Community Noise Conference

Toowoomba: 1-3 October, 1986

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DDIAE, TOOWOOMBA
QUEENSLAND, AUSTRALIA

FROM RAY PIESSE

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FOREWORD

The overall theme of this conference is the achievement of community quietness through effective noise management. Particularly, it is intended as a meeting point for the many disciplines associated with the control of community noise; acousticians, engineers, planners, legislators, administrators, - for all whose interests lie in this aspect of the health and well-being of the community.

An encouraging response to the call for papers has resulted in this set of proceedings achieving the aim of broad coverage. As well as a wide range of topics in the technical sense, there is also a wide geographical spread in both keynote and contributed papers.

It is our hope that through this event there will be a positive contribution to community quietness.

CONTENTS

Keynote Addresses

Stream A

Policy and Law

Community Levels

Community Noise

Prediction Techniques

People

KEY NOTE ADDRESSES

FORMULATION AND APPLICATION OF COMMUNITY NOISE ASSESSMENT PROCEDURES

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ABSTRACT

Community noise is a complex phenomenon with many dimensions. There is a historical dimension to the assessment procedures currently in use which deserves a brief review. Next, there are the critical dimensions of purpose and scope in any community noise assessment process. The complex pattern of community noise environments makes this a vital step so that the scope of a community noise assessment can fit within normal program resources. The spatial and temporal dimensions of community noise are reviewed to define methods for the formulation and application of measurement procedures which account for these dimensions. This review also includes a brief consideration of frequency spectra of the envelope of community noise time histories as one example of a different view of community noise assessment.

1.0 INTRODUCTION

This paper will address the different dimensions of community noise assessment. On Thursday, Dr. van der Molen will address important dimensions involved in the control of community noise and on Friday, Dr. Bronzaft will address the critical dimensions involved in the effects of community noise on people.

My objective in this kick-off paper will be to provide at least one perspective for the formulation and application of procedures for community noise assessment. More simply put, I will talk about effective ways to determine how noisy it is in a community. It seems to me that the most effective ways to assess community noise are those which will clearly inform all concerned about the true noise climate in a community and, if called for, provide the basis for follow-up action by decision or policy makers to set noise control measures into place. In other words, community noise assessment procedures should be both informative and functional in terms of potential noise abatement programs.

Given this objective, let me state just what I hope to cover. First, a bit of history on community noise assessment is appropriate—there are important dimensions in previous studies which are worthy of recall. Next, I will talk about how one can develop effective community noise assessment procedures. This will include consideration of the purpose and scope of such assessments, discussion of the temporal and spatial dimensions of community noise, and a brief examination of the frequency spectra of the fluctuations in community noise levels. All sound levels considered in this paper are A-weighted.

2.0 HISTORICAL BACKGROUND

The first useful study of community noise in the United States was carried out in 1937 in four major cities by Bell Telephone Laboratories (Seacord) using an early model of the current standard sound level meter. The noise at each site consisted of the arithmetic average of 50 "snapshots" of the noise level observed every 5 seconds at the edge of the street. A total of 1,700 residential, commercial, and industrial sites were measured in these four cities, during summer and winter periods.

Although this survey was relatively modest in terms of the total number of site-hours (119) compared to many later studies, it represents one of the largest surveys in terms of number of sites measured. The survey provided a significant benchmark in community noise assessment from several aspects.

- o The simple "acoustic snapshot" method employed, although relatively crude, still has application today as a useful procedure for obtaining rough community noise measurements with nothing more than a sound level meter and a watch.

- o It represents perhaps the first major use of a standard sound level meter to acquire such a large volume of data—thus providing an early example of how advances in instrumentation can drive the development of new noise assessment procedures.

- o The spatial variation in the noise level over all sites in residential areas was found to be approximately normally distributed with a mean value, in terms of an A-weighted sound level, of 55 dB(A) and a standard deviation of the spatial variation of 7.5 dB. These values were obtained in typical urban residential areas in Chicago, Cleveland, and Philadelphia. For comparable areas in New York City, the fourth city investigated, the mean levels were about 10 dB higher but the standard deviation in level was less—about 4 dB. The mean levels in commercial areas in all cities were about 7 to 8 dB higher.

- The seasonal change in levels was small for these data, amounting to an average decrease from summer to winter of about 2 dB.

These general characteristics for the mean noise levels in residential areas are quite similar to those observed in many studies carried out since that time. This is illustrated more clearly in Figure 1 which shows the variation in the median or L_{50} level measured in the daytime period in over 40 community noise surveys in suburban, urban and metropolitan residential areas in the United States and Europe from 1937 to 1978 (Wyle, 1978). In all the cases illustrated, all sources of community noise are included without special emphasis on any one single source such as aircraft or highway traffic. There are, of course, valid reasons for much of the variation in mean levels illustrated in Figure 1. For example, noise levels measured at the edge of a street are higher than those measured close to a residence. The data in Figure 1 include both of these types of measurements. Nevertheless, one clear trend is indicated by the data in the figure—the average noise levels in typical residential areas do not appear to have changed significantly, if at all, over the last 50 years.

This gross generalization assumes, of course, that the type of land use remains constant. In fact, the gradual urbanization that often goes on at the suburban fringes of large cities is a major cause for an actual increase in the number of people exposed to higher residential noise levels. Thus, for a long term resident of such an area, the noise levels in a developing community can and do increase over time. Increasing urbanization is normally accompanied by increasing population density and increasing noise levels. This trend was demonstrated very clearly by the results of a survey of community noise at 100 sites in 14 large cities in the United States carried out in the 1970's (Galloway, et al.). A key result from this study, shown in Figure 2, indicates that the Day-Night Average sound level (L_{dn}) varied, as expected, with population density. For a two-fold increase in population density, the average noise levels in a community will tend to increase by about 3 dB.

Basic information on another important dimension of community noise—its frequency spectrum—evolved out of early studies on community noise. (Bonvallet, Donley, Sutherland). As shown in Figure 3, values of median octave band levels, averaged from a total of over 350 sites from several different surveys, show a remarkable degree of consistency. Only at frequencies above 2000 Hz is there any substantial divergence in these data. The latter variance can be due to changes in weather conditions prevailing for the various studies, or to differences in the amount of insect noise. The important point, however, is that the frequency spectrum of general outdoor ambient noise, <u>in the absence of any single identifiable, dominant source</u>, can be expected to show the type of consistent pattern illustrated in Figure 3. Determination of this type of spectral pattern is an essential requirement if one wishes to set detailed criteria for allowable outdoor noise levels in terms of maximum octave band levels. Furthermore, the difference between the band levels of background noise and band levels of an individual indentifiable noise source is a key factor in assessing the potential intrusiveness or relative loudness of the intrusive source.

This very brief review of some of the basic information available from previous surveys of community noise is hardly definitive for specific locations but serves only to highlight several aspects of community noise—the stability of average noise levels, their average spectra and the variation in these levels with population density. There is much more, of course, to be learned about the specific nature of the noise in your own community, and that's what this conference is all about.

3.0 FORMULATION OF ASSESSMENT PROCEDURES

3.1 Establishing a Purpose for an Assessment. Consider, now, some of the specific reasons for carrying out a community noise assessment. Once the ability to routinely measure noise existed, and greater emphasis began to be placed on living environments, environmentally-oriented city governments began to augment long-standing qualitative common law noise nuisance ordinances with quantitative limits. Within the United States today, there are over 900 noise ordinances in place; two-thirds of these have been established since 1970 (Bragdon). They vary widely in structure but are often based on maximum allowed A-weighted levels at the property line of a receiver such as a residence, or maximum levels at a specified distance from an offending source such as an industrial plant. Specification of such allowable limits has often been preceded by conduct of a community noise assessment to establish the existing noise climate in a community. However, there are other reasons for community noise assessments including:

- Development of environmentally-based land use planning or zoning,
- Evaluation of the relative contribution of various major outdoor noise sources such as highway vehicles or aircraft to a community noise environment,
- Development of noise environment data to support an attitudinal survey of community response to noise,
- Evaluation of the potential environmental impact of some new development.

Thus, there are many dimensions to the purpose of carrying out a community noise assessment. These are closely related to the next aspect of community noise assessment I would like to briefly touch on: the factors which govern the scope and cost of a noise assessment.

There are three critical dimensions involved in the scope and cost of a community noise assessment: the spatial extent of the survey, the time period to be evaluated, and the overall accuracy required. The following guidelines are provided for consideration of each of these dimensions.

3.2 Spatial Sampling of Community Noise. If the purpose of the noise assessment involves development of data for land use planning or zoning, the spatial coverage should obviously include an adequate sample of all types of land use under consideration. A recommended starting point is to obtain a basic land use map of the area involved, along with data on traffic flow on the major streets or highways which traverse the area. These data can then be used to make initial estimates of the traffic noise levels. The maps and estimated traffic noise levels can be combined into preliminary survey planning maps with various basic land uses subdivided into cells by the traffic noise zones associated with the major streets through the area. The traffic noise zones could be based on estimates of the zone that would be exposed to an average noise level greater than a desired criterion value. A practical specification for such traffic noise zones would be that they extend to the full depth of one residential lot on either side of the major streets, or a distance of 60 meters, whichever is less. An area can be divided into traffic noise zones according to the amount of daily traffic flow. For example, streets with a daily traffic flow between 4,000 and 12,000 vehicles would constitute the lower traffic noise zone, while streets with more than 12,000 vehicles per day would fall into a higher zone. Armed with these data, one can then develop a combined deterministic and random sampling plan so that representative noise levels can be established for each type of land use and/or noise zone in an efficient manner. The point I wish to make here is that I believe the most cost-effective and informative approach to accurately assess community noise, in a large area involving many different types of land use, is to account, wherever possible, for the predictable spatial pattern of the noise. This deterministic approach is preferred over drawing spatial samples at random or systematically from a fixed grid pattern without regard to land use or existing noise zone characteristics. The type of noise zone pattern suggested is based on the fact that road traffic is the dominant source of noise in most residential communities. The result is that the line source characteristics of traffic noise provide predictable linear noise zones which form natural boundaries for noise zones or cells that are not directly impacted by traffic noise.

One microscopic view of such a noise zone pattern, based on actual measurements, is illustrated in Figure 4. The figure shows detailed contours, at 3 dB intervals, of average sound level measured over a 45 minute period by a two-man acoustic "rod and chain" surveying team around an apartment complex. The basic gradient in sound level between streets and adjacent buildings is quite apparent in this figure. There is also a complex variation in noise level between adjacent buildings. Obviously, it would not be cost-effective to carry out such detailed measurements for most community noise assessments. Instead, one can consider the type of contours shown in Figure 4 as representing fixed patterns of relative noise level around buildings arranged in a similar way close to adjacent streets. Such a pattern of relative noise level can be effectively transformed into a pattern of absolute levels by a measurement of the absolute level at a convenient reference point. This is essentially the approach taken in most noise surveys in residential areas. A convenient and practical "reference point" in this case could be a position at 1 meter from the building facade and centered on the largest window facing onto the street. This position would usually be unambiguous and has practical significance as a position near what will normally be the most effective pathway for outdoor noise to enter a residence. Alternatively, one could choose a reference measurement point at a fixed setback distance from the nearest street.

An entirely different approach to spatial sampling is employed for assessing a large community noise source distributed over an area such as an industrial plant. One standard procedure has been proposed for this situation which involves measurement at selected positions along the property line of the plant (ISO DP 829).

The number of spatial samples required in any community noise survey will be based on the desired accuracy of the survey. Spatial samples of community noise drawn from a population of similar land use areas have been shown to follow, to a first approximation, a normal distribution (Goff, Sutherland, 1978) with a standard deviation usually falling in the range of 4 to 8 dB. From one group of community noise studies (Wyle) the standard deviation in spatial samples varied with land use or noise zone categories as indicated in the following table.

Table 1. Average Standard Deviation in Spatial Samples of Average (Leq) Community Noise Levels (Wyle).

Type of Noise Zone	Standard Deviation, dB Range	Mean
Residential (Interior Zone)	4.3 - 8.6	5.7
Light Traffic Zone (6,000 - 18,000 ADT)	2.1 - 4.3	3.3
Heavy Traffic Zone (more than 18,000 ADT)	2.1 - 5.1	3.5
Commercial/Industrial	5.8 - 6.3	6.1

Using typical spatial standard deviations values like those in the table, one can then apply convential "Student's" t statistics to predict the size of the measurement sample in each type of land use or noise zone. Figure 5, based on this approach, shows the sample size required to obtain an estimate of the true population mean (noise level) value within the specified 95 percent confidence limits. For example, if a 95 percent confidence limit of +/-3 dB is desired to obtain a reliable measure of the average noise level in residential noise zones (that is, in residential areas not close to a major street), then, assuming that the standard deviation for spatial samples in such zones is about 6 dB, Figure 5 indicates that 18 samples are required. Data obtained by Wyle on temporal correlation of adjacent spatial samples of community noise indicates that the spacing should not be less than about 300 meters to insure that each sample is statistically independent.

3.3 Temporal Sampling of Community Noise. Much has been written about accuracy problems encountered when sampling community noise at anything less than 100 percent of the time, and only a few aspects of this complex problem can be addressed in this paper. First of all, the statistical distribution of temporal samples of community noise levels has been shown to exhibit, on the average, a Rayleigh distribution instead of the approximately Normal distribution as for spatial samples (Sutherland). However, this generalization does not reflect the wide range of statistical distribution patterns that actually appear in temporal samples at individual sites. One early insightful study of these statistical patterns posed a basic model for temporal statistics which, regretably, does not appear to have been pursued further (Donley). This study pointed out that the skewed statistical distribution often observed in temporal samples of community noise is the expected result of adding the approximately normally-distributed noise from the many sources which make up background ambient noise to the noise from individual (identifiable, intrusive) sources which would be expected to have a Poisson distribution. In fact, such a pattern seems quite reasonable in areas where the higher levels in an acoustic environment are dominated by noise from individual road vehicles since road traffic flow is itself modeled by a similar distribution. The point of this diversion into statistical models is to emphasize the importance and difficulty of accurately assessing extreme values in the temporal variation in community noise environments. Extreme values, such as the L_{10} level, represent the noises which will usually be the most disturbing and which are often the target of quantitative noise ordinances. Figure 6, based on one detailed study of temporal sampling errors (Shultz), illustrates the deviation between statistical sound levels measured with several ten minute samples, and levels measured with full 60 minute samples, at two different time periods at the same location. The sampling errors are relatively small for the period with a nearly Gaussian statistical distribution. For the period with a very skewed distribution, the errors in the ten minute samples are much larger for the extreme statistical levels, as one would expect.

The hour by hour variation in community noise levels is one of the most important dimensions to consider in community noise assessment. Sampling of these hourly variations with anything less than continuous measurements will necessarily involve the type of problem illustrated in Figure 7. This shows the 24 hour variation in average noise levels at one site based on full one hour samples and successive 15 minute samples. The latter exhibit the type of actual variation in average level over periods less than one hour—a variation which must be recognized in any temporal sampling scheme. This short term variation in community noise is effectively included in local noise ordinances which are based on maximum allowable levels over specified fractions of any hour.

A very different perspective on temporal variation in community noise is provided by looking at the actual frequency spectrum of fluctuations in community noise level time histories. Why should this be of interest? Part of the reason is that this frequency spectrum represents a more complete description of the temporal pattern of noise level fluctuations than can be provided by statistical levels. In fact, this more complete description could be used to improve the accuracy of any temporal sampling scheme by applying the well known methods for measurement and analysis of any time series. This benefit is less important today due to increasing availability of integrating sound level meters and small digital recording sound exposure meters which make it possible to store and retrieve detailed data from a continuous measurement of community noise. Nevertheless, for noise regulation schemes or ordinances which depend upon accurate knowledge of statistical levels, such as the L_{10} level, there is always room for improved knowledge on how to measure or interpret such data, and fluctuation spectra offer one approach towards development of this improved understanding.

However, there is another reason for looking at such spectra. Several investigators have suggested that the frequency of fluctuation of community noise levels may have a significant bearing on human response to this noise (e.g., Fuller and Robinson, Bennerhult, et al.). Figure 8 illustrates some of the basic data pertinent to this topic. The solid line represents the actual fluctuation spectra measured at a typically busy highway site in England (Sutherland and Ollerhead). Note that this spectrum, which is expressed in terms of one-third octave band values of the fluctuation amplitude in decibels, peaks at a frequency of about 0.1 Hz. This peak fluctuation frequency fell between the traffic flow rate of so-called traffic "platoons" or clumps of vehicles, and the traffic flow rate of heavy vehicles or trucks. The broken line represents the approximate "frequency weighting" developed by Fuller and Robinson to explain their findings on how human response to traffic noise varies with the frequency of the noise fluctuations. Finally, the dotted line in Figure 8 shows the typical frequency spectrum of fluctuations in normal speech sounds (Houtgast and Steeneken). It is interesting to speculate on the potential significance of the shape of community noise fluctuation spectra on annoyance related to interference with speech. I must point out, however, that one study on this very topic has indicated that for a constant average noise level, annoyance and speech interference from traffic noise actually decreased as the amplitude of the fluctuation increased (Pearsons). However, no information was provided in this study on the frequency of the fluctuations, and it is thus not conclusive.

4.0 SUMMARY

In this paper on community noise assessment procedures, I have tried to show how gross trends in average noise levels in typical urban areas show no evidence of significant change over the last 50 years in areas where the population density has not changed substantially. However, average noise levels can be expected to increase in direct proportion to population density. Spectra of community noise from many unrelated studies show a remarkable degree of consistency, making it possible to provide reasonable estimates of average spectral shape of community noise levels for the purpose of setting detailed noise limits in terms of band levels or assessing intrusiveness of individual noise sources. Guidelines for implementing spatial sampling of community noise levels were outlined. Particular emphasis was placed on obtaining details of traffic flow throughout the study area as a key beginning to development of a sampling plan. This plan would recognize that urban areas are partitioned into noise zones consisting of linear traffic noise zones which serve as natural boundaries to the interior residential land use zones or cells not directly impacted by traffic noise. Several aspects of temporal sampling of community noise were also discussed, with particular emphasis on two issues: the critical importance of sampling errors when attempting to accurately measure extreme noise values such as L_{10} levels, and the potential insight into both temporal sampling problems and human response to community noise gained by examination of the spectra of fluctuations in community noise levels.

Space does not allow discussion of the many other aspects of community noise that pertain to its assessment, but it is hoped that this brief review has provided some useful background for you who are actively working to protect a national treasure in Australia—the environmental attribute—Quiet.

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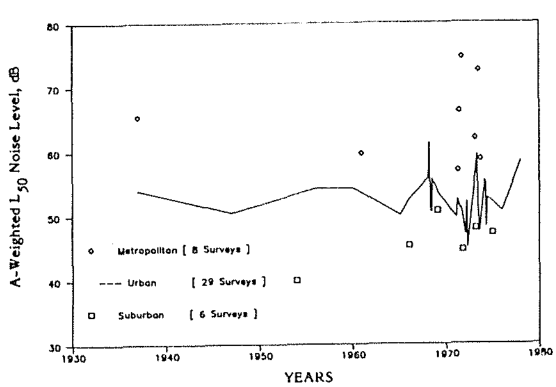

Fig. 1. Median Community Noise Levels, 1937-1978

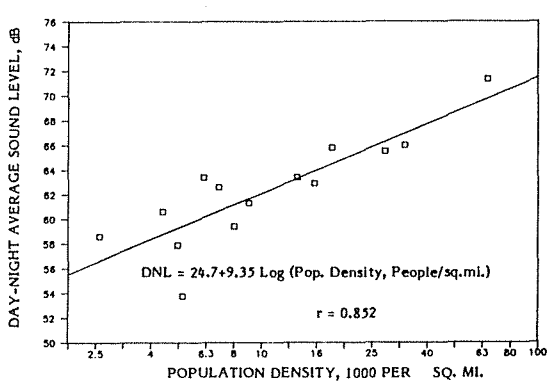

Fig. 2. Average DNL at 100 sites vs. Population Density in 14 Cities (Galloway, et al.)

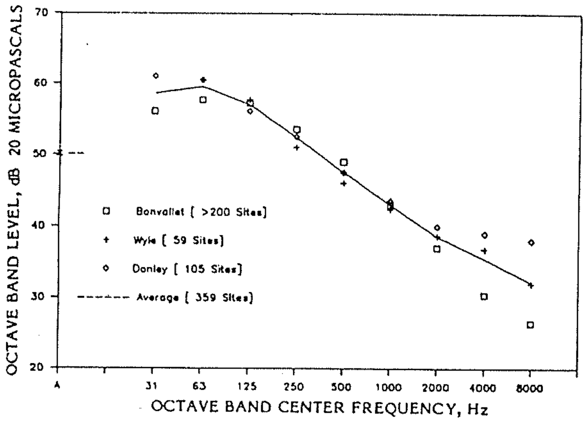

Fig. 3. Average Daytime Median Noise Level Spectra in Urban Areas

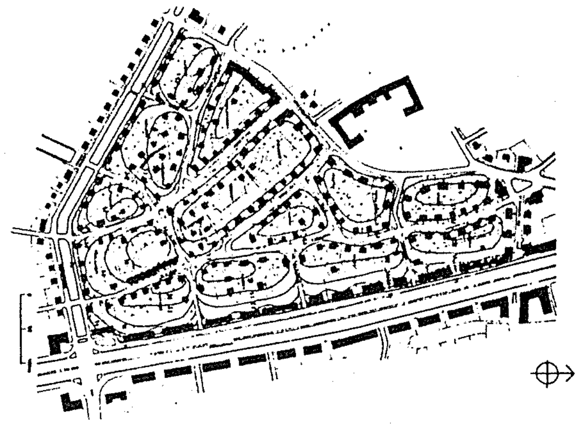

Fig. 4. Spatial Variation of Average Noise Levels Around an Apartment Complex (Nat'l Swedish Inst.).

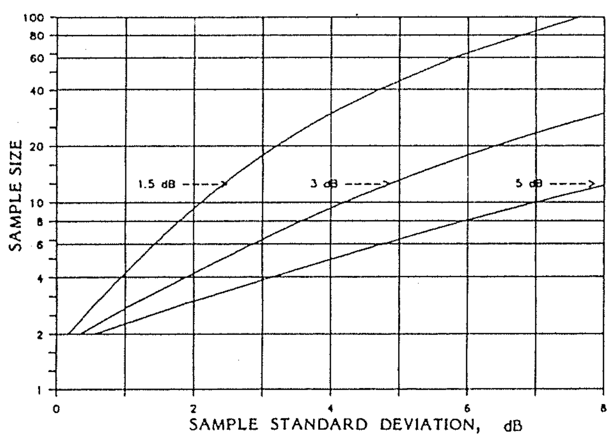

Fig. 5. Sample Size for 95% Confidence in Mean with Confidence Limit of +/- 1.5 to 5 dB.

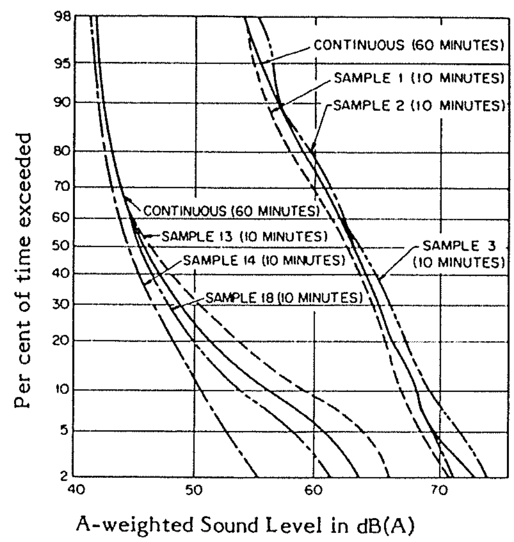

Fig. 6. Cumulative Distributions of 10-minute and hour-long Samples (Schultz).

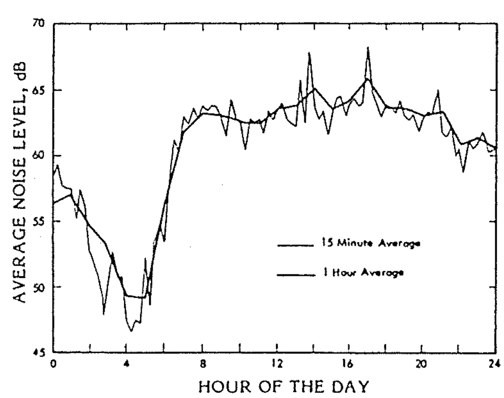

Fig. 7. Variation Throughout a Day of 15 min. and 1 hour Samples of Average Noise Levels in an Urban Site (Wyle).

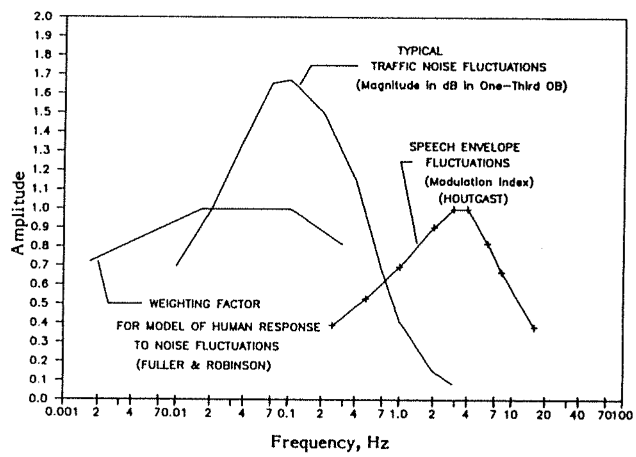

Fig. 8. Fluctuations in Noise, Speech & Human Response

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PLANNING FOR NOISE CONTROL

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ABSTRACT

Success in the implementation of environmental legislation largely depends on public awareness of the importance of good environmental "housekeeping", and the managerial and financial support of the Government.

Planning for noise-control has been one of the major issues in environmental policy in the Netherlands since the Noise Abatement Act came into force in 1979.

In this keynote address the speaker will pay attention to the structure of the legislation and the administration of noise control organisations in the Netherlands. Emphasis will be placed on planning and financial aspects related to noise reduction measures and multi-year programming.

The interaction between Land-use and Town-planning and the zoning of industrial areas will be a central theme, which will be further developed in a further paper.

1.0 INTRODUCTION

In the past ten to fifteen years, there has been a strong development in environmental legislation and administration in the Netherlands. The managerial and financial support of the Government and the public and political awareness of the importance of good "housekeeping" in environmental affairs in our "overcrowded" country, has shown to be effective.
As a part of this legislation, the Noise Abatement Act came into force in several stages over the past six years.
The act includes provisions on:
- noise-control at source
- recreation establishments
- industrial/commercial establishments
- noise-transmission
- zones around industrial areas
- zones along roads, railways etc.
- noise-insulation
- quiet areas
- financial provisions
- multi-year programs
- monitoring units.

Basicly the Act covers three kinds of noise-abatement:
- control at the source,
- reduction of noise-transmission,
- noise-insulation.

The Act does not include provisions on aircraft-noise or on workers-noise-control, these items are respectively covered by the Aviation Act and The Industrial Safety Act.
A central issue on noise-abatement in the Netherlands is, that the planning of noise-control must focus on the prevention of extensive noise, based on the use of the best practicable means (licences) and the zoning of noisy areas (distance). The legacy of bad planning in the past will be eliminated in the following ten years with the financial support of the Central Government.
An inventory of todays situation of the noise exposure on dwellings shows that from the four million housing-units in the Netherlands about 10% are extensively exposed to high noise levels (55 dB(A) or more).

2.0 THE STRUCTURE OF NOISE-LEGISLATION IN THE NETHERLANDS.

The first explanatory part of this paper is restricted to the scope of the Noise Abatement Act. Other noise related Acts, such as The Aviation Act, The Labor Act and the Nuisance Act, will just indirectly be mentioned. In a short survey the "high lights" will be discussed.

2.1 Noise-control at source.

The Noise Abatement Act in the Netherlands provides for the possibility of the Central Government imposing noise-emission limits combined with compulsory typeapproval testing or licensing. Regulations can be laid down with respect to designations or descriptions of equipment for trading purposes (informative labelling), so the consumer will be encouraged to make a noise-conscious choice.

2.2 Recreation establishments.

The Municipal Councils are obliged to lay down regulations with respect to recreation establishments (discotheques, stadiums, amusement parks, fairgrounds and the like) to prevent and restrict noise-nuisance. With respect to the use of sound equipment in recreation establishments a licence issued by the Municipal Executive Council may be imposed in order to ensure an acceptable sound level for the vicinity. In the cases of a new establishment usually an acoustic report is required in which sound insulating provisions and other noise-restricting measures are included. The association of Municipalities in the Netherlands has drawn up a model-regulation for its member Municipalities on behalf of the noise-abatement related to recreation establishments.

2.3 Industrial/commercial establishments.

For establishments capable of causing serious noise-nuisance the Act obliges the Provincial Council to issue licences. The procedure for licensing is laid down in the General Environmental Provisions Act. (appendix 1,list of category-A factories, ± 1200 factories in the Netherlands.) Licences to all the other establishments will be issued by the Municipal Councils. An important provision in the Noise Abatement Act stipulates that the Provincial Councils, when issuing licences, must take account of the limits for noise loads on dwellings and other noise-sensitive premises, laid down in the Act. This establishes a link between the establishment, expansions or change of activities causing noise-nuisance and the immision values which apply within the scope of the zoning around industrial areas as described later in this and in the second paper.

