properties of the noise is described.

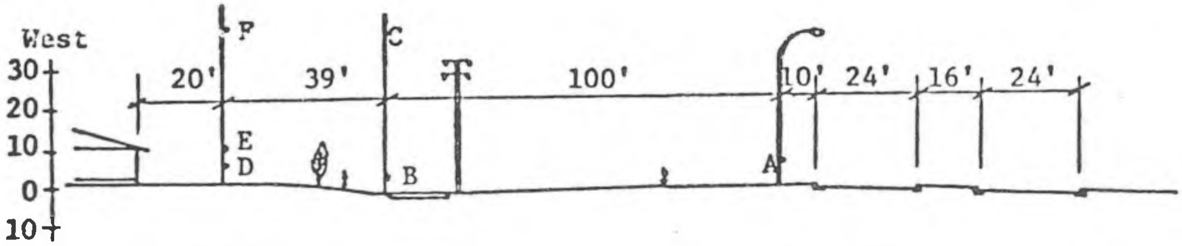
The use of the instrument as a long term (24 hours) survey meter is described.

Calibration methods are outlined.

INTRODUCTION

This paper describes a noise measuring apparatus which was designed and built at the University of Calgary in support of studies relating to traffic noise in the urban environment. The study required detailed measurements of the attenuation of road and railway noise by an array of microphones placed at right-angles to the right of way, as shown for example in Figure 1. These measurements were used to determine the accuracy of traffic noise prediction methods and the adequacy of barrier attenuation desigh formulae[1] and for the development of scaled model analogues.[2] The instrumentation was subsequently used to assist in social surveys and human reaction studies related to the original traffic noise problems.

The nature of the study implied the satisfaction of two operational requirements. First the accuracy of the differences between the microphone readings was of greater consequence than the absolute accuracy of any individual reading. Second, the knowledge of the temporal sequence of the readings was important. These considerations led to the design of an apparatus which was capable of sampling six microphones in succession with the microphones being up to 150 feet from the central measuring instrument.



SITE #13 Middle Section	MIC's	A	B	C	D	E	F
Blackfoot Trail S.W., Calgary	Heights	5	5	40	5	9	40

(160' north of n PL of lane between
Fyfree Road & Fleetwood Drive)

Figure 1. Typical Microphone Array Used in Field Measurements.

DESIGN CONSIDERATIONS

The primary design criteria was set by the need to use an array of microphones in a sampling mode. The rate of sampling is set by the statistical problems it invokes. Once a sampling rate is accepted as the prime criterion then it implies limits for the integration time and the dynamic range of the instrument. Fisk[3] has provided an excellent analysis of the statistical problems of sampling traffic noise. He concluded that the error introduced by sampling is given by:

$$\frac{\Delta L_{eq}}{\Delta L'_{eq}} = \left[\coth \left(\frac{\pi t_c}{\Delta t} \right) \right]^{\frac{1}{2}} \qquad (1)$$

where $\Delta L'_{eq}$ is the error for continuous sampling. The characteristic time t_c is given by $t_c = 2a/V$, where V is the vehicle speed and a is the source receiver distance perpendicular to the road. Δt is the sampling period and ΔL_{eq} the error associated with this period. Equation (1) is shown graphically in Figure 2.

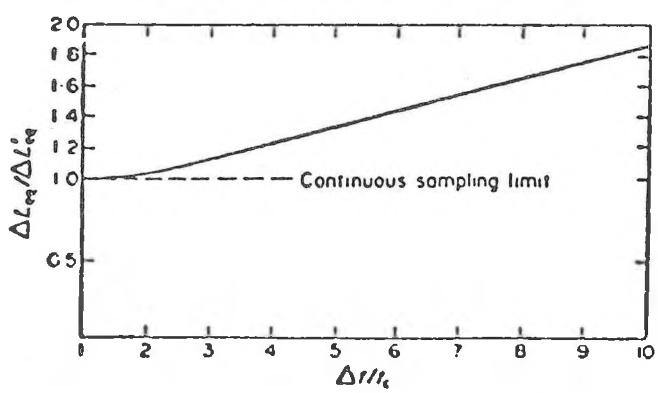


Figure 2. Error in L_{eq} Related to Sampling Period Δt.

We concluded that sampling rates close to 1 per second were required for the most adverse conditions under which it would be necessary to operate. Our initial version of the apparatus used one sample per microphone per second for three microphones. A second version used up to eight microphones (but normally six) and these were sampled at a rate of one microphone each one third of a second.