2.4 Restriction of noise-transmission.

Although preference is given to abatement of noise-nuisance at source, supplementary measures can be necessary to restrict the transmission of noise to the recipients. This subject is dealt with in the Act in respect of important industrial areas, busy roads and railways. In case of busy airfields The Aviation Act provides similar zoning restrictions. Noise zones shall be regarded as areas in which extra attention must be given to the noise aspect.

The drawing up or implementing of plans relating to such areas will usually have to be preceded by acoustic investigations. Existing situations already exposed to an excessively high noise load will enter into consideration for improvement measures (noise reduction programs). On account of the public-health aspects involved, the maximum admissible immission values are laid down in the Act by the

Central Government. To provide the necessary flexibility under certain circumstances and within certain limits, the Provincial Council is enabled to permit higher values. The general target limit for the immission load in zones is 50 dB(A) for a twenty-four hour period (this means: 50 dB(A) from 07.00 - 19.00 h, 45 dB(A) from 19.00 - 23.00 h, 40 dB(A) from 23.00 - 07.00 h). The values in the Act are expressed in equivalent noise-levels (appendix 2).

2.5 Zones around industrial areas.

The Act distinguishes newly designated and existing industrial areas.

2.5.1 Newly designated industrial areas.

The Act places an obligation on a Municipal Council, drawing up or revising a development on land-use plan, which reserves land for industrial purposes and permits the settlement of large noise-producing plants to establish a noise-zone around the area. Outside such a zone the noise-load caused by all the industrial and commercial premises may not exceed a value of 50 dB(A). The size of the zone and the location of its borders will depend on the size and nature of the designated establishments in the area. When planning a zone, the Municipal Council must instigate an acoustic investigation. This investigation must be based on the expected noise-load and the effectiveness of the measures to be taken under representative conditions in the factories.

In new situations (or in combination with existing situations) an indicative list with noise data is used.
The aim of the indicative list is to give the distance at which a noise of 50 dB(A) (for a twenty-four hour period) can be expected from various categories of establishment.
The distances indicated in the list may be used in the planning of new noise-emitting establishments at a stage when no detailed information is yet available on the nature of the establishment and the noise-sources.
The list concerns new establishments and is based on the assumption that methods of noise-control capable of general application will be employed. It is not applicable to existing establishments.
The distances given are indicative, in practice they may vary, due to special circumstances in the establishment or its surroundings.

Another method to get hold on new situations in an early stage of development is the use of "distinguishing values" for typical noise emissions. An inventory of these values for several types of industry is recently made in the Netherlands.

In both cases the implementation has to be based on industrial scenarios depending on the defined commercial and managerial expectations.

2.5.2 Existing industrial areas.

According to the Act the Municipal Councils are obliged, within a period of four years, after the concerning part of the Act came into force, to establish a zone around existing industrial areas where large noise-producing plants are or may be established. Outside this zone the noise-load originated from such areas may not exceed the limit value of 50 dB(A). The establishment of a zone (in a new situation as well) may be part of the drawing up or revision of a development plan which is preferable from a point of view of political decision making. The procedure is virtually the same as for the drawing up of a development or land use plan (appendix 3), as in new situations. When planning an establishment or revision of a zone, the Municipal Council must arrange for an acoustic investigation. The majority of the industrial areas in the Netherlands can be placed under the definition of existing areas. In these situations the maximum permissible noise-load on the external walls of already existing dwellings, in the zone (as well under construction or included in a valid development- or land-use plan) is established on 55 dB(A) (appendix 2). At the request of the Municipal Council or other bodies involved, the Provincial Council (within certain statutory limits) may lay down a higher limit. After having instituted an acoustic investigation the Municipal Council must report cases in which the noise-load (already present) exceeds 55 dB(A) to the Provincial Council. The latter Council will then draw up a noise-reduction or improvement program in consultation with the Municipal Council concerned. The program is enacted by the Minister of Housing, Physical Planning and Environment and, for a certain part, financed from the proceeds of levies.

The acoustic investigations in the Netherlands on behalf of zoning activities are for a large part executed by specialist-consultants on acoustics. The management, the quality-control, the time-planning, the feed-back and the financial administration are in the hands of the Provincial or Municipal Authorities. Extensive consultation of the concerning establishments and the calculation and measurement of the influence of the representative noise sources, leads to the design of the 50 dB(A) contour of which the zone is extracted. The existing noise-sources (according to valid licences), the new developments of industrial activities in the industrial area, and developments of noise-sensitive premises outside the industrial area, influence the border of the zone, the "Environmental Space". (Appendix 3)

2.6 Zones along roads, railways, tramways.

Along busy roads and railways the Act provides in zones as areas of special acoustical attention. The width of these zones is laid down in the Act and depends on the number of traffic lanes. Within these zones, certain noise-limits are laid down by General Administrative Order.

2.7 Noise-insulation at the receiving end.

Noise-insulation measures at the receiving end aim to achieve a proper acoustic living climate inside buildings (see appendix 2). In this respect three main problems are distinguished in the Act:

- noise-insulation against external noise (e.g. industry, traffic etc.)
- noise-insulation between individual buildings
- noise-insulation between certain rooms within one and the same building.

The Municipal Councils are obliged to include the noise-insulation standards of the Act in their building regulations. When evaluating an application for a building permit the Municipal Council must also examine the acoustic aspects involved.

2.8 Quiet areas.

In addition to the zoning arrangements the Act contains provisions for protection of quiet areas. Concrete measures to protect a quiet amenity must be laid down in an ordinance by the Provincial Council and must be approved by the Crown.

2.9 Financial Provisions.

Like the other Environmental Protection Laws in the Netherlands, the Noise Abatement Act operates on the principle that "the polluter pays".

Levies are introduced to pay for the costs of administering the Act. The levies are imposed on licence-holders and users of mopeds, motor-vehicles and other appliances. For example in the form of an additional tax component in the price of fuel.

The proceeds of the levies are essentially to meet:

- administrative and legal charges,
- the cost of compensation to sustain administrative views,
- the cost of compensation payments,
- part of the costs of measures taken in noise zones,
- the costs of research into and development of quieter technology.

In some particular cases, when very stringent conditions in a licence could result in unreasonably large expenses of the applicant, the Act provides for the possibility of fair compensation. An example of such a provision is given in one of the case-studies in the technical discussion in a second paper.

2.10 Indicative multi-year program.

It is laid down in the Act that the Minister of Housing, Physical Planning and Environment shall establish yearly, for the following period of five years, a programme of measures for abatement of noise-nuisance, which is presented to Parliament together with the Budget Chapter of the Ministry.

The object of this progressive planning method is to achieve that the Members of Parliament can form an opinion from one year to another on the progress and effectiveness of the policy. The Provincial and Municipal Councils are obliged to submit to the Minister, annually on behalf of the multi-year programme, a summary of the measures they consider necessary for abatement of noise-nuisance during the next five years, as well as an estimate of the required expenditure for the account of the Central Government.

2.11 Monitoring and Government Services.

The Noise Abatement Act provides for the appointment of monitoring officials at the different levels of Government. The Provincial Executive Committee is directed to promote the coordination of monitoring activities at Provincial level.
The Provincial Council is obliged to institute a noise-nuisance Department on behalf of the tasks allocated to the Provincial Executive Commitee. The services of this Department are not intended solely for fulfilment of the tasks of the Provincial Council, but can also be called in on behalf of other Government bodies.
The noise-nuisance Department will in any case have to include a monitoring section and a complaints section. The Department can be composed of regionally operating units. The duties of such a regionally operating unit can be transferred to a Municipality, a group of collaborating Municipalities or a supramunicipal public body. The Act furthermore provides that the Municipal Councils ensure the functioning of a Municipal monitoring service - unless the Province performs the necessary monitoring at the request of the Municipal Councils.

3.0 THE STRUCTURE OF NOISE-CONTROL IN THE NETHERLANDS.

3.1 Noise-control management.

The backbone of the noise-control organisation is shown in the following summary, with a rough specification of tasks and delegation of power. This organisation garantees a uniform and balanced implementation of the Noise Abatement Act.
Walking down the pyramid:

a) Ministery of Housing, Physical planning and Environment
   Directorate of Environment
   Department for noise-abatement (± 40 employees)
   - legislation
   - noise-standards
   - research (policy sustaining)
   - circulars/scenarios
   - education
   - multi-year programs
   - evaluation.

b) Inspector General (noise section)
   Independent units in nine regions (± 20 employees)
   - trouble shooting
   - prosecution
   - environmental auditing
   - advise and coordination

c) Provincial executives (12 provinces, ± 60 employees, noise section)
   - licences, large industries
   - measurement and complaints units
   - advise and coordination smaller Municipalities
   - noise-reduction programs
   - zoning of multi Municipal zones
   - land-use plan approval
   - feed back to more-year programs.

d) Municipal executives (± 350 employees)
Monitoring units for measurement and complaints and for smaller Municipalities monitoring by regionally operating units.

- intra-Municipal coordination in environmental issues between the different Departments in the Municipality.
- licencing for medium and small noise-producing plants (Nuisance Act)
- zoning of industrial sites in the Municipal areas (Noise Abatement Act)
- issuing of By Laws and Municipal Regulations
- execution of noise-programs (industrial and traffic noise)
- allocation and townplanning related to environmental issues
- building inspection on noise-insulation
- management of Municipal Environmental Control Department (including Noise-Abatement)
- feed-back to the Provincial Authorities.

In the executive field a number of external specialist-consultants on acoustics and societies are very active in the Netherlands. (± 25 buro's, ± 230 employees).
Their main activities are:
- research and development
- technical advice and investigations
- education
- publication

In the educational and publishing field the Noise-Abatement Society in the Netherlands holds a strong position.

3.1 Noise-control planning and financing.

The delegation of power and executionary force, related to noise-control, is laid down in the Noise Abatement Act.This delegation and the strong financial support of the Central Government appears to be succesful. In view of the current situation with regard to policy-supporting research, multi-year financial estimates and the possibilities for meeting the anticipated staffing requirements of Central, Provincial and Municipal Authorities it is expected that it will take from six to eight years to implement the Act in its entirety.
The total official involvement for the implementation of the Act is about 700 employees/years/year over a period of about eight or ten years. Activities for augmenting the staff of the Provincial and Municipal Authorities have received top priority. The multi-year programs are essential towards the planned phased implementation of the Noise Abatement Act. During the past years emphasis is placed on the implementation of those parts of the Act which will be effective in preventing new problems associated with noise-pollution.
An inside look in the "kitchen" of the Governmental noise abatement expenses in the multi-year program 1985-1989 gives the following picture (in million guilders).

	1985	1986	1987	1988	1989
Monitoring units Province and Municipalities	29,5	29,0	28,5	27,6	27,6
Noise-reduction at source	4,1	5,1	5,1	5,1	5,1
Prevention of new bottle-necks (zoning)	11,7	9,5	6,5	4,5	4,5
Noise-reduction program traffic./indust./aircr. noise-insulation etc.	73,2	89,8	103,4	111,2	112,2
Policy supporting research	16,9	14,2	10,7	8,7	7,7
total	135,4	147,6	154,2	157,1	157,1

One of the important activities for Provincial and Municipal executives during the coming years will be the drawing up of noise-reduction programs for industrial noise in cases of a noise-load of 55 dB(A) or more on noise sensitive premises in zoned areas.

The table gives the number of firms that will be involved in noise-reduction in industrial areas as well as the number of dwellings in a noise-reduction situation.

Noise-load above the statutory reduction limit	Number of dwellings in zones around industrial areas
55 - 60 dB(A)	ca. 57 500
60 - 65 dB(A)	ca. 13 000
60 - 70 dB(A)	ca. 1,100
70 - 75 dB(A)	ca. 100

Firms involved in noise-reduction programs

Necessary reduction	Number of firms involved
0 - 5 dB(A)	423
5 - 10 dB(A)	247
10 - 15 dB(A)	60
15 dB(A)	14

A scenario is made to give Provincial and Municipal executives the needed support to get a clear insight in the process. Attention will be given to evaluating costs, effects of phasing the schedule, measures, and the precedence that must be given to source-reduction rather than to insulating the facades of dwellings.

The cost to reduce community noise according to the statutary limits caused by the industry in the Netherlands were investigated by the Ministery for Housing, Physical planning and Environment in 1984. If reduction of noise has to be at source only, then the estimates of the total costs are circa 1 000 million guilders. The total costs of compliance by housing insulation only is estimated as circa 75 million guilders.

The preliminary political choice is to execute noise-reduction programs for industrial noise over a period of 10 years to a total amount of 560 million guilders.
This bill has to be paid by the industries involved. About 180 million will be compensated by Central Government in cases of extreme high cost levels. About 30 million guilders will be spent on housing insulation.
There are a number of reasons why the costs of compliance with the Noise Abatement Act may fall with the passing of time. Any noise-reduction period will provide industry measures into the design of new plants. Several instances of quiet new design have been drawn to attention. Other noise related legislation, such as that planned by the Ministery of Social Affairs and Employment for noise at the work place and the proposed EEC Directives on vehicle engine silencing, is likely to make a beneficial contribution to the relationship between industrial noise and community noise levels. For EEC Directives, of course, the impact will only be felt when the Community Member States incorporate the Directives into their national legislative programmes.

4.0 PHYSICAL PLANNING AND INDUSTRIAL NOISE-ZONING.

In the Netherlands, it is becoming increasingly clear that physical planning and environmental health are interconnected. Therefore, in drawing up Structural plans and Land-use or Development plans, allowance will have to be made for environmental aspects with regard to urban renewal areas but also in new development areas. A sound cooperation with the people in those areas is of great importance. In Amsterdam and several other Municipalities in the Netherlands the establishment of Advisory Commitees on Environmental Issues has been an important step towards the involvement of citizens in the solving (control) of environmental problems.
In those committees, the local Authorities, the environmental protection Organisations, the industries and officials of environmental-control and physical planning Departments are usually represented.

The integration of physical planning and environmental zoning appears to be very effective in the Netherlands. Following survey shows the scale of industrial-noise zoning in Amsterdam. The 50 dB(A) zones cover large industrial areas with about 55 large noise producing plants and about 800 medium and smaller ones (fig 1).

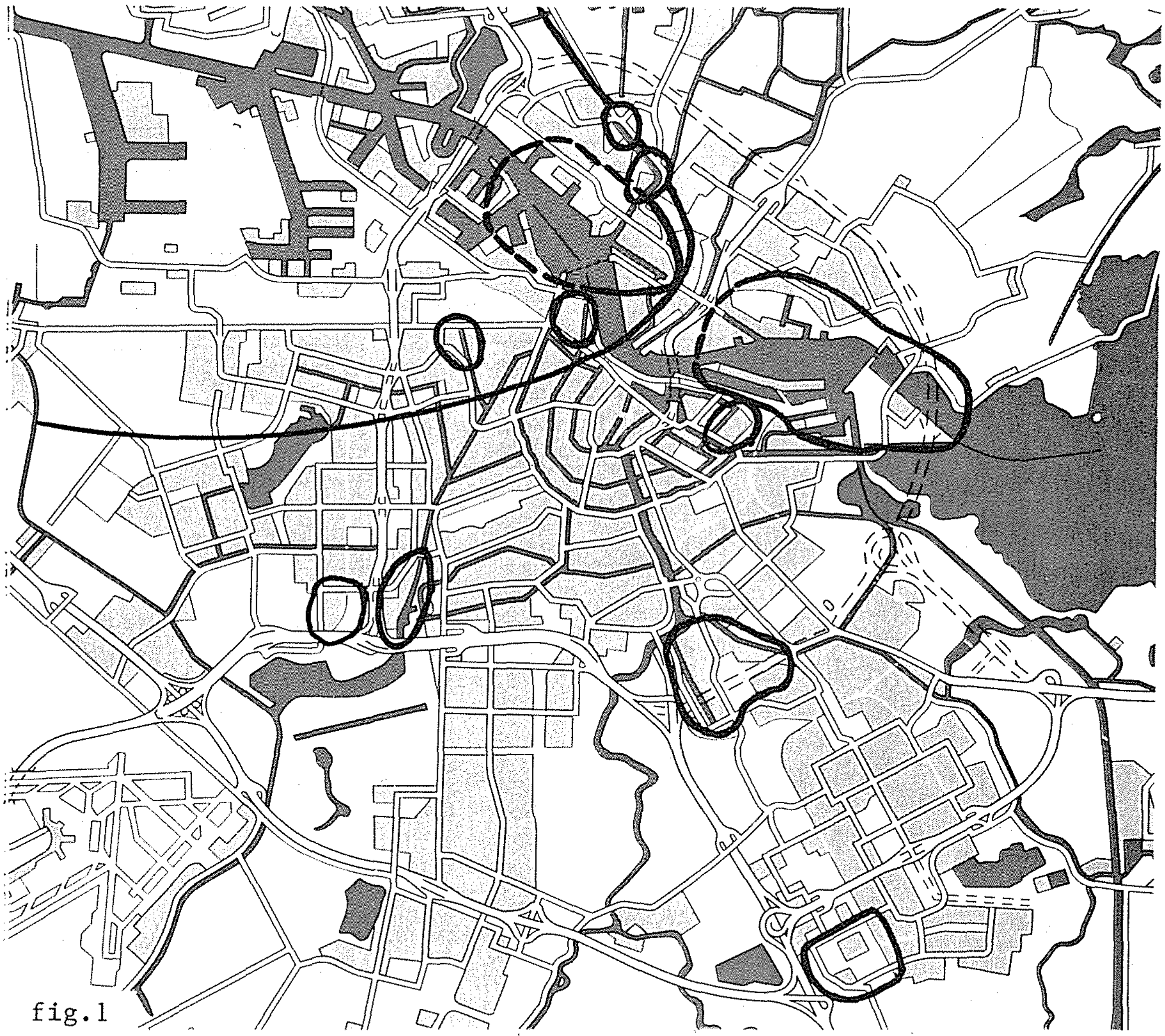
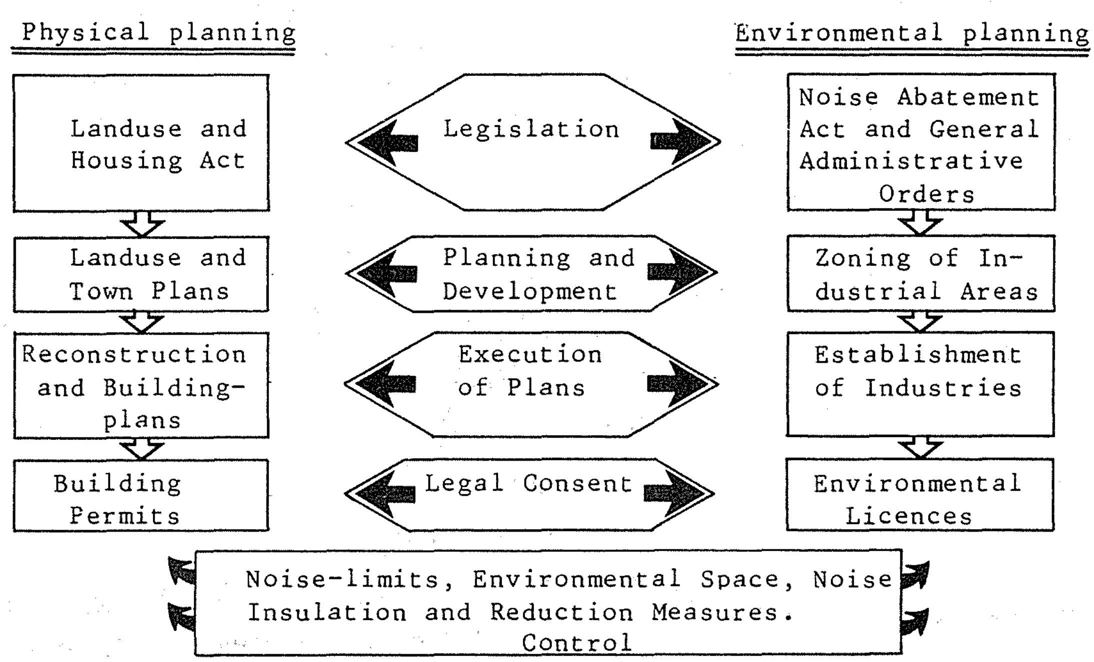


fig.1

The development of noise-sensitive premises in these zones will be tempered. The industrial development will be checked on the provided environmental space in the zone. Although the zoning is a more or less rough tool of noise-control for a group of industrial plants in an area, in individual cases a stringent licensing system gives the local Authorities the opportunity to make a "custom made suit". For all considerable changes in activities or development proposals regarding environmental aspects, the licences have to be reviewed. Building projects of various kinds in zones are under environmental-control. Landuse- or town planning and building approval are in the hands of the local Authorities.
The Provincial Council has a more supervisory and coordinating role. The relationship between physical and environmental planning gives the following picture:



4.1 The impact of industrial zoning in Amsterdam.

In the next pages an impression is given of one of the 17 zoning projects around industrial areas in Amsterdam in which several large shipyards are established. Around the yards there are residential areas with existing dwellings (A) and two development plans for new dwellings (B1 and B2).
The investigations on acoustics by an specialist consultant on acoustics, under the control of the local Authority, resulted in the noise-contours as shown (50-55 dB(A)).

The representative operating conditions were abstracted from a number of scenarios according to the fact that the outside work on shipyards is very changeable. The scenarios are worked out in several (realistic) positions. The envelope 50 dB(A) contour of the individual working positions is chosen as representative (maximum possible) situation. It is clear that this situation is rare but nevertheless realistic. In fact the shipyards got a bit more "environmental space" than normally needed due to the definition of the industrial zone in the Noise Abatement Act, that the 50 dB(A) border may not be exceded in any situation.

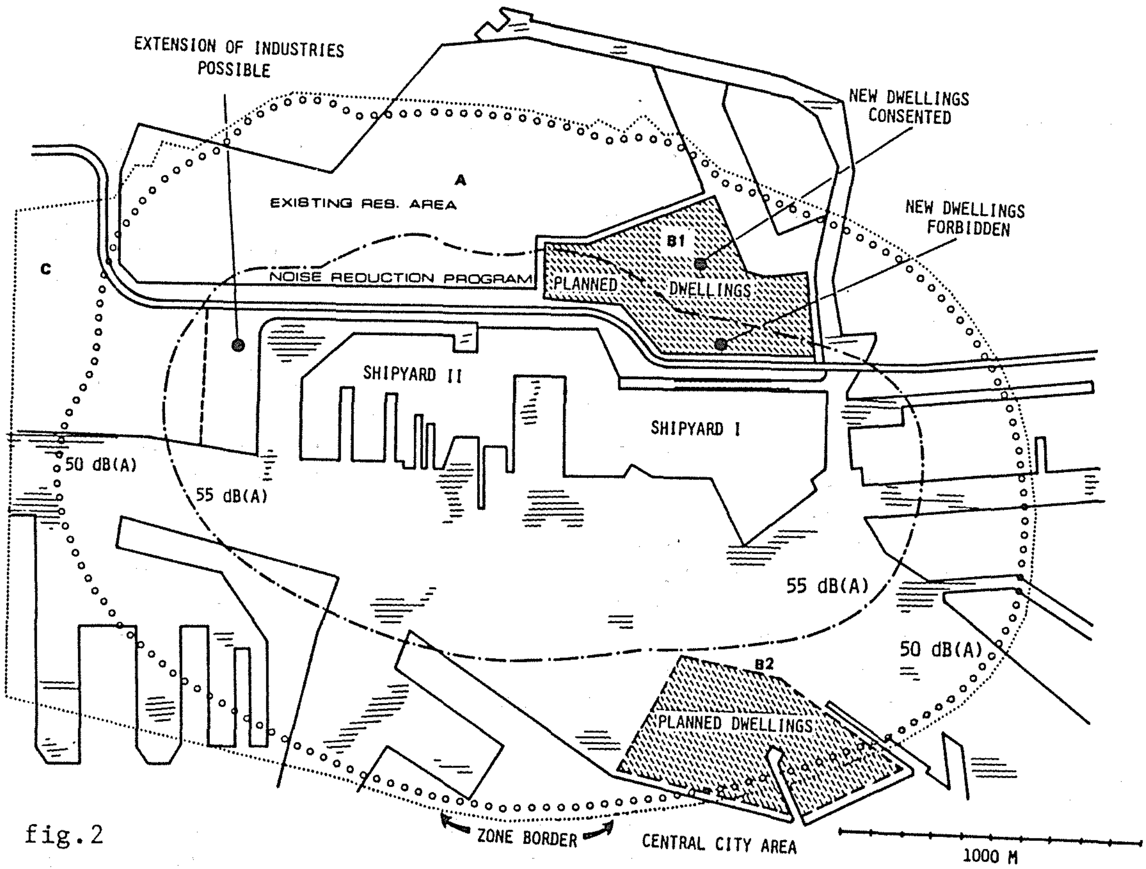


fig.2

According to paragraph 2.5 of this paper the impact of the Noise Abatement Act in this specific occasion gave the following results:

Area A - The largest part of this area (existing situation) is situated between the 50 and 55 dB(A) contour. According to the Act no special measures have to be initiated.
- A smaller part of this area has a noise-load of 55 dB(A) or more. This brings the area under the noise-reduction provisions of the Act. A noise-reduction investigation and a noise-reduction program has to be executed. In this special case the reduction program was inserted in a thermic-insulation program already started in this area.
Due to the fact that the open noise-sources of the yards (gritting etc.) are very hard to abate, the measures are taken at receiving end.

Area B1 - In this area a development plan for circa 1500 dwellings was already drawn up in previous years. The 55 dB(A) contour crosses the area as shown. According to the Act, in the southern part of this area no dwellings are allowed to be built. The political and industrial pressure on each side of the 55 dB(A) contours was rather impressing. In this case the Provincial Authorities played the role of arbiter and prevented that the whole process had to start again. The preliminary deal is made, that about 400 dwellings behind the 55 dB(A) line will not be built in this area.
In the northern part of the area the Provincial Authorities gave consent for a higher noise load than 50 dB(A), to a statutary maximum of 55 dB(A) under the conditions that sufficient noise-insulation is provided in the new dwellings according to the building regulations for inside noise levels (appendix 2).

Area B2 - This development plan for new dwellings can be established under the same conditions as for the northern part of area B1.
In both cases the Provincial consent for a noise-load of maximum 55 dB(A) was given because of the needed flexibility in the urban renewal area of Amsterdam in this stage of the zoning process.

Area C - According to the Act, the noise-zone has to be of at least the same size as the existing (representative, and by licences consented) 50 dB(A) contour. The zone however may be larger, in case of a wanted possibility to extend the industrial activities. In this case there was a need for "some environmental space" in the N-Western part of the area. The negotiations resulted in a zone larger than the existing 50 dB(A) contour on behalf of the industrial development. A remarkable fact is, that recently a shipbuilding industry which gave heavy noise-problems in another part of Amsterdam was replaced to this area.

5.0 EVALUATION AND CONCLUSION.

- Noise-legislation (the Nuisance Act included) in the Netherlands covers, to a large extent, the scope of noise-emitting activities related to community-noise. In the Act incorporated noise-standards give the unquestionable margins and limits to operate. The policy and technical aspects of the Act are fundamentaly sustained by intensive research. The phased implementation of the Act is well planned and meets public consent.

- The Governmental support in the Netherlands of the establishing of noise-control units in the Provinces and Municipalities appears to be very effective. If this support was not realised, the fast implementation of the Act was at least questionable.

- Noise-reduction programs initiated by the Dutch local Authorities and inserted into indicative multiyear programs are a substantial contribution to the abatement of extreme noisy situations due to bad planning in the past.

- The zoning of industrial areas appears to be an appropriate tool of planning for noise-control. The statutory relationship between the Noise Abatement Act and the Land Use Act in the Netherlands provides the basis for a constructive and cooperative attitude towards noise-zoning connected with townplanning.

- The zoning of industrial areas preserves not only the amenity in residential areas, but it also protects the commercial and industrial interests by providing "Environmental space" for development, and stops the uncontroled encroachement of noise-sensitive premises into industrial areas.

- In the Netherlands, about twelve hundred industrial areas have to be zoned in a period of about four to six years. It appears to be that the investigations on acoustics and the following public procedure for the zoning will take more time and energy than was planned.

- The statutory separated Authority in the Netherlands, in cases of the licensing of large noisy plants by the Provincial Councils and the zoning of industrial areas by the Municipal Councils within the areas of Municipal jurisdiction, can be problematical.
  A delegation of Authority in this matter has to be considered. The issuing of licences, above-mentioned, by Municipal Councils, with a Staff with significant expertise in noise-control planning, is from a managerial point of view strongly recommended.

- The representative operational capacity and the structure of the relevant noise-sources in industrial areas, which have to be zoned, has to be clearly defined, in particular in situations with discontinuous noise-sources. It takes a lot of experience and intensive consultation to gather the relevant data. This work has to be done very systematically and the relevant noise-emission has to be related to the "rights" derived from the existing licences of the plants concerned. The need for sufficient managerial input of the local Authorities in this process is evident.

- The drawing up of the noise-contours has to be done with the use of sophisticated computer programs, based on clear guidelines and instructions. Standardization of the current software is of great importance and should be stimulated.
  In this matter, the know-how of specialist consultants on acoustics in the Netherlands has to be coordinated.

- Noise-zoning is a "Continuing story". The "maintenance" of noise-zones has to be safeguarded by an adequate form of "Environmental Auditing".
  A noise-zone has to be a practical and managerial instrument to "forward" planning for noise-control, not a "battle-field" for technical- and legal quibbling.

- "Plans and measures aiming at an improvement of the overall quality of urban life, can be a major factor in the competition for the Olympic games between Capital Cities."

Literature:
- The guide for measuring and calculating industrial noise in the Netherlands
- General Administrative Order, measuring and calculation rules for industrial noise in the Netherlands
- Outline of the Dutch Noise Abatement Act.
- Cost implications of proposed Industrial Noise Legislation METRA
- Guidelines for industrial noise-reduction programs in the Netherlands

Appendix 1

STATUTE BOOK

Decree of October 15th, 1981 defining categories of factories as expressed in article 16, first part, of the Noise Abatement Act (Decree category-A factories Noise Abatement Act).

Article 1

Categories of factories, as expressed in article 16 first part of the Noise Abatement Act, are defined:

I Factories with a total installed engine power of 15 MW or more.

II a) Factories for grinding, roasting, pelletising or sintering of ores with a capacity for this purpose of 10 6 kg/a or more.

b) Factories for the production of pig-iron, pig-metal or primary non-ferrous metals with a capacity for this purpose of 10 6 kg/a or more.

c) Factories for loading and unloading or storing ores with a surface for ores storage of 2000 m 2 kg/a or more.

d) Factories for melting and casting metals or their alloys of which the melting point is greater than 800k, with a capacity for this purpose of 4.10 6 kg/a or more.

e) Hot strip mills and cold rolling mills of metals of their alloys of which the melting point is greater than 800k and of which the thickness of the strip is greater than 1 mm, with a production surface of 2000 m 2 or more; drawing mills for bars (made) of metals or alloys thereof of which the melting point is greater than 800k, with a production surface of 2000 m 2 or more.

f) Factories for the production of metal tubes by means of drawing, rolling or welding with a production surface of 2000 m 2 or more.

g) Iron mills and forges for anchors and chains with a production surface of 2000 m 2 or more.

h) Boiler works, barrelworks and barrel-renovation and -cleaning factories with a production surface of 2000 m 2 or more.

i) Constructional engineering and plate fabricating mills (= sheet metal works) with a production surface of 2000 m 2 or more accommodated in an unenclosed building.

j) Shipyards equipped for building or repairing metal ships with a lenght of 25 m or more.

k) Testing factories or testing places for combustion engines with a total engine brake power for this purpose of 1 MW or more; testing factories or testing places for jet-engines or -turbines with a propelling force of 9 KN or more.

III a) Factories for the burning of fossile fuel with a thermic capacity of 75 MW or more except safety torches used in the exploration and winning of natural gas.

b) Transformer stations with transformers not accommodated in an enclosed building, with a maximum electric power (that can be switched on concurrently) of 200 MVA or more.

c) Gas treatment installations at natural gas winning pits and storage factories (= places) with a capacity for this purpose of 10 2 m 3/d (at 1 bar and 273 k) or more.

d) Factories for the production of coke from coal.

e) Factories for the gasification or transfer of coal with a capacity for this purpose of 10 3 kg/a or more.

IV a) Factories for the refinery of petroleum with a capacity for this purpose of 10 3 kg/a or more

b) Factories for the production of petrochemical or other chemical products with an installed engine power of 1 MW or more accomodated in an unenclosed building.

c) Factories for the production of carbon-electrodes with a capacity for this purpose of 10 3 kg/a or more.

d) Factories for the production of methanol with a capacity for this purpose of 10 3 kg/a or more.

e) Air separation companies with a quantity of air required for the end product of 10 4 kg/h or more.

V Factories for the cleaning of waste water with waterjet or surface aerators with a capacity of 10 5 i.e. or more.

VI a) Factories for the mining of stone and gravel with a capacity for this purpose of 10 5 kg/h or more.

b) Factories for the production of cement or cement clinker(s) with a capacity for this purpose of 10 5 kg/a or more.

c) Factories for the crushing, riddling or drying of sand, gravel and stone with a capacity for this purpose of 10 3 kg/a or more.

d) Factories for the production of cement and cementproducts using presses, vibrating tables, or shuttering vibrators (= formwork vibrators) with a capacity for cement and cement products of 10 5 kg/d or more.

e) Factories for the production of cement or concrete mortar with a capacity for this purpose of 10 5 kg/h or more.

f) Factories for the production of asphalt or asphalt products with a capacity for this purpose of 10 5 kg/h or more.

g) Factories for the production or processing of glass or glass products with a capacity for this purpose of 10 4 kg/h or more.

VII a) Factories for the processing of sugar beets to beetsugar with a capacity for this purpose of 2,5.10 6 kg/d or more.

b) Factories for the production of oils or fats from vegetables or animal raw materials with a capacity for this purpose of 250.10 6 kg/h or more.

c) Factories for the production of fatty acids or alkanols from vegetable or animal oils or fats with a capacity for this purpose of 50.10 6 kg/h or more.

d) Elevator factories for cereals or types of meal with a processing capacity for this purpose of 10 5 kg/h or more, factories for the production of cattle fodder with a capacity for this purpose of 10 5 kg/h or more.

e) Factories for the production of yeast and spirits with a capacity for this purpose of 5.10 6 kg/h or more.

f) Factories for the production of starch or starch derivatives with a capacity for this purpose of 10 4 kg/h or more.

g) Factories for the production of milk powder, whey powder or other dried dairy products with a capacity for this purpose of 1500 kg/h or more.

h) Factories for the production of liquid milk (= consumption milk), liquid milk products or evaporated milk or milk products with a milk processing capacity of 55.10 6 kg/a or more; factories concentrating milk or milk products by evaporating with a water evaporating capacity of 20.10 3 kg/h or more.

i) Green stuff drying plant with a water evaporation capacity of 10 4 kg/h or more.

VIII Factories with 50 or more mechanically driven weaving looms.

IX Factories for the production of paper with a capacity for this purpose of 3000 kg/h or more.

X Sites, not being public roads, intended and set up for the purpose of riding motorbikes, motor vehicles or other motorised vehicles, in competition, in preparation for competition or for recreational purposes and which (sites) are used as such five or more hours a week.
Railway yards used for shunting with the help of a shuntinghill.

Article 2

The categories of factories mentioned in article 1 include all factories falling within their definition.

Article 3

For the application of this decree installations belonging to the same company or factory with mutual technical or functional connections and in each other's immediate environment are considered to be one factory.

APPENDIX 2

Permitted noise levels outside buildings (for new buildings).

Building category	Preferred level	Permitted max.level by Prov. allowance
1 Dwellings (houses, flats, etc.)	50	55
2 Nursing schools, primary schools, secondary schools, homes for elderly, hospitals, nursing homes, social/cultural centers	50	55
3 Psychiatric hospitals, mental homes, homes for visual/hearing disabled, medical homes for children, infants' health resorts, sanatoria, (surroundings included)	50	55
4 Offices	60	65

Permitted noise levels outside buildings (for existing buildings).

Building category	Preferred level	Permitted by prov. allowance	Max.level noise reduction
1 Dwellings (houses, flats, etc.)	55	60	65
2 Nursery schools, primary schools, secondary schools, homes for elderly, hospitals, nursing homes, social/cultural centers	50	60	65
3 Psychiatric hospitals, mental homes, homes for visual/hearing disabled, medical homes for children, infants' health resorts, sanatoria, (surroundings included)	50	55	60
4 Offices	60		80

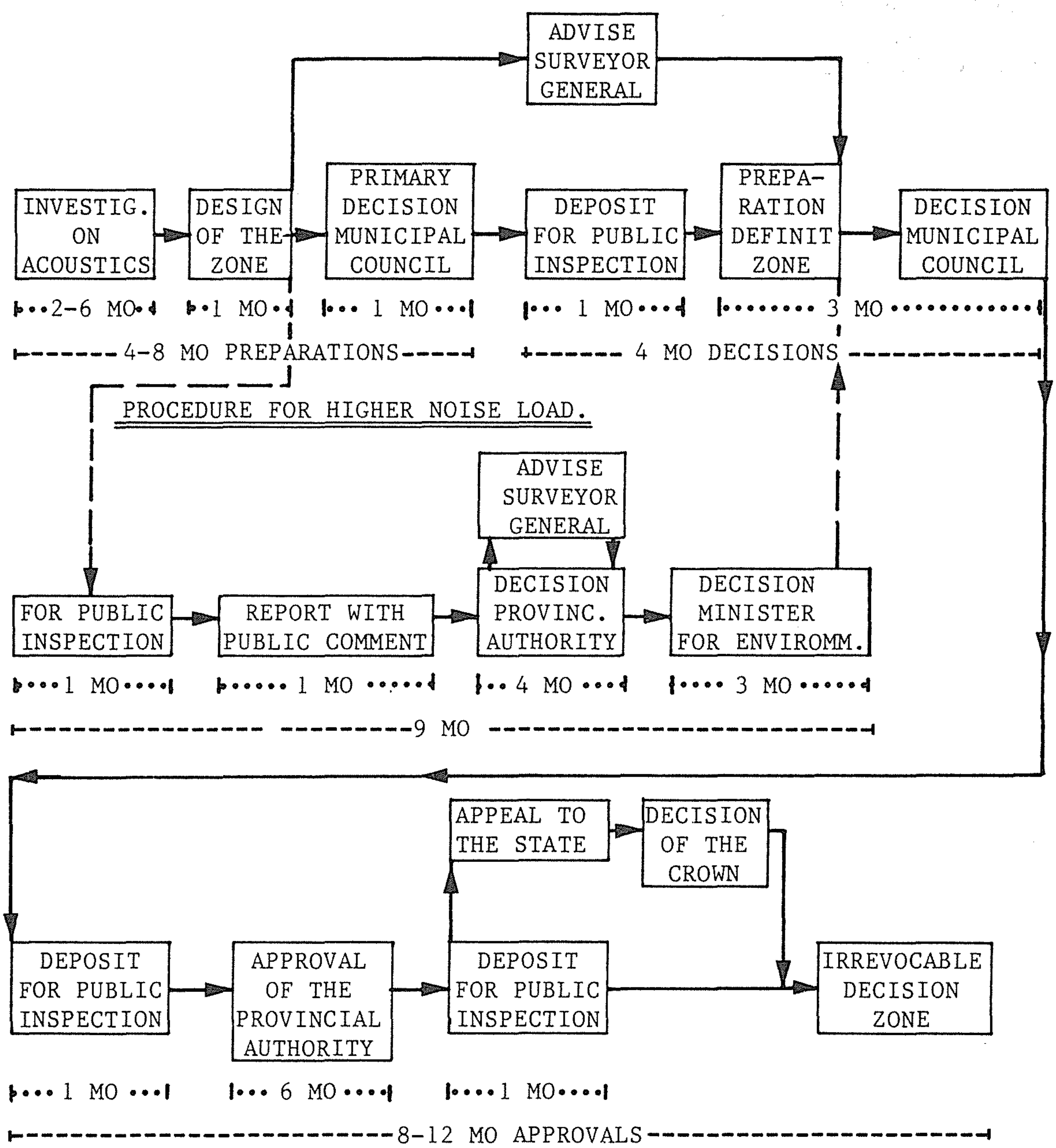
Permitted noise levels inside buildings (for existing buildings).
(with the windows closed)

Building/room category		By prov. allowance (2)	noise reduction level(1)
1 Dwellings - all rooms		35	40
2 Primary schools	-lesson rooms		
secondary schools	-theory lesson rooms		
homes for elderly	-recreation, living, sleeping rooms		
hospitals and nursing homes	-treatment rooms	30	35
psychiatric hospitals, mental homes, homes for visual/hearing disabled	-treatment rooms		
medical homes for children	-living rooms		
infants' health resorts, sanatoria	-sleeping rooms		
3 Nursery schools	-all rooms		
secondary schools	-practice lesson rooms		
hospitals	-patient living		
nursing homes	-recreation rooms	35	40
social/cultural centres	-rooms used for social/cultural purpose		
4 Offices	-working and meeting rooms		40

(1)Noise reduction level: the cases where the outside noise-level at the time of noise zone determination exceeds:
-55 dB(A) (for the category 1, 2 and 3)
-80 dB(A) (for the category 4)

(2)By prov. allowance: all other cases

PROCEDURE OF INDUSTRIAL ZONING. APPENDIX 3



- THE INVESTIGATIONS ARE EXECUTED BY THE LOCAL AUTHORITIES, OFTEN SUSTAINED BY SPECIALIST CONSULTANTS ON ACOUSTICS.

- THE INVOLVEMENT OF THE INDUSTRIAL OFFICIALS, CITIZENS, A.O. IS COORDINATED BY THE MUNICIPAL AUTHORITIES IN AN EARLY STAGE OF THE PROCESS BY PROJECT-TEAMS, PUBLIC HEARINGS AND THE DEPOSIT OF RELEVANT DATA

- THE RENEWAL OF A ZONE FOLLOWS THE SAME PROCEDURE AS A NEW ZONE.

- WHEN A DEVELOPMENT-PLAN IN THE SAME AREA IS PREPARED, THE ZONE HAS TO BE INCORPORATED IN THAT PLAN.

HEALTH HAZARDS OF NOISE

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ABSTRACT

The question of noise as a hazzard to our health and well-being is discussed. The insidious nature of the effects of noise on the human being is difficult to quantify because the variables in the cause-effect relationship are difficult to control. A brief review of the literature is provided to give a general indication of the various effects generally attributed to noise. The results of a research project concerning the effects of noise on reading scores are presented, and a discussion of the importance of public awareness and education as well as government controls is also provided.

Visitors to New York characterize it as a very noisy city but an exciting and vibrant place to spend a vacation. They quickly add that they wouldn't want to live there. Many New Yorkers, experiencing this cacophony of ear-shattering sounds daily, also wonder if the delights of the city overweigh the extreme noise they are subjected to. Those who decide to make New York their home are divided between those who believe the pleasures overwhelm the negative and those who would want to leave but can't. At any rate, nearly eight million people are exposed to roaring subway cars, unnecessary auto-honking, blaring music, roaring overhead planes and people noises common to crowded urban streets.

Yet, noise is not just an urban phenomenon. Even residents in quiet communities find themselves disturbed by noisy next-door parties or early morning lawn-mowing. Imagine how surprised a surburban couple were to wake up one morning to the sound of a windmill erected in the neighbor's backyard. Noise has been prevalent in certain industries but has even spread to the office as large open areas replaced more private quarters. Typewriters, calculators, electric pencil sharpeners and frequent phone ringing make for a very noisy work environment for employees of large companies. With the introduction of the word processer, the noise of the printer added to the sound volume.

As societies became more industrialized, they also became noisier. Airplanes, subway cars, automobiles, air conditioners, vacuum cleaners, and stereos provided us with comforts unknown to our ancestors. Yet, each invention raised the ambient noise level even higher. To have denied ourselves the joys of these man-made creations would have been foolhardy, and so we learned to adapt to the noises accompanying our new found pleasures. Urban cities with their tremendous advantages in the form of educational insitutions, museums, theatres, department stores, urban transportation systems, etc. required a bit more adapting. In fact, as we moved into the eighties, loud music was placed on a pedestal of sorts as it took on the meaning of free expression. Recently, New York City interviews of "Yuppies," young, urban professionals, found that they love dining in noisy restaurants because it makes them feel alive. Noise became part of the scene.

Little attention, if any, was paid to the impact of noise on our well-being, except for recognizing that exceeding loud sounds in the workplace can impair hearing. To this end, the American federal government demanded protection for workers in noisy occupational settings. However, the majority of us do not work near compressors or drills. Is noise dangerous to our health? Must noise be very loud to be hazardous? If noise is indeed dangerous, what can we do about it? It is the purpose of this paper to seek answers to these questions.

Defining Noise

Noise is not simply a loud sound but rather an unwanted sound. Noise does not have to be loud to be disturbing, annoying or hazardous to one's health. It is the unwanted, uncontrollable and unpredicatable nature of sound that characterizes it as noise. Although, most people would find very loud sounds bothersome, the intense sounds of discos are music to the ears of their devotees. It is interesting to note that the very person who enjoys the 100 plus decibels atmosphere of the discotheque might complain about the soft opera music coming through the wall at eight in the morning. The teenager who never complains about the volume of her stereo finds the whine of the neighbor's dog most disturbing when she is studying for her exams. How many of us have difficulty falling asleep when the faucet drip can't be turned off. We are bothered by sounds that are not within our control or when we can't predict their occurrence. We are even more agitated when the sounds are produced by sources we do not like, such as an unfriendly neighbor or the New York City Transit Authority.

Measuring Loudness

The loudness of sound is measured on a scale which takes into consideration the way people respond to this physical phenomenon. The resulting scale is called the decibel (A) scale or dBA. The decibel scale is logrithmic and so an increase in 10 decibels is experienced by the ear as being twice as loud. A range of common sounds can go from the rustling of leaves at 10 decibels, to human speech at 50 decibels, to the ringing telephone at 70 decibels, and to disco music and subway cars at over 100 decibels.

Noise and Hearing

The hair cells of the inner ears respond to sound waves and transmit them to the temporal lobe of the brain for interpretation. Therefore, it is these receptor cells that are vulnerable to injury when the sounds are intense. Although the exact relationship between intense sounds or noise and hearing loss were not known until recently, it had long been accepted that long-term exposure to loud sounds would result in some permanent hearing impairment

The data from two well-known studies (Burns & Robinson, 1970; Passchier-Vermeer, 1968) have demonstrated the risk to hearing for workers in a noisy industrial setting. It is at the 90 decibel level that workers exposed for eight hours daily begin to suffer some hearing deficits. There are, of course, individual differences and the hearing losses are greater for the highly susceptible.

Under the Occupational Safety and Hazard Act, passed in 1970 by the federal government, workers cannot be exposed to over 90 dBA of noise for more than eight hours without proper ear protection. Greater restrictions on exposure-time are set for higher levels of noise. Several years later, there was a concerted effort to lower the federal standard to 85 dBA but the cost to American industry stalled the change. It has been estimated that of the eight million United States workers exposed to noise levels over 85 dBA, over a million and a half have some hearing loss. The cost to industry for lowering the decibel level would be offset by the gain in the number of workers who would be working in an environment less threatening to their hearing ability. Workers are urged to protect their hearing even at lower sound levels but they often don't abide by this recommendation.

Whether noises in an industrialized society affect the populace at large who are generally not exposed to extreme conditions of noise for long periods of time requires additional study. Kryter (1985) states that there may be some deficit after living many years in a modern society, with men suffering a bit more than women. A recent report of college freshmen at an American school indicated less than optimum hearing for these youngsters. Similarly a study by Fearn (1972) reported that the high sound levels experienced at rock concerts and discos has resulted in some hearing loss in those who attend frequently. An American musician boasted on a late night television show that he has earned lots of money even if he couldn't hear as well any longer. Audiologist Jane Mandell of New York City's League for the Hard of Hearing has reported that most users listening to personal headsets play the music at 120 decibels or higher. With so many younger people playing and listening to extremely loud music, we should be concerned about the hearing ability of our future adults.

Noise and Stress

Although we have long been aware that unusually loud sounds can damage our hearing, we have been less aware of the damage of lower sounds to our physical well-being. With noise defined as unwanted sound, then any sound, loud or soft, can be distressing and possibly physiologically harmful. Exposure to these unwanted and uncontrollable sounds can lead to heightened stress and arousal. The body reacts to stress with increases in heart rate, rises in blood pressure, contraction of muscles, rises in blood cholesterol and secretions of hormones. If the noise continues and the individual remains stressed over a period of time then sustained stress reactions can lead to high blood pressure, hardening of the arteries, and ulcers. In other words, stress from noise can result in circulatory and cardiovascular disorders.

Kryter (1985) looks at the studies reporting relationships between noise and hypertension in workers exposed to high levels of industrial noise. Although the results of these studies seem to support the a positive relationship, Kryter questions them in terms of whether the hypertension is more a function of the general unpleasantlness of the workplace rather than the noise per se. In other words, it is not the noise that is stressful but the anger precipitated by thinking your employer cares little about providing better working conditions. Yet, in the final analysis, noise still contributes to the development of high blood pressure.

Studies in Europe and the United States have looked at the impact of noise on the health of people living near noisy airports, streets, and elevated trains. Before examining the health-related effect of noise on these residents, surveys have looked at how people feel about the intruding sounds. People living near noisy airplanes or elevated trains find their lives are constantly being disrupted. Conversations, leisure time activities, reading and studying are all interferred with. Annoyances from noisy sources have been well documented in community questionnaires. Yet, even here there are individual differences with certain people being more sensitive to the disruptions.

Accepting that noise is annoying and irritating, we can now look at the effect on the health of those living in noisy communities. Cohen et al. (1980) have reported higher blood pressure readings for children living and attending schools near the Los Angeles airport. Meecham and Shaw (1978) have reported higher death rates from cirrhosis of the liver and strokes among people living near the Los Angeles airport. Knipschild (1977) found residents near the Amsterdam airport more prone to hypertension.

Kryter (1985), after considering other variables (e.g. socioeconomic status), concludes that the above studies tend to support the cause-effect relationship between noise and physiological health problems. Although further research with more of the variables controlled is needed to confirm the relationship, the existing studies are strong enough to serve as warnings to those living in noisy areas.

People have been known to report that noise is driving them "out of their minds." Should we take this literally? Correlational studies by Abey-Wickrama, et al. (1969) and Herridge and Chir (1972) have found increased mental hospital admissions of people who live near London's noisy Heathrow airport. Again these studies have been criticized on methodological grounds and their findings must be accepted cautiously. Yet these correlational studies, as the others on the physiological effects of noise, gain credence as they grow in number.

Sleep and Noise

In New York City nearly one-half million people live parallel to the elevated trains. Have these people adapted to the passing noisy trains so that they no longer are awakened by them? They claim to sleep undisturbed by the roars and screeches of these trains. Yet, the noise does not have to awaken them to adversely affect their body's reactions. Fay (1981) reports that while these people are sleeping through the din, the more frequent shifts from deeper to light sleep prevent them from adequately recovering from fatigue. Lack of rest for the body can be physiologically harmful and meeting each day fatigued can be hazardous in that you are less able to cope with the necessary activities.

Noise and the Fetus

When a woman is stressed during pregnancy, there is the possibility that her physiological responses may trigger off changes in the developing fetus. She may also be more likely to take drugs to "quiet her nerves " and increased drug use may harm the fetus. Higher incidences of reported birth defects such as harelips and cleft palates have been reported by Jones and Tauscher (1978) in census tracts near the Los Angeles airport. Findings of lower average birth weights among children born to women living near airports were reported by both European and Japenese researchers. Although the evidence is still scanty that noise is dangerous to the unborn child, the U.S. National Research Council warned pregnant women to avoid working in areas which exposed them to loud noises for long periods of time.

Noise, Aggression and Helpfulness

The newspapers are replete with stories of fights exploding over noisy parties and loud stereos. There are even cases of neighbors shooting neighbors who were too noisy. Apparently noise brings out the worst in people. The noise doesn't even have to be especially loud or occur at a time when we are resting or sleeping. Haven't we all experienced some violent feelings when someone has bothered us with a hum, tapping pencil or irritating voice. Stanley Milgram, well-known American environmental psychologist, in trying to explain why people in large cities such as New York tend to be less helpful and considerate, claimed noise was a contributing factor.

Laboratory studies support the hypothesis that noise affects aggressive behavior. Noisy conditions led angry subjects to give more shocks to victims (Donnerstein and Wilson, 1976). Essentially when people are more likely to be aggressive, noise appreciably increases this behavior. Both in the laboratory and in a field experiment, Mathews and Cannon (1975) found noise tended to reduce the likelihood of helpful behavior. Noise may cause people to be less attentive to what's happening in their environment or cause them to be less interested in problems of others.

Noise and Learning

Theodore Wachs (1982), speaking at the American Psychological Association Conference, presented strong evidence of the relationship between ambient home noises and cognitive and language development in infants. Homes were rated according to how noisy they were; included were noises from appliances, radios, televison sets, etc. Infants, between the ages of seven and twenty months, were then tested in these homes for cognitive and language development. Where noise levels were high, infants were below normal in gesturing, in manipulation of physical objects, in comprehension of size and distance, in exploratory and verbal behavior. To explain these findings, Wachs believed that children may escape into their own worlds and make less contact with the outside world, so necessary in normal development.

Looking at children a bit older, Priscilla Hambrick-Dixon (1986) studied preschoolers attending daycare centers near New York's elevated trains and found them slower in certain psychomotor tasks. In studies of children attending schools lying within the paths of New York's two very busy airports, Green, et al. (1982) demonstrated lower reading scores. Cohen and Singer (1973) reported lower reading scores for children living in buildings adjacent to noisy highways and in a later study Cohen (1980) found lower reading scores for children attending schools near airports.

New York City, in 1974, had more than fifty public schools within 150 yards of elevated train track, as well as many other private and parochial schools. As far back as 1878, when the Third Avenue El opened, students had complained that noise from the trains disrupted their study. Even though the Transit Authority had responded to complaints from schools near their trains, little had been done to alleviate the condition over the next 100 years. In 1974 a group of parents who had children attending a school near elevated tracks in upper Manhattan decided to bring the Transit Authority to court on the grounds that train noise hindered their children's learning. The parents, however, had no data to support their contention before a court that required damages to be demonstrated. The case was lost but the parents' action coincided with my interest in looking at the relationship between learning and noise.

With a colleague (Bronzaft and McCarthy, 1975) I examined the reading scores for the children who attended this school during the academic years of 1971, 72, 73 and 74. With half of the school facing the tracks and the other half on the quiet side of the building, we were able to compare the reading scores of two groups of children, comparable in other pertinent variables, but different in the amount of noise exposure. The noise level in the classes facing the trains rose from an average of 59 dBA to 89dBA when trains passed; the quiet side remained at the lower level. About 80 trains passed along the tracks while the classes were in session. It was estimated that about 11% of instructional time was lost due to the passing trains.

Analysis of the data revealed that children on the noisy side lagged behind those on the quiet side by three to four months in the lower grades and by as much as eleven months in the sixth grade. We do not know whether the impact on learning was a function of lost teaching time or that the students studied and took exams in a noisy atmosphere; we only know that noise hampered learning.

With the above study being published at the time that the Transit Authority was given a huge sum of money to abate noise, pressure was put on the authority to use some of this money to abate the noise on the track adjacent to the school. Rubber resilient pads were installed on the tracks near the school as part of a test looking at the ability of this technique to tone down noise. To match the efforts of the transit agency, the New York City Board of Education agreed to acoustically treat the ceilings in several of the noisiest classrooms. The combined noise abatement methods lowered the noise levels in the classrooms from six to eight decibels.

The Transit Authority then asked me to conduct a study on the impact of this noise reduction program. When reading scores of the children on both sides of the building were compared for the two years following the installation (Bronzaft, 1981) it was found that there were no significant differences in reading scores. This research project demonstrated that noise abatement can remedy learning deficits resulting from noisy conditions.

Parents have asked me about the effect of loud stereo music on the studying ability of their teenage children. The music is within the control of the student and can be lowered if the teenager comes to a reading passage that might be too difficult. This situation is not really comparable to the studies cited above. Yet, should the music distract the student from her studies, then we could point to an interference. From personal experiences, I can report that both my daughters have achieved very high grades despite studying to music.

Noise Awareness

The warning signals that noise is dangerous to your physical and mental health are loud and clear. Yet, our societies continue to get noisier and too few people have been enlisted in the battle against noise. The fact that people probably place a higher value on their vision than on audition might explain why so many people have been willing to place their hearing in jeopardy. Secondly, since hearing loss is gradual, people are probably not aware of the toll noise takes. The relationship between noise and stress has not been as widely publicized and so many people are unaware of the dangers of sustained stress. Yet, from the many conversations I have had with people, I know they are aware of noise as an irritant. These same people, however, feel they can do little to still the noises of a metropolis and some even accept the noise as inherent to urban living. People living in quieter regions try to avoid noisy areas, recognizing the disturbing element. Yet, they may suddenly be exposed to a noisy invader in the form of a heliport built in a quiet community or a windmill placed in a backyard. Thus, it will be the responsibility of those familiar with the hazards and dangers of noise to take a leadership role in fighting noise pollution.

Noise Starts with Us

When we look at the opportunities to abate noise, we find the techniques to quiet our surroundings readily available. Much noise is people-produced--people playing their radios and stereos too loudly, unnecessary honking of auto horns, allowing a joyful party to get too loud, neglecting to repair squeaky motors or appliances. People are often not aware that their voices are carrying down the hall or that their door slamming jolts their neighbors. Of the many telephone calls I receive in my position as Chair of the Noise Committee for the Council on the Environment, so many are from individuals complaining about the inconsiderate behavior of the person living next door or upstairs. To these callers I suggest that a chat with the neighbor should remedy the noise problem. Let your neighbor know that the thin walls of the house can't insulate the sounds from a loud party or radio. Ask your neighbor to repair the dripping faucet. In most cases, these requests or reminders are sufficient to still the noise. The complaintant must also realize his or her noises also travel. Educating people about the annoyance of their sound-making can help quiet our surroundings.