The acceptance of a particular rate implied that the dynamic range and frequency response of the instrument had to be limited. Previous experience[4] had shown that a dynamic range of 40 dB was more than adequate for this type of work provided that the minimum level could be chosen to satisfy any particular circumstance i.e. ranging from 40 to 80 dB or 50 to 90 dB and so on. It can be supposed that the successive reading between two microphones can differ by 40 dB i.e. the full dynamic range of the instrument. If a single analogue circuit is used for all microphones the time constant of the true r.m.s. circuit has to be chosen so that any reading does not mask the one which immediately follows it. This requirement leads to a slight modification of the bandwidth of the analogue circuit such that the output at frequencies below 60 Hz are slightly reduced. The effect is very small, however, and of no consequence for traffic noise measurements which are made using an A weighting network.

In order that the temporal information should be preserved it was decided to store the results as they were obtained so that they could be reproduced in correct sequence. The cheapest method available to us for this purpose was an inexpensive cassette tape recorder.

The need for maximum accuracy in the differences between the microphones was met by feeding the sampled signals to a single analogue and digital circuit. Consequently the processing was identical for all microphone outputs and no matter what drifts occurred the effects were the same for each reading.

DESCRIPTION OF CIRCUITS

Figure 3 shows the schematic arrangement which was used.

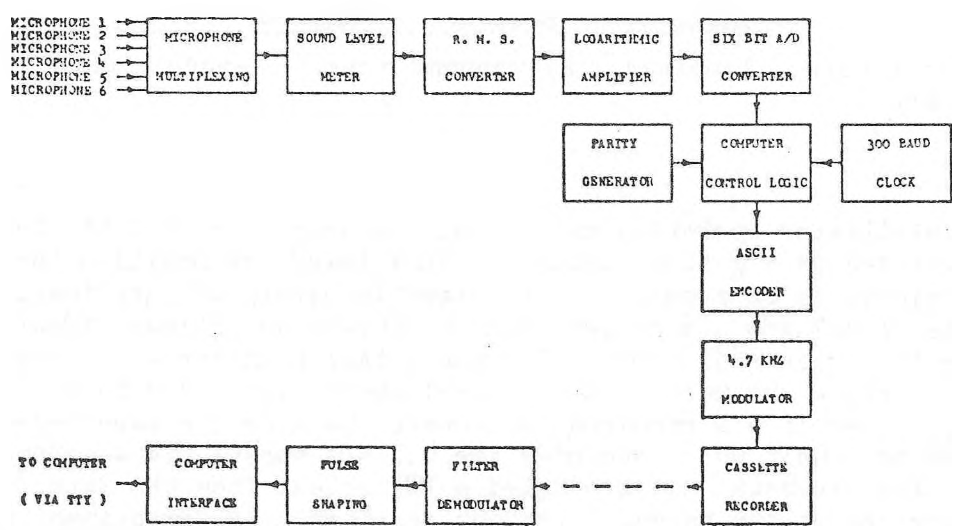


Figure 3. Schematic of Sampling Sound Level Meter.

The output from the six microphones was fed to a reed relay multiplexing unit. Each microphone was connected in turn to a sound level meter. This meter served two functions; it provided an approximate direct reading of the signal being measured and it served as an A weighted preamplifier. The output from this stage was fed to a true r.m.s. circuit and then to a logarithmic amplifier. The output from the logarithmic amplifier was fed to an analogue-to-digital converter which sampled the signal immediately prior to the end of the microphone switching period. A 6 bit converter was used because it was cheaper than more complex types and provided sufficient accuracy (5/8 dB steps). The digital output was displayed on light emitting diodes in binary form so that the operator could check the functioning of the instrument.

The six bit binary output was buffered by additional bits, to provide an ASCII code characters according to the scheme shown in Table 1. The clock circuit generated bits at a rate of 300 per second i.e. at a rate of 100 bits per microphone sampling period. There was thus an opportunity to generate and store associated information. Consequently the data sequence shown in Table 2 was used for each sampling period.

Table 1. Coding for Tape Recording.

Binary Level	0	1 → 26	27,28,29,30,31,32	33 → 58	59,60,61,62,63
ASCII coded character	@	A → Z	[\ ] ^ > `	a → z	{ ,| ,} ,∿ ,?

Example of Coding

Binary Level 23	Character W.
Binary output	010111
Additional bits	1 1
Final character (W)	1 010111 1

Table 2. Sequence of Data Recording.

Carriage return, linefeed, microphone number, space, data, carriage return etc.

An oscillator operating at 4.7 KHz was used to record the data. This signal was fed to a gating circuit which allowed the positive logic digital signal to be recorded on the tape in bursts of pure tone. A frequency of 4.7 KHz was chosen because it gave an optimum signal to noise ratio in the recovered signal. The cheap tape recorder which was used accepted tapes which would run at normal speeds for a period of 90 minutes per side. When it was required to recover the data the tape recorder was connected to a unit which accepted the 4.7 KHz bursts via a narrow band filter. The playback unit generated a TTY signal from the data for transmission by any of the normal telephone couplers. An arrangement was made to use the play-back unit in association with a normal computer terminal so that computer control instructions could be generated as required.