To those who inform me that the neighbor is not responsive to a polite request, I suggest offering the neighbor a pamphlet on the dangers of noise. I have even suggested buying a pair of slippers for the neighbor whose high heels disturb the person who goes to bed early in the evening. If the individual persists in the noisemaking, a letter to the landlord or cooperative board director might be necessary.

Beyond the Individual

When the source of the noise is a community company's cooling units, then it is advisable that a representative group of residents approach the owner of the company to ask him to repair the units or to build insulating materials around them. Should there be resistance to this suggestion, support from a local public official tends to be helpful.

What happens, however, if the source of the noise is a city agency such as the New York City Transit Authority? Although the Transit Authority had responded to the noise complaints it had received from the time the first trains began to roll, noise abatement never received top priority. The managers of the agency viewed their mission as running a railroad. Noise was seen as inherent to the operation. There were those individuals at the authority that sympathized with the hundreds of thousands of people who lived near the train tracks and who suffered from the screeches and thunderous roars. However, these people were not placed high in the management hierarchy and their voices were weak in the overall managerial scheme.

When the Transit Authority opted to defer the maintenance of the system in the 1960's, system neglect resulted in wheels being trued less frequently, grease lubricators not being filled regularly, rails not being tended to, etc. The result was a deteriorating transit system and an increasingly noisier one. Noise was the prominent symptom of a poorly maintained transit system.

In the 1970's a number of citizen groups in New York became more aware of the dangers of transit noise and began to organize in an attempt to place noise abatement higher on the list of needed transit improvements. The parents' association of the school where noise interferred with learning was one such group. The Natural Resources Defense Council, an environmental organization, released several reports on the failure of the transit agency to employ available techniques to quiet its system. A group called the Big Screechers was formed to combat transit noise and was headed by an extremely charasmatic president who was able to garner a great deal of publicity for his cause. These citizen groups also realized transit noise abatement would be a natural fit in a program to bring back the transit system to a "state of good repair."

With the support of the several of the public officials and the media, citizen organizations began to influence the Transit Authority's position on noise abatement. Testimony at hearings encouraged the authority to seek out more funds for reducing the noise. Such funds were used to purchase rail grinders and additional wheel truing machines and to test out materials on the tracks that would cushion the noise.

Yet, New Yorkers were not satisfied with the pace at which the authority carried out its noise reduction programs and pressed the State Legislature for a Rapid Rail Transit Noise Code that would mandate the speedier actions of the transit agency. With the passage of this code four years ago, the Transit Authority had to develop a plan for correcting the noise problems over the next twelve years. Reports of their progress are to be released annually and should they falter in their efforts, they are to present reasons for failure to comply. Despite the passage of this code, the anti-noise groups continue to monitor the authority's behavior and know they cannot relent in their vigilance.

There Ought To Be Laws Against Noise

The City of New York has one of the most stringent noise control codes in the country, passed in 1972. Decibel levels were set for certain types of noise makers such as air compressors, paving breakers, and emergency signal devices. Day-time and night-time standards were set and allowances were made for the granting of individual variances beyond the limitations. The New York City Transit Authority is supposed to function within allowable standards but this section is somewhat vague. On the other hand, the code states that no unnecessary noise be made and defines this as " any excessive or unusually loud sound or any sound which either annoys, disturbs, injures or endangers the comfort, repose, health, peace or safety of a person."

Despite this code and an Environmental Control Board to enforce the code, New York remains an extremely noisy town. It is the failure to strictly enforce this code that allows many of the city's noises to continue unabated. The City Department of Environmental Protection is authorized to issue violations but one of the biggest complaints is against the agency for responding so slowly to citizen requests for help. Part of the problem stems from an outmoded complaint center that has not yet been computerized. Another part of the problem rests with the failure of this agency to delineate the areas it's to oversee in contrast to those under the purview of the police department. We still await a joint plan of action between these two agencies. Thirdly, the New York City police department does not consider stilling a noisy party or a loud music establishment as important as the other responsibilities they hold in crime-fighting.

So even with anti-noise codes and agencies to demand adherence to the laws, New Yorkers are still surrounded by loud sirens, ear-shattering sound reproduction devices, thunderous subway cars and illegal construction sounds. It is for this reason that a group of staunch anti-noise citizens have taken it upon themselves to educate the public on the dangers of noise and to urge the appropriate enforcement agencies to do a better job in noise curtailment. The New York City Council on the Environment has given us the opportunity to work under its aegis. Several of us are members of the Council and/or the Council's Noise Committee. The Council's members are appointed by the Mayor and the city provides the office space but the Council raises its own operating funds for the projects it undertakes. The Council's Noise Committee consists of volunteers who are devoted to the cause. The Committee developed the noise pamphlet produced and distributed by the Council, has prepared reports on the status of the Transit Authority's noise abatement programs, has given testimony at Council hearings related to noise and has tried to assist citizens with their noise problems.

The Federal Government's Role

When the Noise Control Act was passed in 1972, the Environmental Protection Agency was established and charged with the responsibility of conducting research on noise, on setting noise limits for trains, trucks and machinery as well as making recommendations on noise levels for the Federal Aviation Administration. The federal government was also to assist cities and states with establishing noise levels and noise abatement programs. To this end, EPA had published some excellent materials on the dangers of noise and on ways to control noise.

One area in which the government could have played an important role was in the design and manufacture of quieter tools, appliances, motors, compressors, etc. EPA asks for reduction in noise by allowing the manufacturers to use the best available technology. Can we rely on industry to take the initiative in quieting the noisy elements in its products? Had industry been sensitive to the noise problem, then we would not have had two major companies selling New York City noisy traction motors for their new subway cars. It was only after concerned New York citizens learned of this purchase and urged the transit authority to demand quieter motors that the manufacturers agreed to alter the design and produce the quieter motors now being installed. Ironically, the quieter motor turned out to have a longer-lasting life.

In 1982, with the election of Ronald Reagan, the federal anti-noise program has virtually ceased to exist. Noise research and education have been left to the states and cities.

Laws and Enforcements

There are city and state statutes supporting quieter communities. However, the language in these statutes calling for the elimination of unnecessary and excessive noise lack specificity. Secondly, the enforcement of regulations requires adequate funding and money is in short supply throughtout the country. When the federal government turned its back on the noise problem, the states that received financial assistance from the government drastically reduced their concern about noise. It is now the responsibility of citizens to lobby their local officials to increase the allocation of funds for noise control.

Protecting Yourself in a Noisy Environment

In alerting people to the hazards of noise, we hope to enlist them in our goal to quiet our surroundings. In becoming more conscious of the noise problem, we should alter our behaviors so that we don't offend others with our soundmaking. We, in noisy cities, will have to invest some money in purchasing double-paned windows, heavy drapes, and well-sealed doors. A small investment in some ear plugs should help during those very noisy subway rides. For the truly eager-beaver noise fighters, we urge you to educate your friends, neighbors, and community leaders on the dangers of noise and gain their cooperation in quieting their environment and by so doing enrich the overall quality of our lives.

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STREAM A

A PERSPECTIVE ON THE FORM AND PLACE OF LAW ON NOISE

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The traditional common law remedies have only a small role to play in macro management strategies but provide a useful model for testing the unreasonableness of noise through a flexible, multi-factor rather than absolute standard approach. The approach is one which ought to be taken up by legislators in defining unreasonable or excessive noise in preference to absolute measurement standards which have the illusory attraction of simple certainty but ignore the complex inter-relationships of a variety of factors.

The retention of heterogeneous legislative schemes is appropriate in dealing with the diverse sources contributing to noise pollution. Town planning (with reduced legalism) is a device of particular utility for long-term management.

The role of Noise Abatement Authorities ought to be to control through non-coercive means as part of an enforcement function but perhaps more importantly, to co-ordinate management strategies through research and education, as a foundation for advising future concrete proposals.

1.0 INTRODUCTION

The standard examination of the efficacy of common law remedies reveals their inadequacy as mechanisms in management strategy. The common law has a part to play but a limited one. One key principle is the flexible test for unreasonable noise used in the balancing process under the tort of private nuisance.

Rather than turning to a technical legal paper on some particular aspect or aspects of the Legislatures' attempts to take up the challenge of control,the paper takes up the more general ground of selected issues touching upon the place of law and the form of legal intrusion into the overall scheme of control of noise. A central theme is directed to a precatory emphasis upon reduced legalism and corresponding enhancement of common sense and flexibility.

2.0 CINCINNATUS OF COMMUNITY NOISE MANAGEMENT: THE COMMON LAW

It is standard procedure for lawyers commenting upon noise control measures to include in a prominent place in the catalogue, the available common law actions [Gifford (1980) and Testro (1983)]. Those actions are well-settled and relatively well-known, as are their considerable procedural and substantive limitations. Although such actions will retain their place in the management of community noise they are not a significant weapon.

2.1 The Available Common Law Actions and Their Technical Limitations.

A public or common nuisance is some unlawful act or omission to discharge a legal duty which endangers the lives, safety, health, property or comfort of the public [Kerse (1975)]. It retains attendant limitations in the requirement of proof to the criminal standard if a charge is pursued and the technical procedures in a suit for an injunction brought by the Attorney-General or some statutorily authorised public officer e.g. as in Baulkham Hills Shire Council v. A.V. Walsh Pty Ltd [1968] 3 N.S.W.R. 138. For a private citizen to take advantage requires convincing the appropriate authority to take action or overcoming the technical problem of establishing locus standi by proof of special damage in an action in tort as in Walsh v. Ervin [1952] V.L.R. 361.

Action under the imperialistic tort of negligence is unavailable except in an extreme case where actual damage has resulted from the noise interference since the technical requirements of that tort do not recognise mere annoyance or loss of enjoyment.

Strict liability under the rule in Rylands v. Fletcher (1868) L.R. 3 H.L. 330 is also largely inapplicable to noise interference since most noise creators are likely to be held to be a natural user of the land and thereby exempt from the rule and there has only been one case involving noise, caused by an escape of drunken caravan dwellers in Attorney-General v. Corke [1933] Ch. 89.

The potential which was disclosed by the new born tort in Beaudesert Shire Council v. Smith (1966) 120 C.L.R. 145 has died with that tort's demise during subsequent judicial exegesis (Trindade and Cane (1985) at 99].

The individual is left only with the tort of private nuisance and the associated common law right of self help through abatement. Any unreasonable act of disturbing a person in the enjoyment of his land is a private nuisance and the flexible test which has always been applied by the Courts is whether the alleged nuisance constituted "...an inconvenience materially interfering with the ordinary physical comfort of human existence, not merely according to elegant or dainty modes and habits of living, but according to the plain, sober and simple notions obtaining among the Australian people" (per Macrossan S.P.J. in Ruthning v. Ferguson [1930] St.R.Qd. 325 at 326). A 'give and take' attitude is used in determining what is reasonable, in conjunction with such factors as locality, time, duration, nature and motive.

2.2 Substantive Limits of the Common Law System

Common law actions involve complex legal technicalities originating in past history and the adversary system and nature of the forum result in high financial cost without any certain degree of success. In particular, only the Supreme Courts normally have jurisdiction to order cessation of a nuisance by the grant of an injunction.

The major limit is that the system of actions involves protection of individual rights (for those with the necessary resources and courage) in an ad hoc and reactive way and conditioned upon rights inter se. It is curative on the whole rather than preventative, even as between individuals, notwithstanding the availability of quia timet injunctions (Grasso v. Lowe [1979] 39 LGRA 101). It certainly is not preventative in any macro sense and can play little part, except as a back-up mechanism, in the overall structure of management control.

2.3 The Expert Witness and Technical Evidence

In the past, acoustic engineers and other noise experts have not played a definitive part in the common law process before the courts. That is not to say that technical evidence is not relevant or perhaps essential but there are two reasons inhibiting greater influence.

The first concerns judicial scepticism, perhaps contributed to by lack of understanding of the scientific details. Whilst it is not surprising to find expression of the doubts in cases reported 25 years ago e.g. as in Attorney-General v. Farley and Lewers Ltd (1962) 8 L.G.R.A. 186, the reality is that expert evidence may not prevail over subjective non-technical evidence, as occurred in G. Rosetto & Co. Pty Ltd v. District Council of East Torrens (1984) 54 L.G.R.A. 390.

Such an approach is encouraged by the formulation of the principles themselves, relying as they do upon a common sense appreciation of nuisance - the discomfort or degree of annoyance itself is not yet capable of scientific measurement. (Fowler Wood Engineering Constructions Pty Ltd v. Phelps (1960) 7 L.G.R.A. 67 at 75). The decibel itself is a relative measure and for courts to adopt it as an absolute one because of its superficial appeal in providing precision would defeat the very advantage of flexibility in the common law principles (see R v. Fenny Stratford Justices [1976] 1 W.L.R. 1101 esp. at 1106 and Howard Smith Industries Pty Ltd v. Leichhardt Municipal Council (1968) 16 L.G.R.A. 348).

The adversary system forces experts into opposing camps which manifest facility for producing opinions which correspond with the interests of their respective parties. Accordingly, the technical evidence from one expert is often countered and perhaps neutralised by that presented by the expert called for the other side. The origins of the expert witness reside some 500 years ago in the position of independent assessor. There would appear to be a place for re-introducing the position of expert independent of the parties. (See the position of assessor under the Land and Environment Court Act, 1979 (NSW).)

3.0 HORSES FOR COURSES: THE NEED TO RETAIN DIVERSE LEGISLATIVE MECHANISMS

Clearly only legislatures can provide the framework for a structured plan to manage community noise but the sources of such noise are so diverse that it is necessary to ensure that the most appropriate agency is authorised to manage each finite area - ranging from aircraft, boating and highway to town planning, standards for product manufacture, and licensed premises. Whilst many of the agencies have acquired control in respect of noise on purely historical grounds there is no reason to conclude that division between such agencies is not the most appropriate to control noise in their areas of operation. Central control for its own sake may be counted - productive but it is essential that there be be an appropriate agency to review the total scheme and co-ordinate the disparate elements.

Town planning is perhaps the most obvious and important of the legislative measures available for long-term management of community noise. Planning schemes are "...essentially concerned with the orderly development of an area of land for the benefit of the community...both presently and in the future." (Allen Commercial Constructions Pty Ltd v. North Sydney Municipal Council (1970) 20 L.G.R.A. 209 at 210). Town planning cannot overcome all existing nor furture individual problems but does provide an existing facility for large scale management and deserves at least the prominance accorded in the separate session of this conference.

Noise control is but one facet of town planning in Australia. The ability of town planning systems to manage noise will depend to some extent upon the quality of the system of town planning itself. Our system is modelled upon the long abandoned pre-war English system - it is based on excessive legalism with complex definitions and legally binding names and tables of uses, scheme maps, zoning tables, by-laws, planning policies and in Queensland since 1980, strategic and development control plans. The bottom line is expressed candidly by Haupt (1985):

"Contrary to popular opinion, the decision to prepare a planning scheme is not made solely on the basis of attaining a better quality of life by securing the amenity of an area or for environmental protection purposes even though a planning scheme will satisfy these objectives as "spin off" benefits...The drafting of the strategic plan is therefore heavily based on optimisation of the use of existing service capacities and not necessarily "quality or life" considerations.

In Queensland, the right of appeal to a judicial forum, the Local Government Court, has been the subject of a great deal of criticism, particularly from planners, and resulted in calls for an optional appeal system as in Western Australia for those wishing to avoid perceived unnecessary legalism. [Day (1983)]

One of the problems which I have noted has been reconciling the outlook of lawyers with that of planners. For most of the later group I have come into contact with, planning is viewed as a dynamic process interrelated with the political process. For the body of lawyers, the nature of the task is viewed more from the standpoint of defining terms and formulating rules, the edifice tending to become an end in itself. Many lawyers would support the move towards defined noise zoning with stipulated and quantified limits [Rose (1973)] not because of any informed view of the technical merits but because lawyers are trained to approach any system regulating rights and conflicts between citizens by seeking defined limits.

One wonders whether the flexible approach presently taken in respect to 'amenity' in a variety of existing contexts (see C.G.M.B. Company Pty Ltd v. Hornsby Shire Council (1972) 24 L.G.R.A. 414 at 417) ought not to be retained in preference to defined zonal noise limits. Other incentives to developers will need to be explored as a means of encouraging environmental considerations going beyond minimum standards.

The approach to noise management in the planning context, as with other elements in the overall system, needs to be linked to a co-ordinating body reviewing the global picture. The consultation by reference provided under s.13 of the Queensland Noise Abatement Act, 1978 provides that mechanism though it might be questioned whether the discretion accorded to local authorities in forming a view of likelihood of excessive noise as a pre-condition to consultation does not introduce unnecessary voluntarism.

The operation of planning controls will always be subject to a variety of influences arising from the political context in which it operates. In Queensland, for example, "prescribed" developments as determined by Cabinet by - pass Local Government requirements; franchise agreements such as the Iwasaki Resort may be taken outside the normal scheme by special Act; mining projects are treated quite differently and special legislation such as the Fig Tree Pocket Noise Emission Act, 1984 may be enacted in an appropriate climate. Reduction of the exemptions within a legislated scheme or total departure from it, will depend upon a heightening of the profile of noise pollution and the need for controls to balance the influence upon legislators of other factors tending against such control.

4.0 THE QUEENSLAND NOISE ABATEMENT AUTHORITY

In Queensland, as in other jurisdictions, an appreciation of the need for some form of co-ordinating body to oversee the disparate elements involved in the management of noise was arrived at a decade or so ago. The Noise Abatement Authority was established in 1978 and finds its counterparts in other jurisdictions under a variety of guises and names.

The functions of the Queensland Authority are enumerated in s.40. In addition to performance of the principal duties under the Act emphasis is placed upon review and advice. The original membership of 15 stipulated by s.43 was open to criticisms of imbalance, with only one representative of the public (who was a retired manufacturer). Amendment at the end of 1984 reduced the membership to seven and makes no specific provision for the nature of the composition.

The effectiveness of coverage by the Act is limited at the outset by the range of excluded classes in s.4, which comprise seasonal agricultural requirements, annual husbandry, public utilities, licensed premises and certain religious activities. Clearly under any scheme, effectiveness of control will depend upon the degree to which the total environment can be subjected to conformity. The larger the exempted class the less effective the control.

The scheme of the Act, as with some earlier versions, particularly the South Australian model, is to divide abatement of excessive noise into two distinct classes - commercial and industrial on the one hand (to be controlled by the Authority or Local Authorities as delegates pursuant to s.9) and excessive noise affecting residential premises in respect of which responsibility is divided between Local Authorities (s.28), the police in respect of musical, instruments, vehicles and rowdy premises and audible alarm systems.

In respect of the division between the two classes of premises, technical legal problems arose concerning the legal definitions and amendments were introduced in 1982. The problems in legal drafting in respect of classes of premises is one which is shared by other legislative schemes.

There is a system of notices, orders and licenses, including temporary licenses, provided for in Divisions 2, 3, 3A and 4. Statistics indicate that only about 5% of complaints reach the notice stage and very few orders are necessary e.g. 1 in 1982-3; 5 in 1983-4. There has been a clear success in the programme of resolution by consultation rather than compulsion and appropriate comparative data of dispute resolution mechanisms ought to provide the basis for determining legislative schemes in the future.

The factors required to be taken into consideration under s.6(2) in determining whether there is excessive noise sensibly take into account a variety of important contextual features in addition to sound pressure level. In that respect it can be contrasted with legislation with prescriptive certainty through rigid definition and lessened scope for balancing different weightings within the heterogenous whole, as in the case of the Industrial Noise Control Regulations made under s.24 of the Noise Control Act 1976 (S.A.).

The preparation of a model By-law for use by Local Authorities has provided some measure of uniformity but one wonders why that aspect could not have been imposed rather than being left to be voluntarily requested by such Authorities.

One deficiency in the Queensland scheme, as in other schemes, is the absence of appeal rights by complainants if the Authority or its delegate rules against taking action. The provision of a simple right of appeal to a court of summary jurisdiction may have engendered greater public confidence without any likelihood of over-burdening the judicial system. It is in this context that common law rights must be considered and the conferral of limited jurisdiction upon a court of summary jurisdiction would go some way to improving the judicial contribution to management.

Perhaps the greatest limitations for all of the centralised authorities lies in the fact that noise pollution does not and in the forseeable future, is not likely to have, as high a profile and priority compared even with other forms of pollution. As such, it is unlikely to attract generous funding from Government and realistically, must work within those limits. Of necessity, the legal structure within the total management structure will be a model which attracts minimal additional costs.

Perhaps the most important function of the Noise Abatement Authorities is the continuing development of technical expertise and acquisition of data in respect of community noise problems as the basis for concrete proposals in the future, not because of a philosophy of Micawberism for its own sake, but because that is sensible and a necessary compromise. The emphasis upon specific dispute resolution should be upon persuading, by less than blunt coercive means, those causing problems, to voluntarily comply rather than spending time unnecessarily upon law enforcement activities. Johnson (1972) has demonstrated the important role of 'standards' in legal and administrative aspects of noise control and the co-ordinating work of the Noise Abatement Authorities will focus upon the same beneficial effects in a precise and confined way.

5.0 CONCLUSION

I have attempted to suggest that avoidance of legalism and strict law enforcement procedures in managing community noise is preferable to the alternative and that accordingly, the form and place of law ought to be reduced rather than increased. Successful control will depend more upon developing awareness and acceptance than upon legal imperatives. The need to preserve a common sense flexibility in assessing noise for its unreasonableness has been stressed in response to recognition of the complexity involved in making such assessment and in establishing a causal relationship between effect and alleged cause. The attempts to define unreasonable and excessive noise by absolute quantitative measurement is ill-conceived notwithstanding the attraction of simple certainty.

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A REVIEW OF STATE ENVIRONMENT PROTECTION POLICY NO. N-1

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ABSTRACT

The Environment Protection Authority of Victoria has the responsibility of co-ordinating all activities relating to the emission of noise, for preventing or controlling noise and for protecting and improving the quality of the environment.

In fulfilling this function the Authority has developed a specific Policy for the control of noise from Industrial Trade and Commercial Premises. This Policy (SEPP No. N-1), proclaimed in May 1981, provided a specific procedure for the objective assessment of intrusive noise emitted by industry. In order to be applicable to the greatest range of industries, this policy provided for comprehensive evaluation of many facets of noise emission and a thorough investigation of existing background sound levels. The approach has been quite appropriate for the assessment of noise from large multi-source industrial premises although it has tended to represent a degree of "overkill" in considering smaller commercial premises often with single sources such as fans or compressors.

As part of a scheduled review of the Policy, the Authority is considering the possibility of incorporating a two-level assessment technique, one being for the complex situations and the other for the simpler problems.

1.1 INTRODUCTION

The mainstay for control of noise from industry within Victoria has been over recent years and at present still is the State Environment Protection Policy "Control of Noise from Commercial Industrial or Trade Premises within the Melbourne Metropolitan Area" No. N-1 (SEPP No. N-1). This Policy was produced in draft form in 1978 and put out for public comment. Following review and modification in light of comment received, the document was rewritten and proclaimed as a State Environment Protection Policy on 4 May 1981. SEPP No. N-1 was designed to be an objective criterion for assessing noise from a wide variety of commercial and trade activities using a readily available and repeatable technique, less subject to incorrect interpretation and misuse. As a consequence the document requires a fairly rigorous technical assessment based on objective evaluation with a high degree of reliability and accuracy. This is entirely appropriate when assessing major industries and where the cost of abatement is significant. At the same time the policy applies equally to smaller industries. These are the subject of a high proportion of investigations undertaken by the EPA each year and the extremes called for in the Policy, in an effort to absolutely evaluate industrial noise problems, represent a degree of overkill in terms of the accuracy required.

Recent changes to the Environment Protection Act have brought about a two level classification of industries. This was introduced in relation to Section 46A which requires industries of a certain class (those known from past experience to have the potential to be major noise problems), to notify the Authority of intended new works or expansions. This then allows the Authority to set limits which can be designed for by those industries.

In line with the Authority's ongoing review procedures which make all SEPP's liable to review every five years, and in the light of experience gained since 1981, a review of SEPP No. N-1 has been undertaken.

1.1 Policy N-1 1981

In essence, the SEPP No. N-1 released in 1981 sought to control noise by setting limits, having regard to existing background sound levels which were moderated by a rigid link to the land use zoning of the receptor area. On the other side of the coin, evaluation of the noise emission was based on the A-weighted equivalent continuous sound level (L_{eq}) adjusted for character and duration.

The basis for setting permissible levels was closely defined and requires consideration of the land use in the area within 200 m of the measurement point. All land contained in this area is classified as Type 1, 2 or 3 having regard to the likely noise generated by that land use. Type 1 is for quiet land uses (residential, public open space, schools etc.) and Type 2 and 3 are progressively noisier land uses with Type 3 containing general industry and main roads.

From the make up of land use within the 200 m area an influencing factor is determined which leads to separate levels being set for the Day (7.00 am to 6.00 pm), Evening (6.00 pm to 10.00 pm) and Night (10.00 pm to 7.00 am). These are on a sliding scale with limits for all Type 1 (predominantly residential) at 39 dB(A) Night, 44 dB(A) Evening and 50 dB(A) Day while for all Type 3 (predominantly heavy industry) 57 dB(A) Night, 61 dB(A) Evening and 68 dB(A) Day. A mechanism to further fine tune the levels allows consideration of the existing background sound level and modification to permissible levels where significant variation occurs between zoned levels and background. Such background sound level measurements are typically performed over several days.

Evaluation of received noise level is based on a one hour continuous recording of noise which is subsequently edited and analysed in the laboratory. This is then modified by applying adjustments for character and duration. These include a complex tonal adjustment using one-third octave analysis over several samples of noise of at least 24 seconds duration, an impulse adjustment based on the difference between the equivalent continuous sound levels using F or S and I response, an intermittency adjustment for rapidly changing noise levels likely to startle, and a duration adjustment where noise emissions do not occur for the full hour.

The Policy aims for measurements to be made out of doors for direct comparison with permissible levels which are regarded as outdoor limits although where outdoor measurements are not possible, measurements may be taken indoors. In such cases an adjustment for the transmission loss from outside to inside is required. This is based on the transmission mechanism by which the noise entered the room and is specified by the Policy. In addition, where atmospheric conditions significantly affect the measured equivalent continuous sound level the assessment must be based on three measurements taken within thirty days. All evaluations, undertaken by Policy N-1 (1981) require the same rigorous approach irrespective of the size of the industry or the magnitude of the problem.

2.0 REVIEW OF POLICY N-1

As part of the review, consideration was given to the necessity and appropriateness of retaining an all encompassing assessment technique for the complex situation, or alternatively providing a two tiered approach with a comprehensive technique for the complex case, and a lesser assessment for the simple case.

Given the resources required to conduct an assessment in terms of the Policy N-1 1981, it was decided to investigate the possibility of this division.

Shortly before the review commenced, the Environment Protection Act was altered to allow Authority involvement at the planning stages of the development of new industry and expansion of existing industry contained in Schedule 3 of The Environment Protection (Scheduled Premises and Exemption) Regulation 1984. This applied to industries which were known to have the potential to create significant noise disruption. For the purposes of the review it was decided to define industries contained in Schedule 3 as major premises and those not included as minor premises.

It was felt that Policy N-1 1981 provided an appropriate benchmark for the control of industrial noise which, by virtue of its tight objective basis, is interpreted with a relative uniformity by all users.

The value of this definitive approach is of particular importance for use in the planning field, where objective evaluation of future situations allows protection for residents and industry alike.

3.0 DISCUSSION

3.1 MAJOR PREMISES

The proposed evaluation of noise from major premises is by and large based on the Policy N-1 1981 with a general tidying up of procedures and development of the derived point concept. A derived point is a mechanism to allow measurements to be taken at points other than within a noise sensitive area. This has been found to be necessary where for technical reasons no suitable measurement point exists in the noise sensitive area and where generally a more reliable measurement location could be located outside the noise sensitive area. Policy N-1 1981 only allows for measurements outside a noise sensitive area where boundary levels are set. These can only be set where two or more industries contribute to a measured excess. The purpose of boundary levels is to apportion the noise reduction to each industry and provide for assessment at points where each industry can be assessed individually.

The need for one hour recordings and subsequent one hour analysis has been reviewed. The current thinking is to allow for recordings of between five and thirty minutes with the option for a shorter analysis, down to five minutes for steady noise sources. This change, together with a variation to the equipment requirements, will allow for the use of cassette recorder format. Indoor measurements have also been considered with a view to dispensing with the complex indoor adjustments. Measurements are now allowed using a boom outside a window.

The determination of permissible levels is still based on the zoning system, however the Type 1, 2 and 3 categories have been supplemented by a Type 4 use. This has really expanded the old Type 2 and 3 uses into Types 2, 3 and 4 and was necessary to show the distinction between commercial land uses and light industry which were both contained in Type 2 under Policy N-1 1981.

Light industry under the new system has been moved to Type 3 and the previous Type 3 land use (general industry) moved to Type 4. The permissible levels, as with Policy N-1 1981 may still be fine tuned due to unusually high or low background levels. A slight margin above permissible levels has also been included for emergency fire pumps which extends the allowance previously made to standby generators by Policy N-1 1981.

3.2 MINOR PREMISES

The approach anticipated for minor premises under the review is in general accordance with Australian Standard AS 1055 with the measurement technique to be adopted more closely specified. Measurements are generally to be "hand held" and based on an equivalent continuous sound level. This can be determined by use of either an integrating sound level meter or, for most cases, a non-integrating meter and application of procedures in the review to estimate equivalent continuous sound level. A relaxation of equipment standards is also anticipated. To the equivalent continuous sound level, adjustments for character and duration are applied. A tonal adjustment of +2 dB(A) where tonal components are just detectable subjectively and an adjustment of +5 dB(A) where the tone is considered prominent are specified. Similarly an adjustment of +2 dB(A) for noise with a just detectable impulsive component and +5 dB(A) for noise with a prominent impulsive character are to be applied. Duration adjustments in line with those contained in Policy N-1 1981 are applied on an equal energy basis, i.e. when the noise is audible for only half the measurement time a discount of 3 dB(A) is applied.

Consideration of the startle effect caused by rapid changes in noise level is applied, with rapid changes in level of greater than 10 dB(A) on two occasions incurring a +3 dB(A) penalty for the Day and +5 dB(A) for the Evening and Night. A rapid increase in level of between 5 dB(A) to 10 dB(A) during the Night or Evening incurs a penalty of +3 dB(A). An adjustment can also be made for the effect of atmospheric conditions which may give rise to enhanced propagation of noise. This adjustment is confined to propagation distances of more than 150 m, and requires the measurement to be made under worst case conditions to which a variability adjustment in the form of a 3 dB(A) discount is applied.

The derived point concept applicable to major premises has also been considered for minor premises. As in the case of major premises these points are to be used as substitute measurement points. Each derived point is to have a derived level set which is a limit set to achieve the relevant permissible level at the noise sensitive area of concern. The use of derived points is intended to resolve occasional difficulties of a technical nature associated with taking measurements within noise sensitive areas.

Permissible levels set for minor premises are, as with AS 1055, based on background sound level. The background sound level is measured over a relatively short period and is defined as the average of the minimum levels of the sound ambient in the absence of intrusive industrial noise. To this is added a margin of +10 dB(A) for the Day and +7 dB(A) for the Evening and Night to arrive at permissible levels.

To the permissible levels, determined using the background level, an overriding base of 36 dB(A), 30 dB(A) and 25 dB(A) respectively for the Day, Evening and Night periods for indoor permissible levels is applied. Similarly, permissible levels for outdoor measurements are not allowed to fall below 46 dB(A), 40 dB(A) and 35 dB(A) respectively for the Day, Evening and Night.

4.0 CONCLUSION

It is anticipated that revision of Policy No. N-1, in line with the two level approach currently being considered, will greatly speed up resolution of noise complaints and allow for a more effective basis for the control of industrial noise. It is hoped the simplified assessment if adopted will become a useful tool to council health surveyors and by-laws officers involved in the resolution of noise complaints. The objective standards contained in the revision should also form a basis for future planning controls, compliance with which may be determined by local planning authorities.

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NOISE CONTROL - THE LEGAL ASPECTS

A paper delivered at the Conference on Community Noise at the Darling Downs Institute of Advanced Education, 1-3 October 1986

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ABSTRACT

This paper considers the main methods, apart from the specific noise abatement legislation, available for the control of excessive noise. It discusses the nature of private nuisance and the remedies of damages and injunction available to the private citizen. It also considers the interaction of town planning controls and noise prevention, and touches on by-laws and public nuisance.

There are three basic methods available to protect the community against the harmful effects of excessive noise. The first of these, specific legislation, necessarily varies from country to country and from State to State. I understand that the Queensland Noise Abatement Act 1978-1985 is the subject of another paper to be delivered at this conference, and I therefore intend to confine my remarks mainly to the law of nuisance and to the town planning controls.

Nuisance

> "[T]he mere recitation of sources of possible annoyance does not necessarily establish that a nuisance has been committed. Whether a collection of instances of noises ... amounts to an actionable nuisance depends upon intensity, duration, and many other factors."[1]

The term "nuisance" has been defined as "something noxious or offensive; any unauthorised act which, without direct physical interference, materially impairs the use and enjoyment by another of his property, or prejudicially affects his health, comfort, or convenience"[2] "as occupier of such land."[3]

There are two types of nuisance, private and public. Private nuisances are interferences for a substantial length of time with the use or enjoyment of property.[4]

> "That may be a nuisance which is permanent and continued, which would be no nuisance if temporary or occasional only. A clock striking the hour, or a bell clanging for some domestic purpose, may be a nuisance if unreasonably loud and discordant, of which the jury alone must judge; but although not unreasonably loud, if the owner, from some whim or caprice, made the clock strike the hour every ten minutes, or the bell clang continually, I think that a jury would be justified in considering it to be a very great nuisance."[5]

A person commits the tort of private nuisance when he or she "is held to be responsible for an act indirectly ... [i.e. without trespass] substantially interfering with the use or enjoyment of land or of an interest in land, where, in the light of all the surrounding circumstances, this ... interference is held to be unreasonable."[6] It has been pointed out that everyone "must endure some degree of noise ... from his neighbour, otherwise modern life would be impossible and such a privilege of interfering with the comfort of a neighbour is reciprocal";[7] and that "[i]n these days of mechanised living, even a country resident cannot expect his home to be a soundproof sanctuary, or an idyllic retreat where the loudest sounds are the ordinary noises of nature. The growing suburbs of an expanding city inevitably become noisier than they used to be."[8]

Since there must be some give and take between neighbours if people are to live together at all, the key concept is that if the reasonableness or otherwise of the interference. The test is whether the inconvenience should be:

> "considered in fact as more than fanciful, more than one of mere delicacy or fastidiousness, as an inconvenience materially interfering with the ordinary comfort physically of human existence, not merely according to elegant or dainty modes and habits of living, but according to plain, sober and simple notions among the English people?"[9]

The standard is neither that of the ancient Spartans, who deliberately exposed themselves to discomfort in order to become tough, nor whether the particular plaintiff thinks he has been subjected to substantial discomfort and inconvenience, but "whether the reasonable man who resides in that locality would take the same view of the matter."[10]

> "The reasonable man [is] a person whose notions and standards of behaviour and responsibility [are those of] ordinary people in our society at the present time, [a person] who seldom allows his emotions to overbear his reason and whose habits are moderate and whose disposition is equable."[10]

He may therefore be a more accommodating neighbour than the average man!

The law of nuisance protects the ordinary enjoyment of property in the particular locality. It does not protect people who have the misfortune to be specially sensitive. As was held by Lord Selborne L.C.[11]

> "A nervous, or anxious, or prepossessed listener hears sounds which would otherwise have passed unnoticed, and magnifies and exaggerates into some new significance, originating within himself, sounds which at other times would have been passively heard and not regarded."

However, it must be remembered that noises which at some times of day are no more than might be expected in a residential neighbourhood can cause serious harm to amenity if heard, for example, in the middle of the night. As Stanley J. said in the Queensland Supreme Court:

> "It must not be thought that in a proper case I would refuse an injunction to stop a defendant from ruining his neighbour's rest by the noise of starting his car or truck at unreasonable hours, whether he was using it for business or not."[12]

Similarly, while normal church activities have to be expected on a Sunday, the neighbours would have a right to sue if they were subjected to the sound of church bells and massed shouts of "hallelujah" at 6 a.m. on a Sunday morning! Residents living next to a golfcourse have a right not to be awakened at 7 a.m. by golfers' conversation which pervades their home "all day long until twighlight".[13]

The character of the neighborhood is a factor of crucial importance in determining whether or not a nuisance has been committed. A person who decides to live in a basically industrial neighbourhood cannot expect that freedom from noise to which he would be entitled in a high-class residential area, and even there one could not expect the quietness of a rural area. Thus it was held that the congregation of a church in a poort part of Brighton (in England) disturbed by a buzzing noise from a power station had no legal remedy.[14] If the plaintiff's complaint is that a factory is creating a nuisance by noise "the character of the neighbourhood is very relevant and all the relevant circumstances have to be taken into account".[15] The court has to take into account "the standard in respect of discomfort and inconvenience from noise" which would be applied by "the ordinary reasonable and responsible person who lives in this particular area" ... This is "the standard of the ordinary man, and the ordinary man, who may well like peace and quiet, will not complain, for instance, ... of the reasonable noises of industry, if he chooses to live alongside a factory."[15] Nor will he "complain ... of the noise of traffic if he chooses to live on a main street in an urban area".[16] However, there are limits to what members of the public are expected to endure, even on a busy street. When an oil depot was situated almost immediately opposite the plaintiff's house, and almost every night roughly 15 enormous vehicles, some when laden weighing 24 tons, both departed and returned, and the plaintiff was troubled by engine noises, the rattle of empty vehicles, and the sound of gear changes, the court held that "the noise is an interference with the enjoyment by the plaintiff of his house"![17] An injunction was granted restraining the defendants (upon penalty of imprisonment for contempt of court) from so driving their vehicles and operating their depot as to cause a nuisance by noise to the plaintiff between 10 p.m. and 6 a.m..[18] As Stanley J. held in Kidman v. Page:

> "The right of reasonable passage along highways ... does not ... mean that at all times and in all circumstances a road user can regard a highway as a sanctuary from which he can with immunity make life intolerable for persons who happen to live near it, although if he exercises reasonable care towards them in such usage they would enjoy, substantially, the ordinary standards of life in a position in which some noise and dust must necessarily be endured by them...
>
> Any citizen may use the highway in a reasonable manner for his lawful purposes. If by an unreasonable manner of using it he creates a nuisance, by noise, to his neighbours, he is just as liable as if he had stayed on his property and made the disturbing noises."

Where the nuisance emanates from other land, rather than the highway, not only the occupier but the landowner as well may be liable to the plaintiff owner or occupier. The Full Court of the Supreme Court of South Australia awarded $1,500 damages against the defendant landowner in a case[19] in which

> "The nuisance was caused by the hirers of the hall and not by the respondent or its employees or agents. The respondent took such measures as were reasonably open to it to control the noise emanating from the hall but they were unsuccessful. The hall was not soundproof and was therefore unsuitable, having regard to the locality in which it was situated, for functions where loud amplified music was desired."

It was held that

> "an occupier of premises who hires the premises out for a particular purpose, which involves a special danger of nuisance, is liable for any nuisance caused by the hirer in carrying out that purpose.
>
> The respondent let the hall on hire on the occasion which produced the excessive noise, for the purpose of being used for functions likely to result in noise. It is to be expected that when a hall is used for weddings and similar functions, there will at times be loud music and other noise. There is in such circumstances a likelihood of the noise becoming excessive and therefore a special danger, inherent in the purpose for which the hall is let, that a nuisance will result. That being so, the respondent was in my opinion liable to the appellant for the nuisance which occurred. The respondent is not relieved of liability by having taken such precautions as he could to avoid the creation of the nuisance."[19]

The two remedies available to the person the enjoyment of whose property has been injured by a noise nuisance are damages and injunction. Damages are a form of monetary compensation awarded by the court to recompense the plaintiff for his losses. Injunction is an equitable remedy and takes the form of a court order requiring the defendant, on pain of imprisonment until he mends his ways,[20] to cease his infringement of the plaintiff's rights. The plaintiff must of course establish that there has been such an infringement and also (since injunction is a discretionary remedy) he must show the court that this is a suitable case for an injunction. The court will not issue an injunction if it is futile (e.g. if the defendant has sold the property from which the noise originates and has no connection with the new owners) or if the plaintiff does not come with "clean hands" (e.g. if he had encouraged the plaintiff to start up the business which is causing the noise; or is causing a worse noise himself) or if there has been undue delay in bringing the action.[21] Damages and injunction are complementary remedies, and may be obtained in the same action - damages to compensate for the plaintiff's loss of amenity in the past, injunction to prevent similar loss in the future.[22] In one such case, where the distance between a children's playground and the nearest bedroom was thirty feet, "there was a fearful racket coming from the playground, which is to be expected ... [T]he seesaw made a particularly distressing noise ... particularly satisfactory to those operating it, but very unsatisfactory to anybody to hand to listen to it. It made a noise like a mini pile-driver." The judge held that:

> "... I have to hold the balance between the young and the old. Obviously the children on this estate have got to have somewhere to play. The only available place for them to play is the present play area. Equally, the parents of those children must realize that some regard has to be paid to the comfort and the convenience of neighbours who derive no advantage whatever from the presence of the play area because they have no children who are going to take advantage of it. It is a question for the court to arrive at a balance of convenience.

> It has been suggested on behalf of the defendants that, in any event, the noise emanating from the play area could in no circumstances amount to a nuisance because it would not reasonably interfere with the enjoyment of the plaintiff's property by anybody who was not unduly susceptible to the noise made by children. I do not accept that argument. I take the view that we all have to put up with the noise of children for periods during the day, and it may be in the interests of those children for sustained periods of the day. But it is unreasonable to be expected to put up with it from dawn to dusk which, I am told, and I accept, from the plaintiff was what was happening when the playground was first opened. Furthermore, I think some commonsense has to be shown about the apparatus which is installed in the playground, and I am satisfied that to put in a seesaw that can be used to go thump-thump-thump throughout the time that it is in use, is a silly thing to do when it is within 30 feet of somebody's house and that it would be a noise amounting to a nuisance when it was in such constant use. So I think that when this play area first started the noise emanating from it, bearing in mind that it was unrestrained in point of time and bearing in mind the nature of the equipment and the fact that it was being used by older as well as younger children, amounted to a nuisance in law. But I am not satisfied that noise arising from a play area such as this, provided that its usage is restricted, both as to the ages of the children, the nature of the equipment and the hours of the day, does amount to a nuisance."

His Lordship granted an injunction, saying:

> "I shall in this case allow the use of the playground but make an injunction requiring its use to be restricted to the hours between 10 a.m. and 6.30 p.m. and by children under the age of twelve."[22]

In considering the law of private nuisance, it is important not to forget the existence of <u>public nuisance</u>. A public nuisance "is one which is so widespread in its range or so indiscriminate in its effect that it would not be reasonable to expect one person as distinct from the community at large to take proceedings to put a stop to it"[23] i.e. the reasonable comfort and convenience of a class of Her Majesty's subjects is materially affected, as for instance by an ill-organised pop festival. The public nuisance need not affect every member of the public.[24]

Where a public nuisance exists no private individual or community group or even (in the absence of a special legislative provision) local council can sue in respect of it. Only the Attorney-General can sue as representing the public. It is true that he may grant his "fiat" to a citizen, who can then sue in the Attorney-General's place, but if the fiat is refused, even for political reasons, the courts refuse to intervene.[25] However, if the would-be plaintiff can show some special loss or inconvenience to himself over and above that suffered by the public at large, provided that inconvenience is substantial, direct and appreciably different in nature or extent to that suffered by the general public, then he will be able to sue without the fiat.[26]

Town planning controls

The law of nuisance (with the exception of public nuisance) provides a remedy of an essentially private law nature, the remedies being sought by the individual citizen and, normally, after the nuisance has begun. Before that time there could be no loss and therefore no right to damages, and it is difficult to obtain a "quia timet" injunction to prevent an infringement of the plaintiff's rights which as yet he only fears is going to occur. Town planning control, on the other hand, is a public law matter and it seeks to prevent damage to amenity before it occurs rather than intervening afterwards. Indeed, once a planning permit has been granted special statutory authority is required before it can be modified or revoked. Noise is of course only one of a large range of factors which the planner has to take into account, nonetheless it can be not merely a relevant but a decisive factor in a planning body's decision either to refuse a permit[27] or to impose a condition.[28] The Victorian Town Planning Appeals Tribunal went so far as to adjourn the hearing of an appeal so as to enable (inter alia) a report and recommendation from a duly qualified acoustic engineer to be placed before it.[29] Many examples could be given of conditions imposed so as to limit noise from a site on which development is to be permitted. For instance, in permitting an abattoir in a rural zone, the Victorian Town Planning Appeals Tribunal limited machinery noise to 45 dB(A) 6 a.m. - 6 p.m., 40 dB(A) 6 p.m. - 10 p.m., and 35 dB(A) 10 p.m. - 6 a.m., the noise being measured at the boundaries of the appeal site.[30] It is of course very important for the planning permit to specify precisely what the noise limit is and where and when it is to be measured: a condition requiring that "adequate provision be made for the prevention of noise emanating from the [amusement parlour] onto the footpath"[31] may itself turn out to be inadequate should it prove necessary to take steps to enforce it. Indeed, even a requirement under public health legislation that "the level of noise in the said premises ... shall not exceed 70 dB(A)" has been struck down by the courts for uncertainty:[32] Watkins J. said:

> "I agree, however, ... that in the instant case it can properly be said that there was an imprecision in the form of the term complained of in the order which makes it void for uncertainty. The sound meter, assuming it to be accurately used and adjusted, can, according to the order of the justices, be taken to any part of the public house, and I dare say at any one of different places it could produce a different reading. Moreover, the readings which would be registered upon the sound meter would be affected not only by the sound coming from the juke-box but also by the number of people in the public house and the hubbub created by their general conversation and so forth. The form can be validly criticised upon the basis that the place for determining whether a nuisance exists is not to be ascertained by standing, in the case of noise, in the premises from which the noise emanates, but by standing in the nearest of the dwelling places, and listening to the noise flowing into that place. Thus, if I had been the justices and tempted to make such an order as this, I would, in yielding to the temptation, have chosen a spot, after visiting all the relevant premises, at which sound meter readings should be

taken so as to judge whether the terms of the nuisance order were being kept or not. For the sole reason that the justices failed to achieve that result I have come to the conclusion that this application succeeds."

Lord Widgery C.J., whilst agreeing with Watkins J. that that part of the particular order failed for uncertainty added:

"This case, however, does throw up for the first time the very interesting question of whether the introduction by modern science of the conception of the decibel cannot be used for the purposes of precision in cases such as the present.

I agree with Watkins J. that it can and should. It seems to me that if the justices can take the trouble to hear evidence which translates noise into a decibel reading and satisfy themselves that any emanation of noise in excess of a certain level is a nuisance, they can as well describe that which is to be done as a reduction of noise volume to below so many decibels instead of using the time-honoured formula of 'abate the nuisance'. I think that we should try to use the advantages which scientific development gives us rather than to reject them, and I think here there is an opportunity of using a scientific approach to what has always previously been a somewhat haphazard assessment."[32]

A problem arises because each planning application or appeal is considered on its merits, and the body deciding whether to grant the application is not bound even by its own previous decisions,[33] with the result that conditions imposed even by the same body in similar cases can vary erratically. A good example is provided by the conditions imposed by the Victorian Town Planning Appeals Tribunal in relation to dog breeding.[34] Such unexplained differences can lead to dissatisfaction with the planning process and so cause difficulties of enforcement.

While the courts recognise the citizen's need to be protected against "aural aggression"[35] it is important for the objector to a town planning application to provide adequate proof of his case.[36] Merely establishing breach of a technical noise standard may be insufficient, as it has been held that an assessment of noise impact

"must have regard to at least five factors: intensity of the particular noise, its duration, its frequency of occurrence, its quality in terms of tonal content and finally psychological factors in the hearer ... A technical standard ... can address itself to the first three of those factors, it may or may not adequately address itself to the fourth but quite obviously it cannot in any way address itself to the last. It is well established that one person may find the sound of a Beethoven or Mahler symphony played at a particular sound level to be quite acceptable but heavy rock played at exactly the same sound level in the same circumstances quite objectionable. To another the reverse could be the case. Additionally, a particular sound may conjure up reactions which then colour any objective assessment of the sound itself. For example, it has been suggested concerning noise nuisance at airports that the

> noise of jet aircraft was found to be objectionable because people, or some people, associated that noise with the possibility of a potential aircraft crash. Because of this I believe that it is always a little suspect to assess potential noise nuisance solely from anticipated sound levels and that the criteria set down in a standard such as AS1055/1978 should therefore be applied not in an unthinking sense but as part of the process of making as objective an assessment as possible of potential nuisance."[37]

Town planning control is not confined to imposing conditions in individual land use permits. Noise (as an aspect of amenity) is relevant in deciding what is the proper zoning for an area of land, and may also be relevant in deciding whether to grant a permit for subdivision e.g. for residential purposes. For example, if land is situated near an airport, or along one of the approach routes, noise is a factor that should certainly be taken into account in determining its proper zoning. Indeed, the courts would expect to find that the planning legislation authorises a local authority to control noise by means of its district scheme, so that requirements are laid down applicable to all properties in a particular zone.[38]

Parliament is also likely to provide a power under which local authorities can make by-laws for the "removal, suppression and abatement of nuisances".[39] By-laws made under such a power are independent of town planning schemes and permits, and the landowner or occupier must comply with both sets of controls. By-laws made under such a power must of course be restricted within the limits laid down by Parliament - if the power is to prevent and suppress nuisances, the council cannot create new types of nuisance not known to the common law, nor can it prohibit activities which cannot amount to a nuisance.[40] Within these limits a by-law can impose an absolute prohibition - it is no excuse that, for example, the noise is caused by guard dogs or that the defendant did not intend to breach the by-law.[41] An example of a valid by-law made under a power to suppress nuisances is one which defines a noise as "a nuisance for the purpose of this by-law if it occasions undue distress, annoyance, or irritation to any person".[42] (The word "undue" is vital to the validity of this by-law as it excludes unreasonable annoyance on the part of unduly sensitive persons).

Conclusion

The noise control inspector needs to be aware that his powers under specific noise control legislation do not stand alone. Should he find that an individual or company is persistently and deliberately breaching the Act, and that the statutory penalties are inadequate to put a stop to such activities, the inspector may enlist the aid of any of the independent controls on noise.[43] If several authorities get together and discover that each of them has a problem of enforcement as against some person, it would be reasonable for them to co-operate in bringing prosecutions and, should these fail to secure compliance, in suing for an injunction to enforce the law. The courts have shown themselves reluctant to grant injunctions to enforce the criminal law, but will do so in cases of flagrant breach where the criminal penalties are inadequate to restrain the commission of an offence.[44] A history of breaching related controls could be an important factor in this context.

1. Kidman v. Page [1959] Q.S.R. 53 at 55-6; 6 T.P.G. para. 742 (The Town Planning and Local Government Guide, The Law Book Co., summarises relevant cases, including the decisions of the courts in relation to noise, from Australia, New Zealand, the U.K. and Canada).

2. Jowitt's Dictionary of English Law (2nd ed., 1977) John Burke, Sweet & Maxwell Ltd., London.

3. Salmond on Torts (17th ed., 1977), R.F.V. Heuston, Sweet & Maxwell Ltd., London, p. 50.

4. Ibid., pp. 51-2.

5. Bamford v. Turnley (1862) 31 L.J.Q.B. 286 at 292, per Pollock C.B., quoted in Stroud's Judicial Dictionary (4th ed., 1973), J.S. James, Sweet & Maxwell Ltd., London, p. 1794.

6. Street on Torts, (7th ed., 1983) Butterworths, London, p. 231.

7. Winfield and Jolowicz on Tort, (11th ed., 1979), W.V.H. Rogers, Sweet & Maxwell Ltd., London, p. 356.

8. Kidman v. Page [1959] Q.S.R. 53 at 55; 6 T.P.G. para 739.

9. Walter v. Selfe (1851) 4 De. G. & Sm. 315 at 322, per Knight-Bruce V.C.; 64 E.R. 849.

10. Salmond on Torts, supra, p. 56.

11. Gaunt v. Finney (1872) L.R. 8 Ch. App. 8, at p. 13. (There is an exception if the defendant's own conduct has made the plaintiff hypersensitive to noise - Salmond on Torts, supra, p. 58.)

12. Kidman v. Page [1959] Q.S.R. 53 at p. 65.

13. Sans v. Ramsey Golf & Country Club Inc. 68 A.L.R. (2d) at p. 1323; 5 T.P.G. para. 88 (The New Jersey Supreme Court compelled the club to relocate the tees). See also the curious decision of the English Court of Appeal in Kennaway v. Thompson [1980] 3 All. E.R. 329 at p. 333; [1981] T.P.G. para. 1300.

14. Heath v. Mayor of Brighton (1908) 24 T.L.R. 414; Salmon on Torts, supra, p. 55.

15. Halsey v. Esso Petroleum Co. Ltd. [1961] 1 W.L.R. 683 at pp. 691-2; 7 T.P.G. para. 35 (see also para. 49).

16. Ibid., at p. 692; 7 T.P.G. para. 79.

17. Ibid., at pp. 698-703; 7 T.P.G. para. 80.

18. [1959] Q.S.R. 53 at pp. 60-1; 7 T.P.G. para. 451.

19. De Jager v. Payneham & Magill Lodges Hall Inc. (1984) 36 S.A.S.R. 498. See pp. 500-502, per King C.J.; [1985] T.P.G. para. 1380.

20. Imprisonment for breaching an injunction is not for a fixed term; the defendant can be kept in prison by the court until he has "purged his contempt" by apologising for breaching the court's order and undertaking to obey it in future. Should he then breach his undertaking, the court will send him back to prison. Injunction is therefore effective in securing compliance where a fine might fail, even though injunction is a civil remedy and a fine is a criminal remedy.

21. For further comments on injunction in relation to noise, see "Noise: Problems and Remedies" by K.H. Gifford Q.C., [1985] T.P.G. para. 284 at p. 109.

22. Dunton v. Dover District Council (1977) 76 L.G.R. (U.K.) 87, at pp. 89-93, per Griffiths J., [1985] T.P.G. para. 115 (English Queen's Bench Division).

23. Winfield and Jolowicz on Tort, supra, pp. 353-4. Note also s. 230 of the Queensland Criminal Code.

24. Salmond on Torts, supra, p. 49.

25. Gouriet v. Union of Post Office Workers [1978] A.C. 435 (House of Lords). (This was not a case of public nuisance, but the principle still applies.)

26. Winfield on Tort, supra, pp. 354-5.

27. See, for example, Squash Centres (Ashfield) Pty. Ltd. v. Ashfield Municipal Council (1981) 4 Australian Planning Appeal Decisions [A.P.A.] 394 at pp. 396-7 and 400 (N.S.W. Land and Environment Court Assessor decision). See also s. 13 of the Noise Abatement Act 1978-1985 (Qld.).

28. See, for example, the requirement as to sound insulation and siting of noisy equipment and plant imposed by the English Secretary of State for the Environment [1971] Journal of Planning and Property Law 475 at p. 478; 19 T.P.G. para. 341.

29. Posset v. City of Knox (1977) 9 V.P.A. 71; 28 T.P.G. para. 445.

30. McKenzie v. Shire of Broadford (1978) 11 V.P.A. 118; 29 T.P.G. para. 180.

31. Stor and Spranger v. Manly Municipal Council (1975) 3 L.G.A.T.R. 186 at p. 188; 26 T.P.G. para. 1241 (N.S.W. Local Government Appeals Tribunal).

32. R. v. Fenny Stratford Justices ex parte Watney Mann (Midlands) Ltd. [1976] 1 W.L.R. 1101 at pp. 1106 and 1107 (English Divisional Court). For a provision to be held null and void for uncertainty it must be not merely ambiguous but either meaningless or so phrased that honest men applying the formula could reach different results due to a subjective element in the formula itself. See King Gee Clothing Pty. Ltd. v. Commonwealth (1945) 71 C.L.R. 184. For an example of a control

which was sufficiently certain see Bitumix Ltd. v. Mount Wellington Borough Council [1979] 2 N.Z.L.R. 57 at p. 65; [1981] T.P.G. para. 266 (New Zealand Supreme Court, now High Court.)

33. It is of course bound by the principles of law as laid down by the superior courts.

34. Contrast, for example, Bricknall v. Melbourne and Metropolitan Board of Works (1976) 4 V.P.A. 93; 26 T.P.G. para. 1118 (dogs to be locked in kennels at night) with Bulmer v. Melbourne and Metropolitan Board of Works (1981) 6 A.P.A. 263 ("Unless being exercised on leash all dogs must be locked in their kennels 6 p.m. - 7 a.m. Eastern Standard Time and 9 p.m. - 6 a.m. Eastern Summer Time."). Even where specific times are given these have varied considerably in relation to Summer Time.

35. Francis v. Chief of Police [1973] 2 All E.R. 251 at p. 259 (Privy Council).

36. For an example of failure to provide such proof, see Brighton Laundry and Dry Cleaners Pty. Ltd. v. City of Brighton (No. 2) (1976) 4 V.P.A. 200; 26 T.P.G. para. 1853.

37. Carroll v. Kogarah Municipal Council (1984) 10 A.P.A. 278 at p. 280 (N.S.W. Land and Environment Court, Assessor decision).

38. Bitumix Ltd. v. Mount Wellington Borough Council [1979] 2 N.Z.L.R. 57 at pp. 61 and 65; [1981] T.P.G. paras. 264-7 (New Zealand Supreme Court, now High Court). See also [1985] T.P.G. para. 284, at pp. 106-8.

39. Local Government Act (Qld) s. 30. The exact wording will off course vary from Act to Act: see, e.g. [1981] T.P.G. para. 263 and [1984] T.P.G. para. 878. Note sections 28 and 29 of the Noise Abatement Act 1978-1985 (Qld.).

40. Rice v. Daire (1982) 30 S.A.S.R. 560 at 568; [1984] T.P.G. para. 388 (South Australian Supreme Court).

41. See the cases referred to in [1985] T.P.G. para. 284 at pp. 108-9.

42. 1955 Qld Government Gazette p. 804.

43. Even building control provisions may be relevant - the reason for the excess noise might well be a failure to comply with the building controls in the erection of the premises from which the noise emanates.