The instrument was adapted to serve as a community noise monitor. In this role the instrument sampled a single microphone once per second and stored the information on a tape which ran at one third normal speed. It was arranged that the circuit operated for ten minutes in a 25 minute period. The tape recorder was able to store data for an 18 hour period when it was operated in this manner. Consideration was given to the provision of short term digital storage which would store the data obtained from continuous sampling (with the usual loss of temporal order) for periods of up to 30 minutes. It was planned that at the end of that time stored data would be read onto tape, and the registers reset for the next period. The expense of this modification has not justified its incorporation up to this time because the additional accuracy it could produce was not required.

The apparatus, which is shown in Figure 4, operated from storage batteries which required charging after 48 hours of continuous operation.

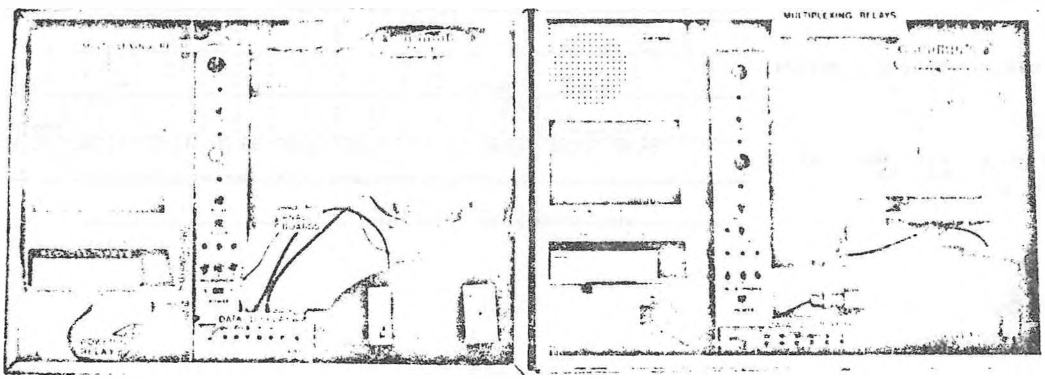


Figure 4. Early and Later Version of Apparatus.

Figure 5 a shows the output obtained directly from the magnetic tape and Figure 5 b shows the data sorted and interpreted. Figure 6 shows a histogram obtained from the data together with the derived descriptors and the microphone calibrations. It is to be noted that the sensitivity of the microphone placed next to the roadway was reduced by 10 dB relative to its neighbours. Table 3 shows the data obtained for field readings associated with the microphone array shown in Figure 1.

Traffic Noise Data Sample Before Statistical Analysis

6 Microphones ASCII Coded Data With Microphone Nos.		6 Microphone Data After Conversion from ASCII to Numerical Values 0 to 63					
1	f	38	34	40	32	38	4
2	b	30	36	42	30	38	3
3	h	38	35	40	27	35	4
5	`	30	30	35	23	29	4
6	f	21	25	35	26	31	3
7	D	22	30	37	26	35	5
1	^	27	33	40	29	39	3
2	d	40	37	39	28	34	3

Figure 5 a.   Figure 5 b.

Sample Statistical Computer Output For 1 Hour Data in 6 Microphone Mode of Traffic Noise

```
/OTLEV7

CALIBRATION POINT: MIC1= 54.15 MIC2= 43.75 MIC3= 45.05 MIC4= 47.05 MIC5= 44.55 MIC6= 44.95
MICROPHONE NUMBER 1
L90=63.0dB A
L70=72.0dB A
L50=74.0dB A
L10=79.0dB A
ENERGY EQUIVALENT NOISE LEVEL =  75.8 DBA
MICROPHONE NUMBER 2
L90=62.0dB A
L70=64.0dB A
L50=65.0dB A
L10=70.0dB A
ENERGY EQUIVALENT NOISE LEVEL =  67.8 DBA
MICROPHONE NUMBER 3
L90=61.0dB A
L70=57.0dB A
L50=70.0dB A
L10=73.0dB A
ENERGY EQUIVALENT NOISE LEVEL =  71.6 DBA
MICROPHONE NUMBER 4
L90=61.0dB A
L70=64.0dB A
L50=59.0dB A
L10=70.0dB A
ENERGY EQUIVALENT NOISE LEVEL =  67.0 DBA
MICROPHONE NUMBER 5
L90=62.0dB A
L70=59.0dB A
L50=67.0dB A
L10=73.0dB A
ENERGY EQUIVALENT NOISE LEVEL =  68.0 DBA
MICROPHONE NUMBER 6
L90=67.0dB A
L70=63.0dB A
L50=70.0dB A
L10=73.0dB A
ENERGY EQUIVALENT NOISE LEVEL =  70.5 DBA
STOP
/

RETURN,HIST
RETURN,HIST.
/LIST
 1834  60  47  34   110.   120.   1.63
 10.4   9.1   7.1   9.6   9.2
90 70 50 10  4
/
```