44. Gouriet v. Union of Post Office Workers [1978] A.C. 435 (House of Lords).

THE PORT MORESBY WHARF DEVELOPMENT PROPOSAL AND THE ENVIRONMENTAL PLANNING ACT

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ABSTRACT

In Papua New Guinea (PNG) there is no legislation which deals exclusively with the regulation of noise. There are, however, several laws which are used to control noise problems. These include the Environmental Planning Act, the Environmental Contaminants Act, the Health Act and some Council Rules. This paper demonstrates how the Environmental Planning Act is used to regulate noise expected to arise from a new development, by presenting a case study of the proposed Port Moresby wharf development.

1.0 INTRODUCTION

In Papua New Guinea, an important piece of legislation for curbing excessive noise levels in the community is the Environmental Planning Act. Under the provisions of this Act a proponent intending to embark on a development project must submit an environmental plan. The plan must outline clearly all the major environmental issues that may arise from the project and means of minimising any potential problems. Prior to the approval of the plan, the Department of Environment and Conservation carries out its own assessment.

One such study was conducted on the Port Moresby wharf development proposal. This proposal, submitted by the PNG Harbours Board, included the installation of copper concentrate facilities. A noise survey was conducted at the Bougainville Copper Limited wharf at Anewa Bay to provide an indication of the sources and levels of noise expected from copper loading equipment. Noise surveys were also carried out at Port Moresby wharf to determine present noise levels, and at Lae Port wharf. Assessment of typical noise levels arising from Anewa Bay and Lae would allow the Department of Environment and Conservation to predict likely noise levels originating from the proposed development of Port Moresby wharf and, if necessary, to prescribe noise level limits on the wharf area under the Environmental Planning Act.

2.0 METHOD

A Sound Level Indicator, Model No. MO21OO-T was used to measure noise originating from three large wharves in Papua New Guinea.

At the Port Moresby wharf, measurements were recorded at sites along the sea front at approximately 100m intervals, at locations on Port Road directly behind these wharf front sites, and at the boundary of a residential area approximately 30m from the wharf.

At Anewa Bay Port, readings were taken at the centre of the wharf while copper concentrate was being loaded for shipment, and approximately 30m and 60m from the wharf centre.

At Lae, noise levels were obtained from the wharf centre, the gate leading into the wharf, and at the edge of the residential area.

At all 3 areas, noise levels were determined in the early morning, late morning, noon, mid-afternoon, early evening and late evening. Recordings at each wharf spanned a period of at least 3 days.

3.0 RESULTS

3.1 Port Moresby Wharf Noise levels measured at Port Moresby Wharf are presented in Table 1. The highest noise level was recorded at the main wharf area and was due to intermittent noise from forklifts, trucks and ship engines when work at the wharf was at its peak during mid-afternoon. High noise levels from peak hour traffic were obtained in the morning and mid-afternoon . At night, noise from the wharf was undetectable but noise from the Yacht Club disco, waves and wind was audible.

Table 1: Noise Levels at Port Moresby Wharf

Date	Time (hrs)	Site	Source of Noise	Noise Level (Maxima) dB(A)
28-1-86	1410	Main Wharf	Forklifts/trucks and ship engines	64
	1420	Yacht Club	Passing traffic	50
	1425	Lancron	Passing traffic	61
30-1-86	2225	Yacht Club	Disco music from club	58
	2235	Lancron	Surf and wind on boat riggings	54
31-1-86	0740	Main Wharf	Passing traffic	52
	0745	Yacht Club	Passing traffic	53
	0750	Lancron	Passing traffic	63

Noise levels measured along Port Road are presented in Table 2. During the day the principal noise source was passing traffic. At night noise sources included the wind and music from the Yacht Club disco approximately 20m distant.

Table 2: Noise Levels on Port Road, Port Moresby

Date	Time (hrs)	Site*	Source of Noise	Noise Level dB(A) (maxima)
28-1-86	1442	Port Road at back of Lancron	Passing traffic	68
	1450	Port Road at back of Yacht Club	Passing traffic	68
	1455	Port Road at back of Main Wharf	Passing traffic	52
30-1-86	2250	Port Road at back of Lancron	Wind through leaves	47
	2254	Port Road at back of Yacht Club	Club disco	50
	2257	Port Road at back of Main Wharf	Wind through leaves	47
31-1-86	0800	Port Road at back of Lancron	Passing traffic	65
	0805	Port Road at back of Yacht Club	Passing traffic	60
	0810	Port Road at back of Main Wharf	Passing traffic	63

* All sites are approximately 5 metres from houses

3.2 Anewa Bay Port Wharf The main source of noise at Anewa Bay Port was tractors shovelling the copper concentrate onto the conveyor. (Table 3) From the centre of the wharf, noise levels from the tractors ranged between 52 and 58 dB(A). These levels are similar to those obtained by Maunsell Consultants in a report prepared for the PNG Harbours Board. The filter/dryer plant was also a major noise source. Predictably the noise level from the port decreased as the distance from the source increased.

Table 3: Noise Levels at Anewa Bay Wharf

Date	Time (hrs)	Site	Source	Noise Level dB(A) (Maxima)
01-5-86	1300	Centre of Wharf	Tractor at concentrate shed	58
	1306	30m from Centre	Filter/dryer plant	53
	1312	60m from Centre	Filter/dryer plant	42
03-6-85	0930	Centre of Wharf	Forklift and Crane	52
	0935	30m from Centre	Filter/dryer	46
	0940	60m from Centre	Filter/dryer	42
04-5-86	1900	Centre of Wharf	Tractor at concentrate shed	53
	1915	30m from Centre	Filter/dryer	44
	1930	60m from Centre	Filter/dryer	42

3.3 <u>Lae Wharf</u> At Lae wharf, houses have been built on the perimeter of the container storage area. Operations at this wharf begin at 0800 hrs and cease at 2200 hrs each day, and during this period noise from the wharf was measured at 42 dB(A) within the residential area (Table 4). Noise from the wharf was undetectable after work stoped at night. Maximum combined noise from trucks, forklifts and ship engines of above 50 dB(A) was common in the wharf centre and entrance, since Lae is the largest port in Papua New Guinea and many vehicles move in and out of the port each day.

Table 4: Noise Levels at Lae Wharf

Date	Time (hrs)	Site	Source	Noise Level dB(A) (Maxima)
05-5-86	1400	Wharf centre	Forklifts	51
	1410	Entrance	Vehicles	54
	1425	Residential Area	Noise from wharf	42
06-5-86	0910	Wharf centre	Ship engine, trucks and Fork lifts	54
	0915	Entrance	Vehicles	59
	0925	Residential Area	Wharf area	42
07-5-86	2204	Wharf centre	Ship engine	46
	2215	Entrance	-	-
	2220	Residential Area	-	-

DISCUSSION

The major noise source affecting the residential area facing Port Moresby wharf was passing traffic on the 2-lane Port Road. This is of major concern as the noise levels often exceed the standard of 55 dB(A) presently being followed by the Japanese Government for a 2-lane road during the day time. The typical noise level originating from busy ports such as Lae Wharf (Table 4) is well below the Papua New Guinea recommended maximum level of 75 dB(A) for industrial areas.

The proposed redevelopment of the Port Moresby Wharf would include copper concentrate loading facilities. The determination of noise levels at Anewa Bay Port identified sources of noise from such facilities and gave an indication of what is to be expected if the Port Moresby wharf development proposal is implemented. The major noise sources at Anewa Bay Port were tractors used for loading copper concentrate, and the filter/dryer plant. For the Port Moresby wharf development, it is assumed that the filter/dryer plant would be located near the mine site at Kiunga on the Fly River in Western Province. Thus, the plant would not be a problem to residents near the wharf. If the copper concentrate shed is fully enclosed as suggested by the Port Moresby Port Feasibility Study (Maunsell Consultant), the noise from this source could be reduced.

This study showed that noise levels around the wharves in Papua New Guinea are generally below the maximum level recommended by the government. The task of the Department of Environment and Conservation is to ensure that extension of the Port Moresby Wharf would not increase the noise level above the present level. The Environmental Plan submitted by the PNG Harbours Board suggested that an increase of 3 dB(A) would not be of much concern to residents near Port Moresby Wharf. Under the Environmental Planning Act the Department of Environment and Conservation is empowered to impose certain conditions on several aspects of the environmental parameters in question. In this case the Department suggested that the concentrate shed be fully enclosed so that noise from the tractors is trapped within the shed. Department also recommended that wharf operations begin at 0800 hrs and end at 2200 hrs each day. These actions would ensure that residents near Port Moresby Wharf are not exposed to raised noise levels due to the wharf development.

These suggestions would be imposed as conditions for the approval of the development plan. By applying the Environmental Planning Act, the Department of Environment and Conservation is able to control noise pollution in Papua New Guinea and safeguard the health and welfare of the community.

CONCLUSION

Noise pollution in Papua New Guinea can be regulated by the Environmental Planning Act. This Act puts the responsibility of maintaining the quality of the environment on the proponents of projects who must identify and assess possible environmental problems and suggest methods of minimising any potential problems.

By following the provisions of the Environmental Planning Act it was possible to identify major noise sources at wharves in Papua New Guinea and suggest methods of noise control to regulate the noise level expected to arise from the proposed Port Moresby Wharf Development.

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URBAN NOISE AND THE RESIDENTIAL ACOUSTICAL ENVIRONMENT

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ABSTRACT

We have recently interviewed more than 900 families in three residential areas and made acoustical measurements at several representative locations. From these interviews and measurements, we have been able to describe the current situation, to identify internal and external noise sources and their relative proportions, to identify trends in development and to find the relations between L_{eq} and high annoyance.

A prediction method for estimating traffic noise has been put forward. The influence of external noise sources on residential areas could be ameliorated to some extent by reasonable city planning and enforcement of existing regulations.

Some of the families belonged to the middle-income level in China require not only quiet housing, but also acoustical privacy. An analysis of problems in the acoustical environment in some low-cost housing in China is made and some suggestions for improvement are put forward.

1.0 INTRODUCTION

Dwelling construction was developed quickly in recent years in China. The completed areas of new dwellings were about one hundred million square metres every year in urban areas, and the scale of the construction has been developed from scattered to conjoined residential areas. According to the new Five-Year Plan of China, more new dwellings will be constructed. The "Standard of Environmental Noise of Urban Area"(GB-3096-82) has been published in China in 1982, so the quietness of a dwelling's environment is included as one of the criteria of its quality. In fact, investigations and considerations of the quality of the residential acoustical environment were not taken into account during the process of planning and design in many cases as much as the appearance of the city, the limited area for each family and the cost of every square metre, thus producing some undesirable consequences. For example, some teachers preparing their lessons at home have to put on earplugs; in a residential area, thirty families (accounting for nearly 6.3% of the total number) have to close the windows of their room when they stay at home without air-conditioning in the summer though the weather is very hot.

This paper first finds the relations between sleeping, working, resting and high annoyance. It then puts forward a prediction method for estimating environmental noise level of dwellings along the traffic road under the simplified conditions. Lastly, it sums up some planning and design measures for obtaining adequate acoustic environment for the inhabitants.

2.0 ANALYSIS OF THE RESULTS OF THE SURVEYS AND THE MEASUREMENTS

The total number of vehicles per hour and the noise levels listed in table 1 show the changes between 1976-1986 of the same road in the same city. It shows that the noise level increased markedly due to the great increase in the total number of vehicles per hour. On the other hand, the various household appliances (especially various sound appliances) owned by the residents increased rapidly and resulted in obvious changes in the composition of the noise inside the residential area. Fig.1 shows the composition of the noise inside the residential area.

TABLE 1
Comparisons between the total number of vehicles/h and the noise levels in 1976 and 1986

Time of Statistics and Measurements	Number of Vehicles/h							Traffic Noise Level from The Center of Flow of Nearside Carriageway dB(A)			
	Heavy		Light		Motorcar		Total				
	Number	%	Number	%	Number	%	Number	L_{10}	L_{50}	L_{90}	L_{eq}
0800-0900 8th, Oct. 1976	508	70	222	30	0	0	730	78	66	60	71.4
0800-0900 15th, May 1986	420	33	692	54	164	13	1276	79	72	65	75.3

We have two kinds of list for interviewing the residents. The first list, asks the people to answer eight questions about their living circumstances, did not mention the word "noise", in order to avoid inducing people to say that noise annoyed them. After the first list is finished, the residents are asked to evaluate their residential acoustical environment by using roughly three ranks (i.e. satisfactory, fair, and highly annoying) on the second list. Because existing average standards for dwellings in China are still lower, these rough

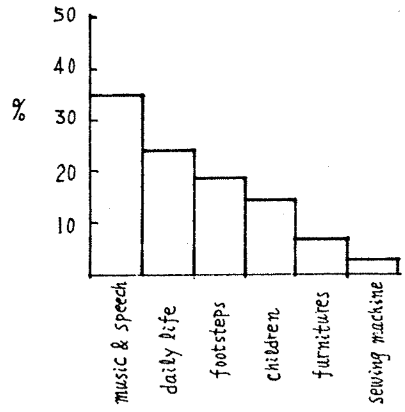

Fig.1. The composition of the noise inside a residential area

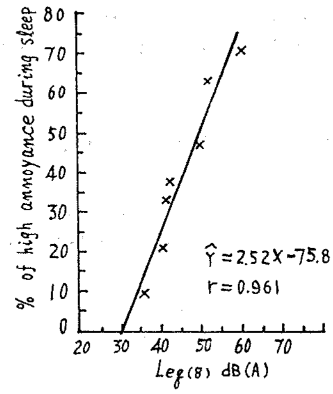

Fig.2. The relation between % of people with high annoyance during sleep and the noise level

ranks could remove the effects of other nonacoustical factors in the rank of "highly annoying".

Fig. 2 shows the relation between the percentages of high annoyance during sleep and the noise levels. Regression analysis shows that the correlation coefficient reaches 0.961.

Fig. 3 shows the relation between $L_{eq(16)}$ and high annoyance during work. The subjective responses were based on 385 families (accounting for nearly 43% of the total number of families in the two residential areas surveyed and measured). They are teachers, engineers, newspaper reporters, editors and cadres. Their activities and work at home in general have similar requirements of quiet in their acoustical environment, so the correlation coefficient of the regression analysis reaches 0.995.

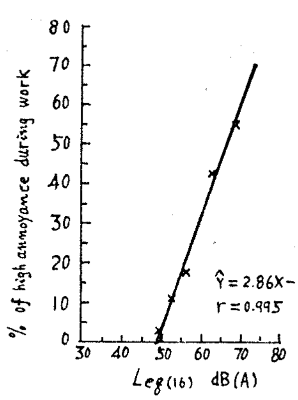

Fig.3 The relation between % of people with high annoyance during work and the noise level

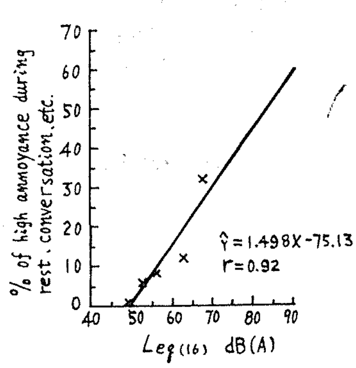

Fig.4. The relation between % of people with high annoyance during rest, conversation, etc. and the noise level

Fig, 4 shows the relation between $L_{eq(16)}$ and high annoyance during rest, conversation and music appreciation. Because the requirements and interests of the residents in these fields are different, it is found that the requirements of the noise control are lower than for work, the correlation coefficient is also lower.

3.0 PREDICTION OF THE TRAFFIC NOISE LEVEL IN DWELLINGS ALONG ROADS

In general, under conditions of free flow, the traffic noise level transmitted to the dwelling depends on the total number of vehicles per hour, the percentage of heavy vehicles, the distance from the noise source, and the extent of the road that comes into the view of the residents. The noise level of the dwellings facing the road at distance D is given by

$$L_D = L_0 - 10\log(\frac{D}{X_0}) + 10\log(\frac{\theta_D}{180}) \quad dB(A)$$

where: L_0 is the traffic noise level at the given distance X_0 (outside the dwellings). The value of L_0 can be obtained from the department of the monitor in the cities or measurements on the spot, in dB(A)

D is the distance from the traffic flow to the external wall facing the road in m

θ_D is the extent of the road that comes into the view at the position of the measurement or observation, in degrees. Fig. 5 shows the corrections for the different θ_D under the same traffic flow on the same road and the comparison with some results of the measurement.

Generally speaking, because the distance from the traffic flow to the receiving points on the different floors above source height are greater than the horizontal distance, lower outdoor noise levels would be expected at the upper storeys of a multi-floor dwelling than at road level. A Canadian report pointed out that this reduction in outdoor noise levels is offset by the dependence of the building's noise insulation on the angle from which traffic sound arrives. For this reason, the distance correction is based only on the horizontal distance between the dwelling and the traffic noise source, if the ground surface is "hard" (for example, if the pavement has hard shop fronts, and other hard surfaces). Table 2 shows

TABLE 2
Noise levels of different floors measured at the same time

Floor	Noise level, L_{90} dB(A) (Average values over four hours)
1	54.5
2	52.5
3	54.5
4	53.0
5	54.3
6	53.1
7	54.5

the noise levels measured at the receiving positions of different floors of a dwelling facing the road at the same time. This analysis

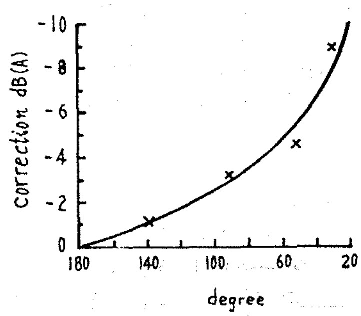

Fig.5. Relation between corrections and view angles

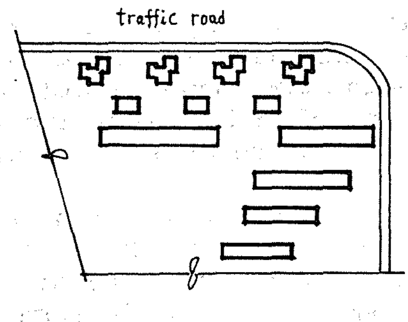

Fig.6 An example of residential district, that did not take noise interference into account

has to have further proof with more measurements and analysis of the theory.

4.0 PLANNING AND DESIGN MEASURES FOR PROVIDING QUIET RESIDENTIAL ENVIRONMENT

4.1 Due to the irrational traffic systems and the distribution of industry in some cities, people living in urban areas suffer from severe noise pollution. For example, there are two main railroads passing through the urban area of a provincial capital city. The nearest distance is less than 20 m between the railroad and external walls of the dwellings facing the railroads, and the average number of trains coming and going is five per hour during night. The ambient noise level is often 37-43dB(A) in the quiet of the night, but the noise level increases rapidly to more than 80 dB(A) when the trains pass. In another medium-sized city, the number of small airplanes from a nearby flying school doing drills above the city is 60-120 per hour, the area attacked by high air noise is about 12 square kilometres. In some other cities, heavy vehicles must pass

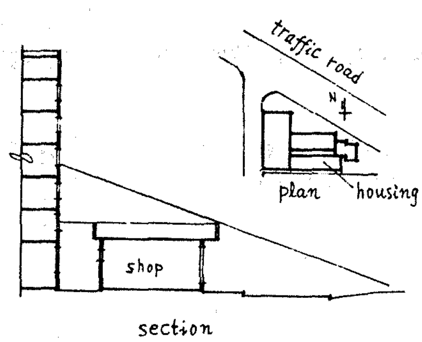

Fig.7. A good example of Shop-housing

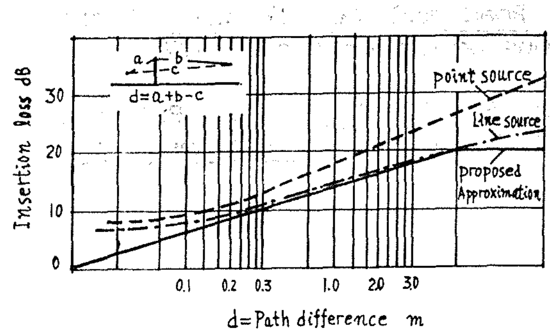

Fig.8. Path difference VS insertion loss for a barrier of infinite length

through the urban areas, because there are no highways around the cities. With the development of cities and the increase of population in urban areas, the state of noise pollution is worsening. In fact, if there were national regulation of noise control, the standards (GB-3096-82) mentioned above would be put into effect forcefully, and the problems of noise pollution would sure be solved with the replanning and reconstruction of the cities.

4.2 The layout of a new residential area and the design of the mon-omer of the dwellings must take into account the requirements of the acoustical environment after the site is chosen. Fig.6 shows a district near a road. If the strip form dwellings were planned near the road as the first row, the acoustical environment would be distinctly improved. Another good example, shown in Fig. 7, is shops and housing. Most dwelling units in this building are arranged above the shops and drawn back 20m. The first floor of the market acts as a barrier so from the comparison of measurement with the remaining small part of the building, the noise level emitted by the traffic flow decreased obviously. The curve in Fig. 8 can be used for estimating the insertion loss for a barrier of infinite length.

4.3 The secondary rooms of the dwelling unit can be placed near the road, in order to reduce the interference by noise from traffic flow. According to the results of the measurements, a corridor with glass windows can decrease the noise level from the outside environment by more than 20 dB(A). F.R.Fricke's investigation shows that the maximun attenuation obtainable was approximately 6 dB(A) at the face of the building behind the balcony (using a white-noise source).

4.4 Acoustical privacy between two adjacent units in the dwellings has become increasingly important. The flanking transmission of sound due not only to the selection of the partition, but to the big holes or windows installed on the interior wall separating the secondary rooms of two dwelling units is serious. It can be avoided easily if it is considered at the initial stage of the design by the architects.

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COMMUNITY RESPONSE TO NOISE IN AUSTRALIA: RESULTS OF THE 1986 NATIONAL NOISE SURVEY

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ABSTRACT

A social survey was carried out in February 1986 to assess the extent of community noise disturbance in Australia. A total of 2,332 people were interviewed in all federal electoral divisions. The results indicate that noise is the most serious form of environmental pollution experienced by residents. The rank order of neighbourhood problems which respondents were either concerned about or affected by is: 1) noise disturbance; 2) unpleasant odours, smoke or dust; 3) poor tasting water; and 4) spilled garbage or litter.

The survey also assessed the relative disturbance caused by various types of noise pollution using a number of different indicators of reaction. The noises which have the greatest impact on residential communities were found to be traffic and barking dogs. Twenty per cent of Australian residents experience at least moderate annoyance because of each of these two noise sources. Overall, 40% of Australians experience disturbance to listening activities or to sleep because of some form of noise pollution. The most commonly reported causes of annoyance from individual motor vehicles in all States are hotted-up cars and motorbikes.

The survey confirmed that complaint data is a poor indicator of the community impact of noise. Also, reaction to noise was found to decrease with age but to increase with education level. The present survey provides a baseline for future monitoring of the effectiveness of national noise control strategies in Australia.

1.0 INTRODUCTION

Studies of community reaction to noise in Australia have typically focussed on either one particular type of noise or on noise in a particular location, e.g., aircraft noise (Hede & Bullen, 1982); traffic noise (Brown, 1978); military range noise (Bullen & Hede, 1984). These studies have aimed primarily at establishing the relationship between the amount of noise and the reaction experienced by a community. There have been no studies aimed at assessing the extent of disturbance resulting from the many different sources of noise pollution throughout Australia. The present study aimed to fill the need for data on the overall impact of noise on the general population. The survey is referred to as the National Noise Survey. It was funded by the Australian Environment Council and carried out on behalf of the Council's Environmental Noise Control Committee.

2.0 METHOD

2.1 The Questionnaire The number of questions in the survey was limited by financial constraints. The questionnaire was based on those used in previous noise surveys (Hede & Bullen, 1982; Bullen & Hede, 1984). The items covered were: neighbourhood problems concerned about and affected by; noises heard; disturbance to listening and sleep; noise annoyance; complaints about noise; most bothersome noise; motor vehicle noise; noise sensitivity.

2.2 Survey Procedures The survey was conducted as part of the Roy Morgan Research Centre's weekly omnibus survey, which entails personal interviews with approximately 10 respondents aged 14 years and over in each of the 110 federal electoral divisions in Australia. Interviews were carried out over two successive weekends in February 1986. The total number of respondents was 2332 and the sample breakdown by states was: N.S.W. - 779; Vic. - 593; Qld. - 408; S.A. - 199; W.A. - 199; Tas. - 80; A.C.T. - 59; N.T. - 15.

3.0 RESULTS

3.1 Noise As A Neighbourhood Problem The first two questions were designed to assess the relative impact on residents of the four major types of environmental pollution (air, noise, water, waste). To ensure an impartial response these pollutants were set in the context of other "neighbourhood problems". Respondents were shown a list of nine problems (presented in four different orderings) and were asked which, if any, of the problems:

- "are you, yourself, concerned about?";
- "are you, yourself, personally affected by?"

The results (Figure 1) show that noise disturbance is the most serious neighbourhood problem experienced by residents. Significantly more people were concerned about and affected by noise disturbance than by other pollutants. The rank order of neighbourhood problems which respondents were either concerned about or affected by is: 1) "noise disturbance"; 2) "unpleasant odours, smoke or dust"; 3) "poor tasting water"; and 4) "spilled garbage or litter". (Note that these were the terms used in the questionnaire).

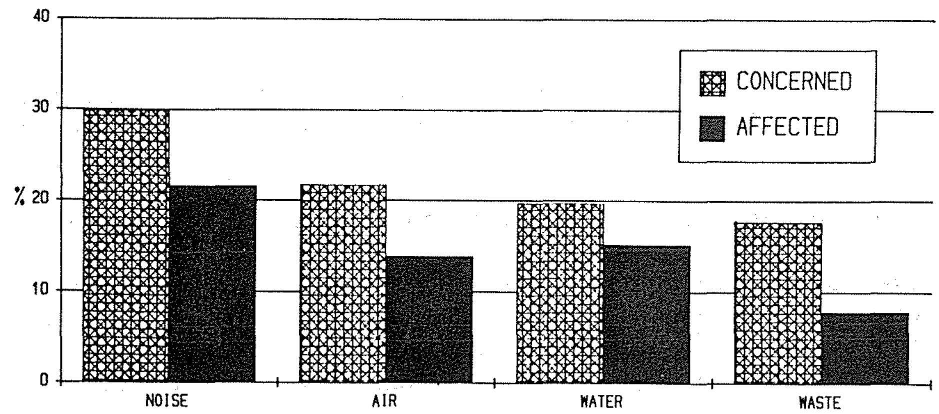

FIGURE 1. PERCENTAGE OF RESPONDENTS CONCERNED ABOUT AND AFFECTED BY MAJOR TYPES OF POLLUTION

While noise was the most commonly reported neighbourhood problem overall, there was some variation across states (see Figure 2). Noise was the problem most often reported as affecting residents in New South Wales (24%), Victoria (21%), Queensland (22%) and Western Australia (22%), whereas poor tasting water was the most commonly reported problem in South Australia (32%) and Tasmania (11%). Unpleasant odours, smoke or dust was the second most reported problem in Victoria (17%) and Queensland (21%), but was of less concern in Western Australia (7%). Spilled garbage or litter was not rated highly in any state. Other neighbourhood problems reported were: not enough cycling tracks (21% concerned about, 10% affected by), not enough footpaths (16%, 9%), lack of trees (16%, 5%), not enough parks (14%, 5%) and ugly appearance of area (12%, 4%).

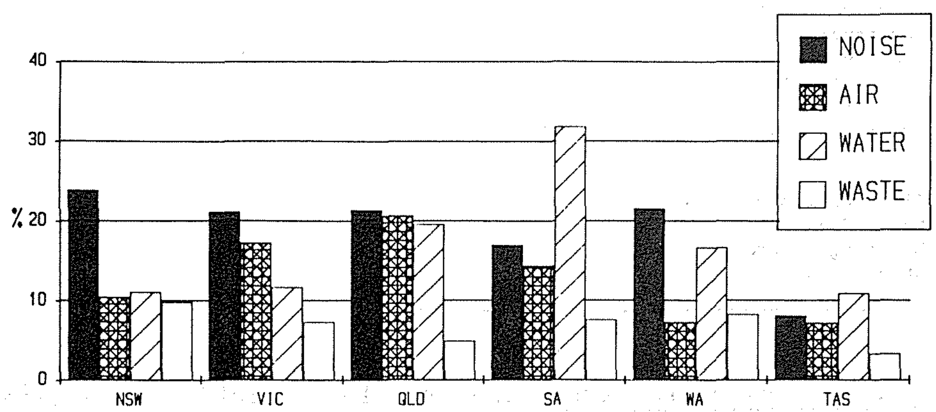

FIGURE 2. PERCENTAGE AFFECTED BY MAJOR TYPES OF POLLUTION IN EACH STATE

3.2 Types Of Noise A number of reaction indicators were used to assess the relative disturbance caused by the different types of noise. Respondents were shown a list of 18 noises (again, four different orderings were used) and were asked to specify which:

- "noises do you, yourself, hear when you're at home?";
- "noises disturb you when you're listening to TV, radio or music at home?";
- "noises disturb your sleep at home?";
- "one noise would you most like to get rid of?".

Also, respondents were given a 0-10 rating scale with the extremes labelled "not at all annoyed" and "extremely annoyed", and were asked to rate:

- "how <u>annoyed</u> you are by (each noise heard) at your home?".