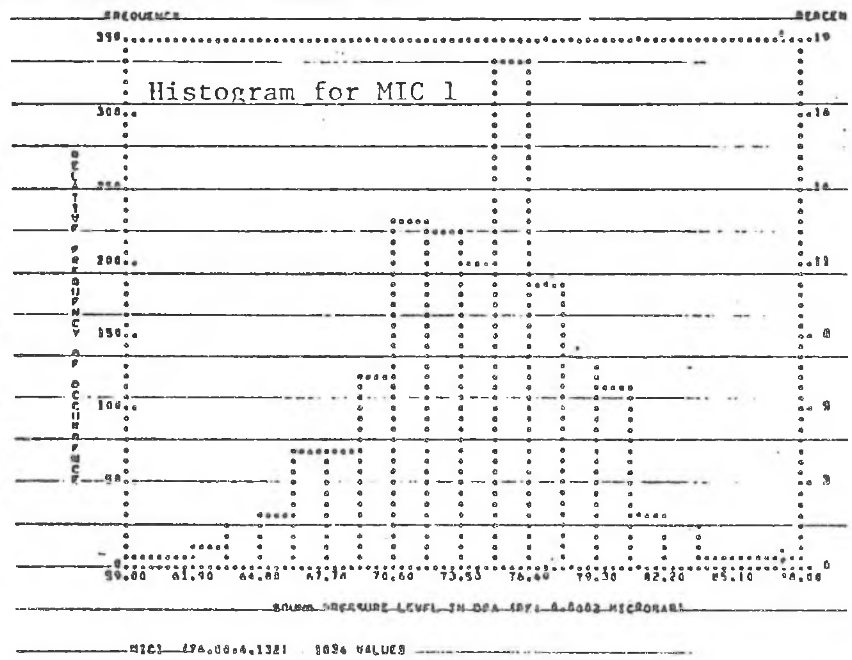


Figure 6.

CALIBRATION

The calibration of the system with its 6 microphones was achieved in two stages. First each microphone was placed in an enclosure with an approximately white noise field. The intensity of the sound was a constant when averaged over a period of time. This average level was measured by a precision sound level meter which had been calibrated separately. Each microphone with its associated head amplifier and cable was placed in the same position in the sound field in turn and the digital output recorded. Second, in the field, a precision sound level meter was used to monitor the same sound field as the microphone placed closest to the road. This data was used for comparison with the information obtained by the sampling instrument. At the start and finish of each field measurement a pistophone operating at several frequencies was used to check the outputs of each microphone in turn.

CONCLUSION

A measuring system, designed primarily for field measurements of traffic and railway noise and its attenuation by barriers and buffers is described. The method uses relatively cheap integrated circuits and records its data on a cheap tape recorder. The advantages of the instrument in reducing errors related to the differences in the readings between the microphones is described. Sample field data is given. The operation of the unit as a survey monitor is also described.

Table 3.

TRAFFIC NOISE MEASUREMENT DATA

SITE NO. 11 SECTION Middle

LOCATION Blackfoot Trail S.W., Calgary

DATE 26-5-76 TIME PERIOD 11:40 - 12:42

MICROPHONE POSITION ON DIAGRAM	MEASURED NOISE LEVEL (dBA)				
	L_{10}	L_{50}	L_{70}	L_{90}	L_{eq}
A	82	76	73	69	79.4
B	67	61	60	58	63.7
C	73	70	69	66	71.0
D	62	57	55	53	59.8
E	65	59	57	55	61.9
F	70	68	67	61	67.3

DIRECTION	VEHICLE VOLUME (VEHICLES/HR)			
	AUTOS	MEDIUM TRUCKS	HEAVY TRUCKS	MOTOR-CYCLES
Southbound	1021	32	48	2
Northbound	472	45	89	0

AVERAGE VEHICLE SPEED N.B. - 47.5 S.B. - 47 mph

AMBIENT TEMPERATURE 16 °C

WIND SPEED 5 mph DIRECTION S.E.

SKY DESCRIPTION Clear, light clouds and haze

GROUND COVER 2" grass from Blackfoot to Mic B, gravel and clay from Mic B to Mic D

ROADWAY GRADIENT 1.5 %

ABSOLUTE INSTRUMENT ERROR 0.7 dBA max.

STATISTICAL STANDARD DEVIATION OF L_{eq} (ΔL_{eq}, ref. D.J. Fisk) 0.2 dBA

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Note: This paper is to be presented at INTERNOISE 77, Zurich, Switzerland