Table 1 gives a profile of the impact of each type of noise in terms of the percentage of respondents specifying the noise on the various reaction indicators. The noises in Table 1 are listed in rank order of their impact on residents (the primary indicator is "most like to get rid of").

<u>Table 1</u> Profiles of reaction to different noises on a range of indicators (figures are percentages based on total sample;"-" = <0.5%)

	REACTION					
TYPE OF NOISE	Noise Heard	Disturbs Listen-ing	Disturbs Sleep	Moder-ately Annoyed	Highly Annoyed	Most Like To Get Rid Of
Traffic	45	13	12	21	6	17
Barking Dogs	45	8	15	21	9	16
Lawn Mowers	44	9	2	13	3	6
Noisy Neighbours	15	4	5	8	4	5
Trail Bikes	13	4	2	7	4	5
Aircraft Noise	24	9	2	8	2	5
Garbage Collection	26	-	7	8	2	3
Neighbour's TV/Music	14	4	4	6	3	3
Railway Noise	17	5	3	6	2	3
Noisy Parties	10	3	5	6	3	2
Burglar Alarms	7	2	2	3	1	1
Construction Noise	5	1	1	2	1	1
Entertainment Venue	3	1	1	1	1	1
Sporting Venue	4	1	-	1	-	1
Factory/Shop Noise	3	-	-	1	1	1
Air Conditioner	4	-	1	1	-	-
Scare Guns	2	-	-	-	-	-
Shopping Centre	1	-	-	-	-	-
Other Noise	2	1	1	-	-	2

3.3 <u>Most Serious Noise Problems</u> The profiles in Table 1 indicate that the worst noise problems in Australia are traffic and barking dogs. Almost half the population hears these noises (45% "Heard" in both cases). Also, these noises were equally likely to cause moderate annoyance with 21% of respondents giving ratings $\geqslant$4 in both cases. This indicates that each of these noise sources at least moderately annoys over 3 million Australians. However, barking dogs were more likely to cause high annoyance (rating $\geqslant$8) which was reported by 9% of respondents as compared with 6% for traffic noise.

Activity disturbance is regarded as an important indicator of the community impact of noise. The two major disturbances were assessed in this survey, namely, disturbance to listening activities, and sleep disturbance. Overall, 40% of respondents reported experiencing disturbance to listening activities because of some form of noise, and 42% reported sleep disturbance. Listening to TV, radio or music was most likely to be disturbed by traffic noise (13% of respondents) and barking dogs (8% of respondents). Sleep disturbance was most likely to be experienced because of barking dogs (15%) or traffic noise (12%). No other noise caused a high incidence of disturbance to both listening and sleeping, although aircraft and lawn mowers caused considerable disturbance to listening (9% in both cases) and garbage collection caused considerable sleep disturbance (7%).

The extent of the activity disturbance caused by traffic noise and barking dogs explains why these two noises stand out as those which Australians regard as the worst noises. Almost one third of respondents selected them as the ones they would most like to get rid of (17% traffic; 16% barking dogs). Table 2 lists the percentage in each state who nominated each noise as the one they would most like to get rid of (only the top 10 noises are shown). It can be seen that traffic noise and barking dogs were by far the worst noises in all states. The next worst noise in each State was: N.S.W. (garbage collection); Vic. (lawn mowers); Qld. (aircraft); S.A. (aircraft); W.A. (noisy neighbours); Tas. (aircraft).

Table 2 Percentage of respondents in each state selecting noises as the one they would most like to get rid of ("-" = <0.5%).

	STATE					
NOISE	NSW	VIC	QLD	SA	WA	TAS
Traffic	15	18	16	18	20	13
Barking Dogs	17	14	13	16	19	22
Lawn Mowers	5	7	6	5	3	6
Noisy Neighbours	5	3	6	2	4	2
Trail Bikes	5	5	6	6	3	1
Aircraft	5	4	7	7	2	9
Garbage Collection	6	1	2	2	-	-
Neighbour's TV/Music	4	3	3	3	2	1
Railway Noise	5	3	2	-	1	-
Noisy Parties	2	3	2	5	-	-

3.4 Noise Complaints The survey asked respondents whether they or any family member had complained about noise, and to specify which noise(s) and who they complained to. The incidence of complaint was very low and bore little relationship to the other indicators of noise reaction. The only noises complained about by more than 0.5% of respondents were: barking dogs (4%); noisy parties (3%); traffic, noisy neighbours, neighbour's TV/music (2% each); trail bikes, garbage collection, burglar alarms, entertainment venue noise (1% each). It is notable that lawn mowers, aircraft and railway noise are rarely complained about even though the other indicators of reaction clearly show that they cause considerable disturbance to residential communities (see Table 1).

Respondents indicated that when they do complain, most complaints are made to the police (27%), the local council (21%) or to a neighbour (21%). Complaints about barking dogs are mostly directed to either a neighbour (30%) or to the local council (29%), whereas most complaints about noisy parties are made to the police (70%), and about traffic to the local council (52%).

3.5 Motor Vehicle Noise Respondents were also asked to indicate which, if any, of a list of noises from motor vehicles:

- "are you, yourself, annoyed by when you are at home?"

The results summarised in Table 3, indicate that the most common causes of annoyance to residents in all states are hotted-up cars (30% annoyed) and motorbikes (24% annoyed). Other frequently reported causes of annoyance were squealing brakes (19%) heavy trucks (19%) and general traffic noise (14%).

Table 3 Percentage reporting annoyance from motor vehicle noises in each state. ("-" = <0.5%)

		STATE					
NOISE	TOTAL	NSW	VIC	QLD	SA	WA	TAS
Hotted-up Cars	30	31	31	27	31	32	26
Motorbikes	24	25	24	24	26	19	12
Squealing Brakes	19	18	22	11	25	20	12
Heavy Trucks	17	19	16	17	11	17	9
General Traffic	14	14	16	13	13	11	11
Car Horns	9	9	10	6	9	9	5
Buses	3	4	2	4	1	1	-
Delivery Vans	2	3	2	2	1	1	-
Other Noise	2	2	2	2	-	3	2

3.6 Sensitivity To Noise Noise sensitivity is known to be an important determinant of noise reaction. Respondents were asked how noise sensitive they were compared with other people. Overall, 10% rated themselves more sensitive, 21% said they were less sensitive and the majority (66%) considered themselves to be the same as other people. Of those rating themselves more sensitive, 25% reported having made a noise complaint, in contrast to only 11% complainants out of those who said they were less sensitive.

3.7 Demographic Factors Community reaction was assessed in terms of the respondent's age, occupation, income, and education level. The only variable to show consistent effects on the various indicators of reaction were age and education level. There is a general tendency for noise reaction to decrease with increasing age, but to increase with higher education levels. These effects (which are illustrated in Figures 3A and 3B for overall noise reaction and for annoyance from the major two problems, traffic noise and barking dogs), occurred for virtually every reaction to every noise. Interestingly, a similar trend was evident for complaints.

4.0 DISCUSSION

The present survey has shown that noise is the most serious pollution problem affecting residential communities in Australia. In a comparable U.S. study, noise was found to be as significant an environmental problem as air and water pollution (S/V News, 1979). Respondents in the present study appeared able to distinguish between the two reactions,

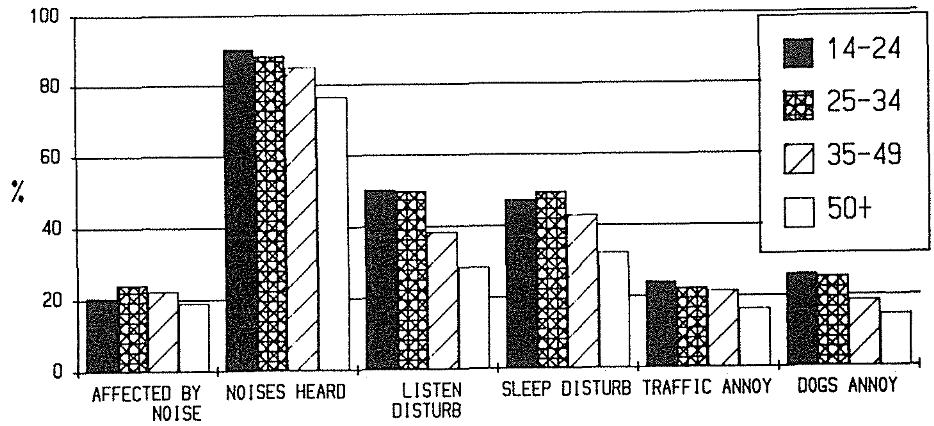

FIGURE 3A. EFFECT OF AGE ON NOISE REACTION

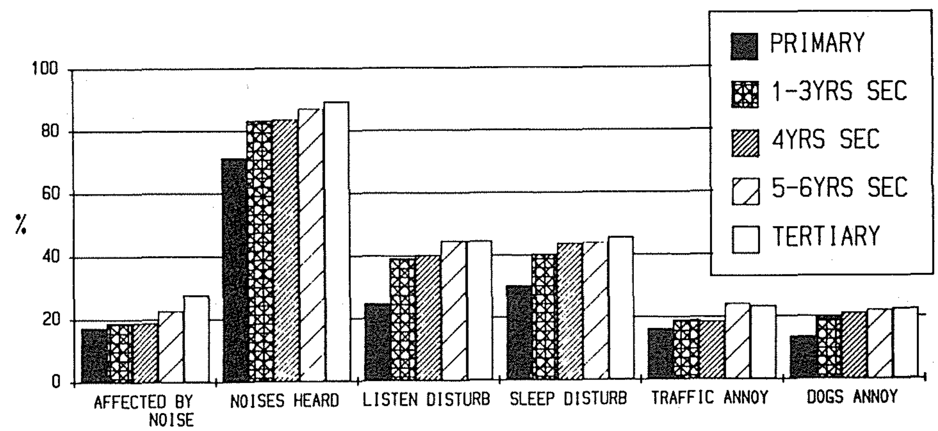

FIGURE 3B. EFFECT OF EDUCATION ON NOISE REACTION

"concerned about" and "affected by". The greater level of 'concern' presumably reflects the fact that people will respond to socio-political aspects of environmental problems which don't 'affect' them personally. This also highlights the need for investigators to be clear about the type of reaction they are assessing; where community annoyance and the impact on residents is under investigation, the reaction "concerned" is not the appropriate measure.

The present results point to traffic noise as the number one priority in environmental noise control in Australia. The results indicate that more than three million residents experience at least moderate annoyance from traffic noise, and about two million suffer disturbance to sleep or to listening activities. As Hede (1984) has shown, traffic noise annoyance in Australia is increasing. This increase cannot be halted unless a high priority is given to controlling traffic noise on a national basis.

The other priority in noise control is in the area of domestic noise. Three of the top four noise problems fall in this category, namely, barking dogs, lawn mowers and noisy neighbours. Another two, neighbour's TV/radio/music and noisy parties, also rated high in impact on residents (see Table 1). Responsibility for control of such noise in Australia generally rests with local councils and the police. However, a national educational campaign which fosters an attitude of consideration for neighbours would increase the effectiveness of domestic noise controls.

5.0 CONCLUSIONS

The main findings of the National Noise Survey can be summarised as follows:

1. In terms of impact on residents, noise is the most serious type of environmental pollution.
2. Forty per cent of Australian residents experience disturbance to listening activities or to sleep because of some form of noise pollution.
3. The noises which cause the greatest disturbance to residents are traffic noise and barking dogs. Other domestic noises also have a significant impact.
4. The most commonly reported causes of annoyance from individual motor vehicles are hotted-up cars and motorbikes.
5. Complaint is a poor indicator of community reaction to noise.
6. Noise reaction tends to decrease with increasing age, but to increase with education level.

The present survey provides for the first time, a national perspective on the environmental noise problem in Australia. The results should be considered by regulatory authorities in deciding their future priorities for noise control. This study should be repeated in three years time and the results compared with the present baseline data to assess changes in the community impact of noise and to monitor the effectiveness of national noise control strategies.

NOTE:

The views expressed in this paper are those of the authors and do not necessarily represent those of the Australian Environment Council.

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SYDNEY AMBIENT NOISE STUDY

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ABSTRACT

Community noise management requires facts for the effective performance of its roles of planning, organising, directing and controlling programmes and initiatives.The aim of the Sydney Ambient Noise Study (SANS) is to provide such facts and answers to the following questions:

1) What is the present noise "climate"?

2) Are noise levels increasing?

3) If there is an increase, what are the likely causes?

The SANS consists of remote moniterings at residential sites.A-weighted percentiles and L_{eq}'s are recorded and statistically processed.The long term averages are obtained for the day, evening and night periods for the various site categories.Background frequency spectra were also obtained.

This paper describes the monitoring and analysis systems, as well as the results of the study.

1.0 INTRODUCTION

The Sydney Ambient Noise Study was commenced in 1979. The programme was suspended shortly afterwards to await the arrival of more efficient equipment (a digital cassette recorder - B & K. 7400). The decision to recommence the study was made in July 1984. The first step in recommencing the study was to remonitor the original 1979 sites to see if there were any changes.Data from 6 sites was reported in 1979, representing a total of 222 hours of monitoring. Four sites were remonitored for a total of 473 hours in 1984.

2.0 METHODOLOGY

Briefly each site was chosen to be definitely an R2 area,which is one with low density transportation.The following Bruel & Kjaer measurement chain housed in a modified box trailer was used for the monitoring.The microphone assembly consisted of a 4165 microphone connected to a 2619 preamplifier and surmounted by a UA0393 rain cover as well as a UA0570 wind "sock" with bird spike.This fed into a 4426 Noise Level Analyser which transfered its statistics every 15 minutes into a 7400 Digital Casette Recorder.A 2312 Printer was connected to this system as a check.

Analysis was performed by replaying the 7400 into a HP9845 computer for a hard copy, statistical analysis or into a 2131 Real Time Analyser and then the HP9845 for frequency analysis.The microphone was 1.2m above the ground and in approximately the mid-front yard.It was at least 3m from the nearest reflecting surface .The kerb to microphone distance varied with each site.

The system used in 1984 was esentially the same as in 1979.The only differences were that the rain cover,bird spike and the 7400 were not used.The microphone axis was horizontal and the data was recorded every 20 minutes by the Printer in 1979.This data was typed into the HP9845 for processing.

3.0 RESULTS

3.1 Measurement Time Interval Results A-weighted ambient noise levels, were sampled each tenth of a second for about 14 $^1/_2$ minutes (the measurement time interval). Then these were analysed statistically. The L_1, L_5, L_{10}, L_{50}, L_{90}, L_{95} and L_{99} percentiles as well as L_{eq} were recorded on the B&k 7400 on the hour and every 15 minutes thereafter. These levels are ascribed to the whole 15 minute interval (print interval).The corresponding weekly - graphs for L_5, L_{10}, L_{90}, and L_{95} percentiles as well as L_{eq} were drawn to see the trends and patterns.

3.2 Reference Time Intervals Results The percentile and L_{eq} levels corresponding to the 15 minutes print intervals for each site were averaged arithmetically over 3 separate periods (reference time intervals) for each day of monitoring. The periods were; daytime (7am - 6pm), evening (6pm - 10pm) and night (10pm - 7am).

3.3 Long Term Site Average Values for the long term average percentiles (dB(A))and L_{eq} averages for each site were obtained by averaging each of the daytime, evening and night averages (reference time interval results) over the number of days monitored.Further averaging of these figures over the R2 sites gave the LONG TERM AVERAGE R2 values.These are presented below in Table 1.The corresponding cumulative distribution curves are in figure 1.They give an environmental noise profile of R2 areas.

Table 1. The Long Term Average Percentiles for the 1984 R2 sites for the day, evening and night periods.

LONG TERM AVERAGE PERCENTILES dB(A)								
Site	L_{01}	L_{05}	L_{10}	L_{50}	L_{90}	L_{95}	L_{99}	L_{Aeq}
	Daytime (0700 - 1800 hrs)							
20012	62.4	56.6	53.5	45.5	41.9	41.2	40.2	52.4
20013	64.7	58.1	53.8	43.4	39.2	38.5	37.4	52.8
20015	60.7	52.8	49.0	41.6	39.1	38.6	37.9	49.7
20018	59.8	53.9	50.4	43.2	39.4	38.6	37.5	49.1
Average R2	61.9	55.4	51.7	43.4	39.9	39.2	38.3	51.0
STANDARD DEVIATION	2.2	2.4	2.4	1.6	1.34	1.3	1.3	1.9
	Evening (1800 - 2200 hrs)							
20012	53.5	48.2	45.4	40.4	38.0	37.5	36.8	45.2
20013	64.4	56.9	52.1	42.4	39.4	38.9	38.2	52.4
20015	48.4	44.0	41.9	37.9	36.1	35.7	35.0	40.9
20018	54.9	48.0	44.5	36.6	33.9	33.3	32.4	43.8
R2 Average	55.3	49.3	46.0	39.3.	36.8	36.3	35.6	45.6
STANDARD DEVIATION	6.7	5.4	4.3	2.6	2.4	2.4	2.5	4.9
	Night (2200 - 0700 hrs)							
20012	47.6	43.5	41.7	37.4	35.0	34.5	33.8	40.2
20013	52.9	44.9	41.5	36.2	34.3	33.9	33.3	43.3
20015	43.3	39.8	38.4	35.5	33.7	33.4	32.7	37.1
20018	43.8	39.7	37.4	31.9	29.6	29.2	28.6	35.5
R2 Average	46.9	42.0	39.8	35.3	33.2	32.8	32.1	39.0
STANDARD DEVIATION	4.4	2.6	2.2	2.4	2.4	2.4	2.4	3.5

3.4 Daytime Background Spectra Daytime (0700-1800) tape recordings were made at each 1984 site and then frequency analysed in the laboratory. Averaging these over the sites (4), the unsmoothed average daytime R2 background frequency spectrum, shown in figure 2, was obtained.

3.5 1979 Results Table 2 summarises the previous (1979) R2 results. It is included so that a comparison with 1984 data can be made.

Table 2. The 1979 Long Term site and R2 averages for each of the reference time intervals (day, evening and night).

MONITORING SITES 1979		NOISE LEVEL DB(A)					
		7 am - 6 pm		6 pm - 10 pm		10 pm - 7 am	
NO.	Address	L90	Leq	L90	Leq	L90	Leq
2006	9 Burns Street Marsfield	37.3	45.4	46.1 44.2	49.7 49.1	33.6 37.6	37.3 41.5
20012	53 Melaleuca Drive	38.5	45.2	44.2 39.6	50.1 42.9	40.6 32.9	45.0 37.1
20013	6 Devon St Epping North	38.0	50.2	39.5 37.9	54.2 53.2	32.5 31.4	47.5 44.7
20015	24 Byora Crescent	37.1	50.3	36.2 35.3	49.2 47.8	30.8 29.7	39.8 35.8
20017	184 Ewos Parade Cronulla	32.0	47.1	35.3	45.7	33.4	38.7
20018	12 Government Road Mona Vale	35.0	45.4	40.9 41.8	45.1 45.6	30.1 34.5	37.8 39.7
Average 6 sites		36.3	47.3	39.6	48.2	33.3	40.4
Standard deviation		2.4	2.4	4.0	3.4	3.1	3.6

4.0 DISCUSSION OF RESULTS

4.1 Comparison of '79 with '84 data Two parameters, viz. L_{90} and L_{eq}, were used in comparing the '79 with the '84 noise monitoring data. The L_{90} and L_{eq} are measures of background and ambient (background and foreground) noise respectively. The 1979 L_{eq}'s were averaged arithmetically and for comparison purposes so were the 1984 L_{eq}'s. The Australian Standard AS1055 - 1984 however, recommends logarithmic averaging for L_{eq}'s and these are given in table 3(a) for future comparisons.

Table 3(b) compares the average 1984 and 1979 L_{90}'s and L_{eq}'s. The averages were over 4 1984 sites and 6 1979 sites. There is one set of values for each of the three reference time intervals.

Table 3(a) - The 1984 L_{eq}'s for each site averaged logarithmically for the day, evening and night periods.

Site	Log-Averaged L_{eq} dB(A)		
	DAYTIME	EVENING	NIGHT
20012	57.1	51.1	46.7dB
20013	53.9	54.1	47.7
20015	53.4	44.1	46.7
20017	52.2	45.6	42.4
Average R2	54.6	50.5	46.3

Table 3(b)- Comparison of the 1984 average (4 sites) L_{90} and L_{eq}'s with the 1979 average (6 sites).

Reference Time Period	L_{A90}			L_{Aeq}		
	1984	1979	Diff	1984	1979	Diff
day	39.9	36.3	3.6	51.0	47.3	3.7
evening	36.9	39.6	-2.7	45.6	48.2	-2.6
night	33.2	33.4	-0.2	39.0	40.4	-1.4

The Student's t distribution was used to determine if these differences were significant at the 95% level of confidence.The daytime L_{90} increase over the period 1979-84 was statistically significant.Although the decrease in evening and night noise levels

CUMULATIVE DISTRIBUTION GRAPH

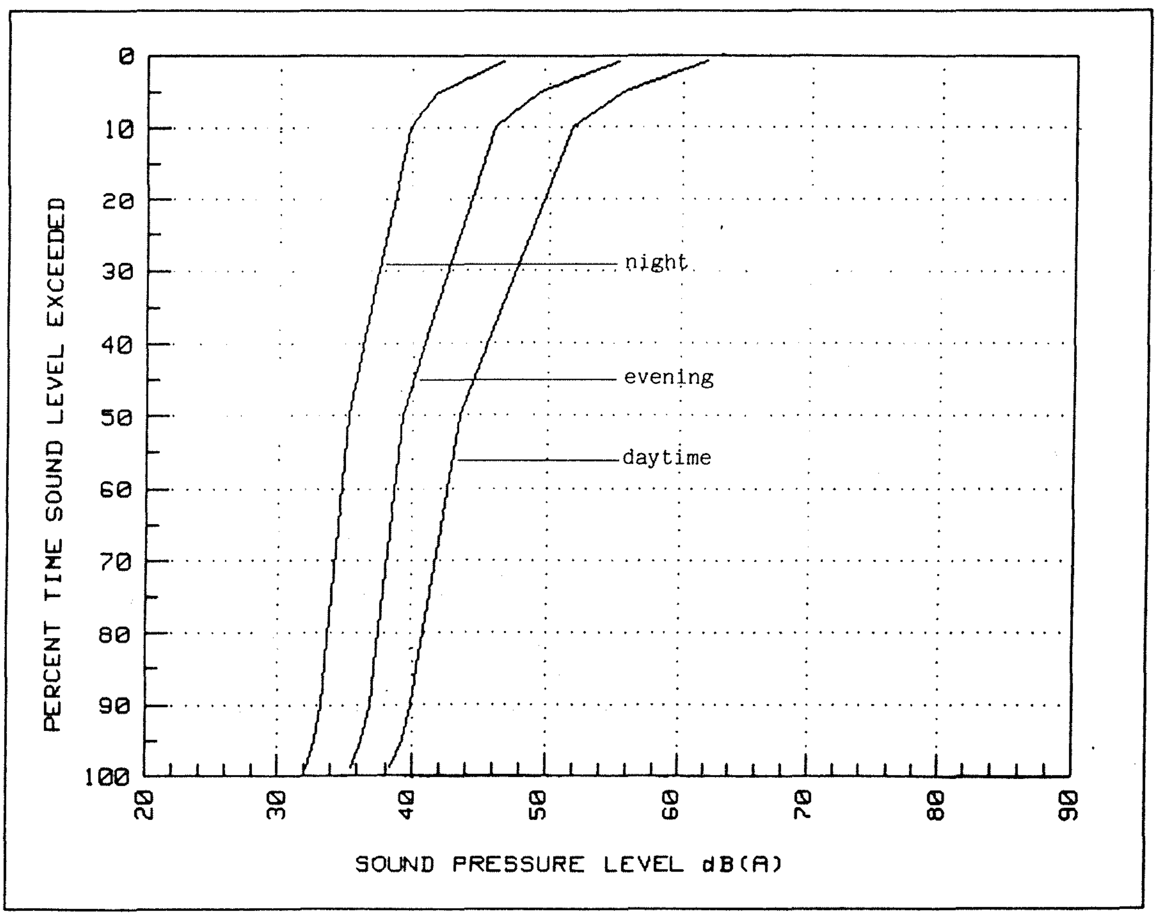

Figure 1. The Long Term average R2 cumulative distribution curves for the night, evening and daytime.

over the period 1979-1984 was not statistically significant, it may be a trend masked by the variability of the data. This suspected trend may be confirmed by increasing the number of sites and reducing the variability (standard deviation) by deleting weather affected data. There appears to be no single dominant cause for the increase in daytime background levels.

4.2 Further Comments on the Study. The remote monitoring of this study (1979 and 1984) was performed sometimes under non ideal weather conditions.Some of the data suspected of being weather affected was included in the average calculations.Exclusion of the suspected data would have reduced the average levels and variability somewhat.

ONE THIRD OCTAVE BAND SPECTRUM ANALYSIS

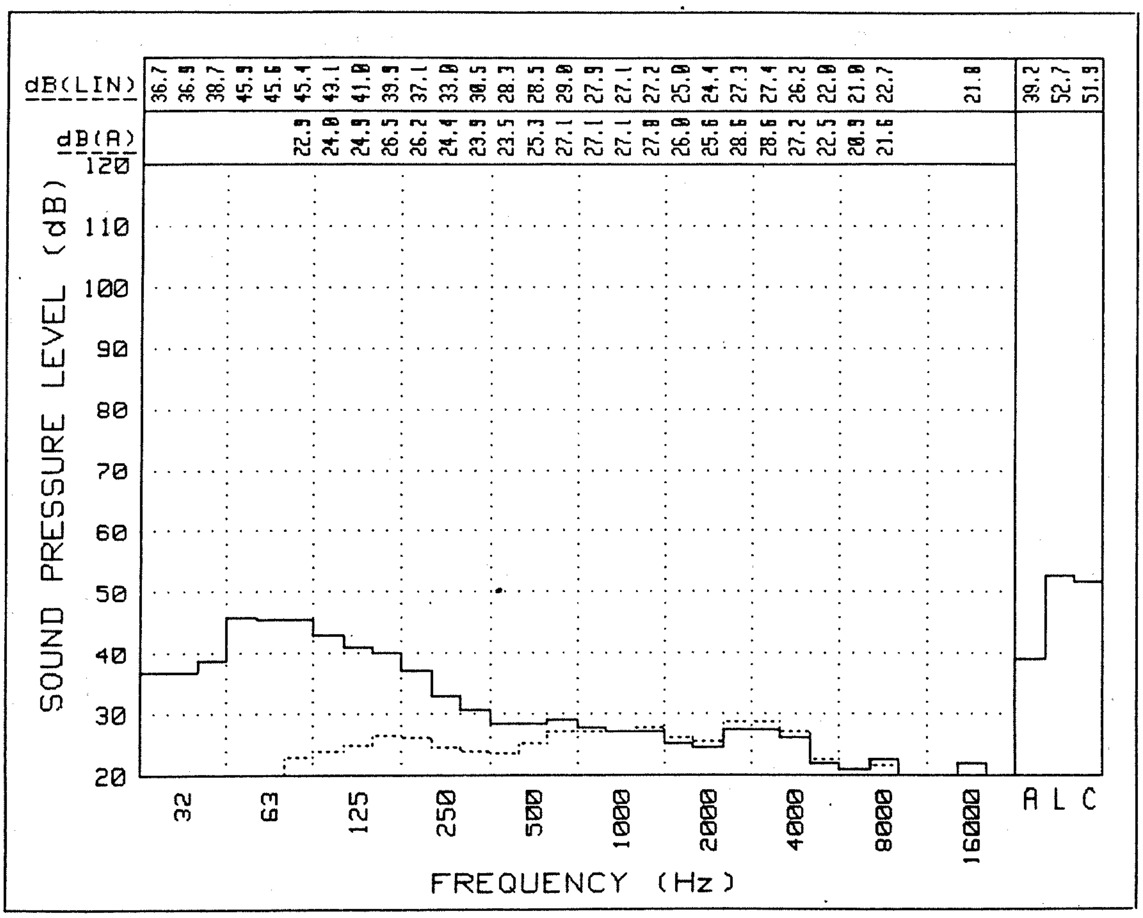

Figure 2. Shows the average daytime background frequency spectrum. (1984)

The weather (wind speed, %R.H. and rain) should be monitored simultaneously with the noise so as to reject and possibly correct for weather adversely affected data and so increase reliability of the data.This would decrease the variability (standard deviation).

More tape recordings should be made simultaneously with the remote monitoring so as to check the remote monitoring integrity and to get valuable spectral data during the day,evening and night periods.

If these trends are confirmed by further monitoring in the Rl to R6 area categories (now in progress) then the question remains what is causing these changes and what should be done about it? Although traffic noise is a factor in the daytime increase, preliminary analysis indicates that it is not the major cause.Other possible factors are the changing attitudes and lifestyles of people and the changes in the manufacturing industry.

5.0 CONCLUSIONS

5.1 The long term average R2 daytime background level (L_{A90}) of the sites monitored increased over the period 1979 - 1984 by a statistically significant (at 95% level of confidence) 3.6 dB(A).

5.2 There may be a trend of decreasing evening and night levels in these R2 areas even though the changes are statistically not significant.

5.3 The value for the R2 long term average L_{A90}, a measure of background noise level, was found to be 39.9, 36.8 and 33.2 dB(A) for the daytime, evening and night periods respectively. The corresponding standard deviations were 1.3, 2.4 and 2.4 dB(A).

5.4 The value for the R2 long term average L_{Aeq} (a measure of the total noise energy) was found to be 54.6, 50.5 and 46.3 dB(A) for the daytime, evening and night periods (log averaged).

5.6 The values obtained for the R2 daytime background spectrum are shown below:-

LIN CWT AWT	CENTRE FREQUENCY									
	32	63	125	250	500	1K	2K	4K	8K	16K
52.7	36.7	45.9	43.1	37.1	28.3	27.9	25.0	27.4	21.0	19.0
51.9	36.9	45.6	41.0	33.0	28.5	27.1	24.4	26.2	22.7	21.8
39.2	38.7	45.4	39.9	30.5	29.0	27.2	27.3	22.0	19.0	19.0

The top, middle and bottom rows correspond to the lower, middle and upper 1/3 octaves of the respective octave bands.

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TOOWOOMBA NOISE SURVEY - A FIRST APPRAISAL

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ABSTRACT

A survey of background and ambient noise levels was undertaken in Toowoomba for the purpose of producing noise contours of the city. Ten minute day-time samples were taken twice at each of 500 locations.

An initial analysis of the data according to land use is described and it is suggested that the L_{90} data is a reliable basis for future land use decisions.

Following completion of the survey, inner city traffic was re-routed to a ring road system. A re-survey of the affected area was inconclusive in assessing the effect on the central city noise climate.

1.0 INTRODUCTION

The literature reports the results of noise surveys conducted in urbanised communities for many and varied reasons. Mostly, the purposes have been to monitor changes in noise over time (1) and to establish the major noise sources in communities (2-4).

From April to July, 1985, a survey was carried out in Toowoomba in order to produce L_{90} and L_{eq} noise contour maps for one of Queensland's larger regional cities.

2.0 AIMS OF SURVEY

The primary aim of the survey was to produce daytime noise contours reflecting L_{90} and L_{eq} noise levels for the city of Toowoomba and subsequently, to use the maps as part of a Quiet Community Promotion.

A second aim of the survey was to establish the variation, for both the L_{90} and L_{eq} parameters, in the spatial samples in different land use areas and to plot their distributions.

An attempt was also made to assess the change in noise climate in the Central Business District following the introduction of a ring road system to keep heavy vehicles away from the inner city.

3.0 SURVEY DESIGN

3.1 General

The Survey was designed to describe the general noise climate over a large area (89 sq km) using a large number of sampling points and restricting the measurements to short time periods during the day, rather than a detailed analysis of measurements over extended daily time periods at only a few locations.

3.2 Timing

Because of generally favourable weather conditions in Toowoomba from April through to July, the Survey was conducted during this four month period.

3.3 Spatial Sampling

A grid of approximately 500 sampling points was plotted on a map of the city using a 364 m interval. This grid size was convenient because it placed the majority of monitoring sites along roads, thereby enabling quick access to most locations, as well as meeting the human and financial resources of the survey.

It was assumed that the 364 m interval gave statistically independent spatial samples.

3.4 Temporal Sampling

The noise climate at each location was monitored twice, once in the morning and once in the afternoon, for a period of 10 minutes each. The contours were plotted from the arithmetic mean of the two samples taken at each grid point.

Sampling was confined to daytime between 9.00 am and 12.00 noon and 2.00 pm to 4.00 pm Monday to Friday inclusive. At least 5 hours sampling time was needed to enable in the order of 20 sites per day to be monitored.

Two further sets of ten minute samples were taken at a later date at 25 central city sites following re-routing of heavy vehicles to a ring road system.

3.5 Noise Descriptors

The L_{90} and L_{eq} noise descriptors were used to represent background and average noise levels respectively during the day. Traffic noise is the major community noise source in Toowoomba and this was reflected in the L_{eq} contours.

3.6 Weather Constraints

Sampling was not carried out in wind velocities greater than 15 km per hour nor during other adverse weather conditions.

4.0 METHOD

4.1 Instrumentation

Bruel and Kjaer 2230 sound level meters were used. Calibrations were carried out prior to each set of sampling periods.

4.2 Microphone Location

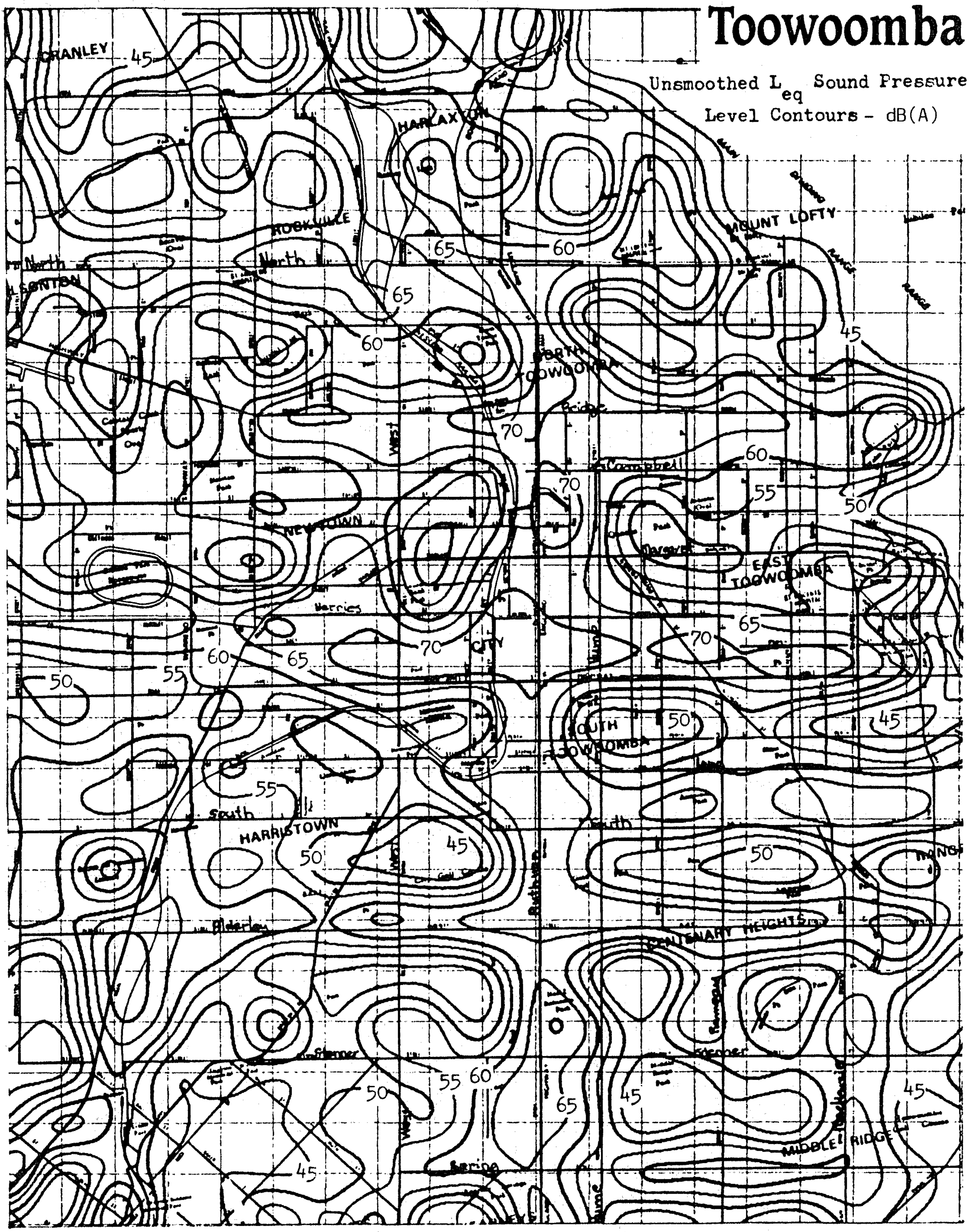
The microphone was placed as close as practicable to the exact grid point with the exception of locations along thoroughfares. To ensure a consistent effect of traffic noise on the L_{eq}, readings were taken on the footpath at a fixed setback distance of 6m from the centre of the nearest traffic lane. Care was taken to ensure that the meter was not shielded from approaching traffic noise.

4.3 Processing of Data

The raw data was processed using a bicubic spline interpolation programme to fit 5 dB(A) interval contours exactly to the values obtained for both L_{90} and L_{eq} noise levels. These are reproduced in Figures 1 and 2. In both cases, it was found that smoothing the results produced less complex contours for the public relations exercise for which they were primarily produced.

Figure 1: L_{90} Contours Imposed on Street Map of Toowoomba (Smoothed) - dB(A)

Figure 2: L_{eq} Contours Imposed on Street Map of Toowoomba (Unsmoothed)



5.0 ANALYSIS

5.1 Analysis of Spatial Samples According to Land Use

The sampling grid was overlain on a zoning map of Toowoomba and a simple analysis of the spatial samples according to the three main land uses was undertaken. The distributions of the grid values for each land use are shown in Figure 3 and a summary of the mean and standard deviation values for the same land uses is contained in Table 1.

Figure 3: Distributions of L_{90} and L_{eq} Noise Levels According to Land Use

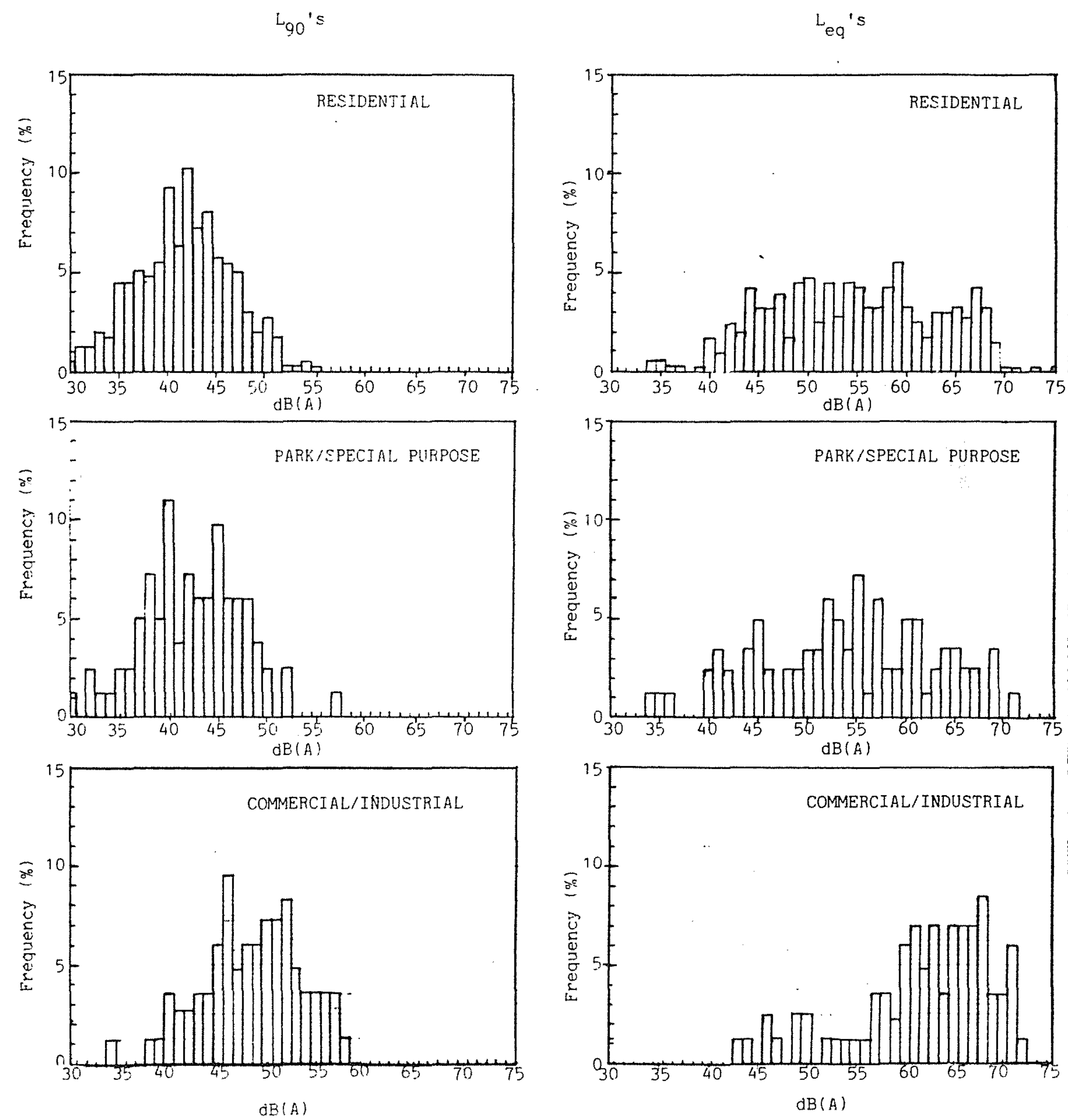


Table 1 (a): L_{90} Data for Various Land Uses

Zone	No. of Samples	X	s
Residential	332	41.95	4.88
Commercial/Industrial	82	49.27	5.7
Park/Special Purpose	82	42.57	5.13

Table 1(b): L_{eq} Data for Various Land Uses

Zone	No. of Samples	X	s
Residential	332	55.1	8.53
Commercial/Industrial	82	62.43	6.9
Park/Special Purpose	82	54.5	8.7

It is suggested that the high variation (standard deviation) in all zones for the L_{eq} parameter is due to two factors namely, too short a temporal sampling period and very variable traffic flow.

5.2 Analysis of Temporal Sampling

The accuracy of the temporal sampling employed was tested using data from 10 x 10 minute replications at 5 randomly chosen sites. Ninety five % confidence intervals were calculated and, for the L_{90} values, all of the 2 x 10 minute means fell within these limits, whereas less than 50% of the L_{eq} values met this degree of accuracy. This tends to indicate that longer sampling periods would be required for L_{eq} data if the same level of accuracy was desired. Error in short-term sampling of L_{eq} is well documented (5).

5.3 Analysis of Inner City Repeat Survey

The new traffic management system for the inner city area affected a relatively small area (12 points) on the sampling grid. The grid points immediately outside the ring road path were also monitored in an attempt to see if the re-routing had spread the noise.

A re-plot of L_{eq} contours showed a very small shift outwards in an easterly direction of the 65 dB(A) contour. From observation, this shift resulted from the re-direction of heavy vehicles down Hume Street, a main North-South thoroughfare to the east of

Ruthven Street, the main central city street.

A students t-test analysis of the Ruthven Street data indicated that the change in L_{eq} levels was insignificant at the 95% confidence level.

The results tend to indicate that the noise climate in the central city was not significantly reduced by the introduction of the ring road system. However, as mentioned elsewhere in this report, the short temporal sampling may have affected the results.

CONCLUSION

The spatial and temporal sampling undertaken gave reliable data for L_{90} values and the contours should provide a useful foundation for future planning and administrative decisions related to noise control in Toowoomba.

Accuracy of the L_{eq} data would have been improved by longer temporal sampling. However, the 5 dB(A) contour interval disguised the error to some extent. The L_{eq} contours reflect major traffic routes, there being few other widespread noise sources in the city.

Re-routing the inner city traffic created slight outward shift of the 65 dB(A)L_{eq} contour. The effect on the inner city noise climate was inconclusive due to the short term temporal sampling designed into the original survey.

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TOWN PLANNING RESPONSES TO COMMUNITY NOISE PROBLEMS

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ABSTRACT

Town planning and community noise share common ground. Neither is a precise science, although aspects are based on quantitative analysis. Controls, of necessity, rely on measurable standards. Both are subjective topics and matters of opinion and varying perceptions.

Town planning experience of noise problems suggests that most complaints arise from impacts on residential amenity. Problem noises are usually intrusive in nature and their impact proportional to the contrast with background levels.

Town planning techniques used to minimise adverse effects of community noise include:

- Separation by zoning;
- Development control measures;
- Objection and appeal provisions;
- Strategic planning;
- Traffic and subdivision planning; and
- Consideration of regional architectural styles.

Town planning cannot prevent community noise conflicts. But it does provide a framework to minimise impacts. More importantly it provides mechanisms for the community to participate in establishing and maintaining standards.

1.0 INTRODUCTION

Town planning and community noise share significant areas of common ground. It's not just that both are considered a necessary evil, a product of our progressively more complex and intense society. It's not just that both are, on occasion, regarded by some as outright nuisances.

Town planning is not a precise science although many aspects are based on quantitative analysis, and many controls, of necessity, rely on measurable normative standards. Similarly community noise is subject to personal interpretation and opinion although characteristics of the noise can be scientifically measured and established standards are expressed in measurable terms.

Both planning success and community noise are matters of "perception." Canberra's physical planning form is praised by some for its academic clarity and visual order. Others, while conceding that it is well laid out, wonder aloud what it died from.

This range of perceptions can be compared with the reactions to the practising of bagpipes in the stillness of a Sunday morning. The skirl of pipes never fails to thrill the Scottish blood in some veins nor to curdle the blood in others who suspect someone's cat is being strangled.

The perception of community noise can also evolve through time and familiarity. For example, people living near train lines generally become used to the train noise over time.

2.0 TYPES OF PROBLEMS EXPERIENCED

In my town planning experience, the most commonly perceived community noise problems involve:

1. Traffic noise
2. Barkings dogs, especially in kennels
3. Panel beaters
4. Squash courts
5. Amplified sound
6. Trail bikes, and
7. Quarry blasting.

Problems most often arise when these noise sources impinge on a residential area. The complaint is invariably that the noise has an adverse effect on the enjoyment of residential amenity.

The common element in all these situations seems to be the intrusive nature of the sounds. The perceived impact is related to the degree of contrast with background levels. Many people would be quite surprised at the measurably high sound levels they will happily tolerate in some situations in comparison to the relatively low measurable level of noises that are considered to be causing nuisance in other situations.

For example, the general hum of the continuous flow of traffic is often less annoying than the intrusive noise of individual vehicles imposed upon low background noise levels.

3.0 TOWN PLANNING TECHNIQUES

How can we develop a town planning approach and what techniques do we have at our disposal?

3.1 Separation by Zoning

The classic and still useful approach is that of separation of incompatible uses by zoning.

Generally, industrial zonings which can encourage noisy uses, are located well away from residential areas. But compromises are often made. It is desirable for convenience and safety to locate primary schools within predominantly residential areas but have you ever heard (or measured) the sound levels from a primary school at lunchtime or 3.00 pm?

3.2 Development Control Measures

Development control measures can be applied in respect of uses which require the consent of the local authority for their establishment. Each such application is considered on its merits and, if it seems likely that the use proposed will create a noise nuisance affecting its neighbours, the application can be refused on that ground.

Where there is some argument or doubt as to whether the use may or may not create a nuisance, conditions may be imposed to minimise the potential for adverse effect. Such conditions could specify maximum noise levels as measured in specific locations. Such a condition may be difficult to effectively monitor and police. Or the conditions could prescribe specific architectural or landscape treatments such as the provision of solid masonry walls, earthen berms, minimum distance separations and the like.

3.3 Objection and Appeal Provisions

Applications for establishing potentially noisy uses by either rezoning or consent are subject to objection and appeal provisions. If a potentially affected party feels the proposed use will harm the enjoyment of his own property, he can object to the application and submit to the local authority the reasons, including noise nuisance, why the application should be refused. If, in the face of such objection, the local authority does approve it, the objector can appeal to the Local Government Court. The Court will then decide and may refuse the application or impose further conditions to reduce the likely adverse effects.

3.4 Strategic Planning

Strategic planning can go a long way toward minimising noise nuisance conflicts in that it requires local authorities to think through "their planning goals and objectives". The Strategic Plan, and similarly the Development Control Plan, identifies a pattern of preferred dominant land uses for each part of the area as well as indicating the intended transport routes. In structuring these plans the planner endeavours to separate the categories of preferred uses such as industries from the categories such as residential which are most likely to be sensitive to noise nuisance.

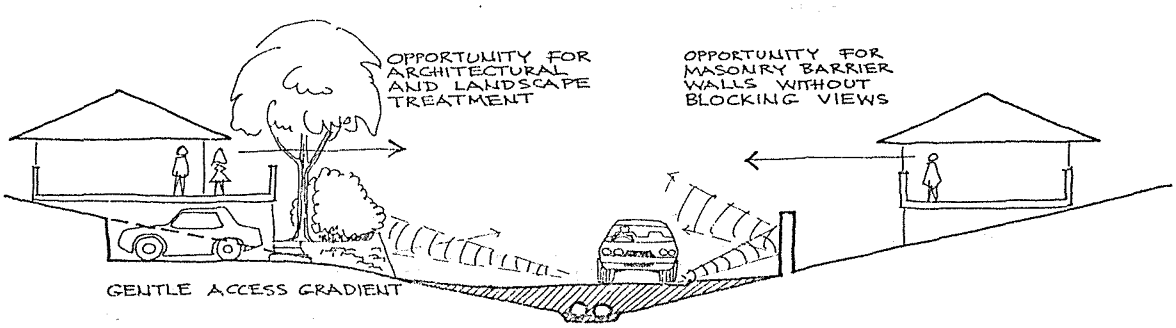
In administering a Strategic Plan, the local authority decides which uses are consistent with and necessary for the full enjoyment of the preferred dominant use and will decide applications accordingly. Such a plan helps the developer proceed with confidence. If he is proposing a potentially noisy activity, he knows in what location he will likely gain approval and in which he will not be considered a nuisance. On the other hand, a developer proposing a use sensitive to noise nuisance can identify areas unlikely to be affected.

3.5 Traffic Planning

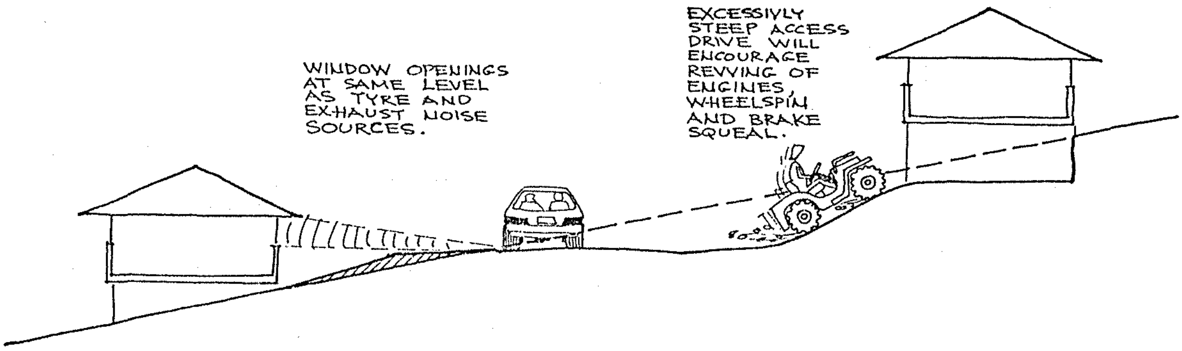
The principle most commonly applied to minimise the impact of traffic noise is encouragement of the use of arterial roads for through traffic and heavy transport rather than dispersing such traffic through local streets. Arterial roads can be routed away from sensitive areas and can often utilise design techniques such as earth mounds or concrete barriers to minimise the noise impact.

Through traffic can be discouraged from traversing residential areas by making the streets curvilinear and discontinuous. This technique also tends to reduce operating speeds and thus lower noise levels. Subdivision design layouts can sometimes achieve lower noise impacts in other ways as well. In undulating or hilly terrain, it is often useful to locate the streets along depressions wherever practicable. As well as the other benefits of containing drainage within the road reserve and giving dwelling sites the more elevated positions, the technique can help reduce noise levels.

The gradient of the depression is usually less than that of running roads over spurs so vehicle operation is quieter. And keeping the vehicles below the level of the dwellings seems to reduce the noise impact on the residents.



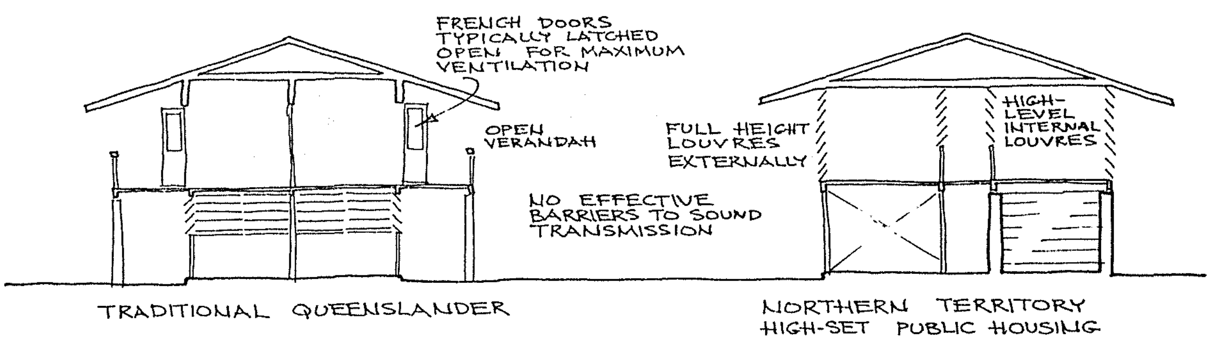
SUBDIVISION DESIGN WITH ROADWAYS IN DEPRESSIONS



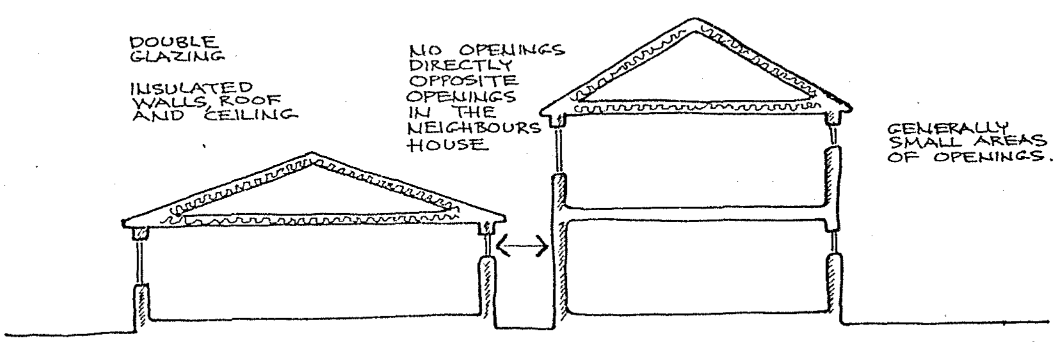
SUBDIVISION DESIGN WITH SIDELONG ROADS

3.6 Consideration of Regional Architectural Styles

While not strictly within the scope of town planning considerations, the impact of community noise will vary with different building styles and the planner should take this into account in determining minimum allotment sizes and building line setbacks. The open louvred style of non-airconditioned tropical home offers no barrier to the impact of noise. The insulated masonry cottages with double glazing in small windows more typical of the cooler climates offers, by contrast, a veritable fortress against noise intrusion. These differences can be reflected in the siting of dwellings and also in the relationship between residential areas and potential noise sources.



TROPICAL HOUSING STYLES



HOUSING FOR COLD CLIMATES - (OR AIR-CONDITIONING)

4.0 CONCLUSION

While town planning in itself cannot guarantee that community noise conflicts do not occur, it does provide a framework which can be used to help minimise the impact of potential conflict. Perhaps more importantly, it can provide mechanisms by which the community can express its feelings in specific cases and participate in establishing and maintaining standards appropriate to the particular local authority area.

VERIFICATION OF AN ENVIRONMENTAL NOISE MODEL USING COMPLAINT DATA

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ABSTRACT

Noise prediction technology is sometimes necessary not only to reduce the noise emission of individual machinery and equipment in the plant to ensure compliance with community noise regulations, but also to consider allocation of these machines within the plant area and construction of effective housing for noise control. Reliable prediction of the noise climate is of utmost importance for realising noise control measures at minimum expense.

A mathematical model programmed on a Sharp pocket computer Model PC 1401 has been developed to predict noise levels at various distances from a noise source for varying terrain and meteorological conditions. The model includes attenuation based on geometrical spreading, atmospheric absorption, ground effects, meteorological conditions and natural and man-made barriers.

A description will be given of the application of this model to three typical cases where allegedly excessive noise at the reception point has resulted in complaints being lodged with the Division of Noise Abatement and Air Pollution Control, Queensland.

1.0 INTRODUCTION

Noise emissions forecasting is particularly valuable in the planning of large plants or commercial buildings in which a multitude of sound sources may contribute to the total sound pressure level measured at the property line or in nearby residential neighbourhoods. By considering separately the discrete sources of noise, the effect of selected sound abatement measures can be quickly determined and, if required, be incorporated into original plans and specifications. In the case of a large number of sound sources, calculations of sound pressure levels at the receiving points can be extensive, and is best done with the aid of a computer.

A mathematical model has been developed and programmed on a Sharp pocket computer Model PC 1401 which enables noise levels to be predicted for distances greater than 100 metres away from discrete noise sources for varying terrain and a range of meteorological conditions. Consideration has been given to basic concepts of attenuation based on geometrical spreading, atmospheric absorption, ground effects, meteorological conditions and natural and artificial barriers.

A number of complaints concerning allegedly offensive noise from commercial and industrial premises have been lodged with the Division of Noise Abatement and Air Pollution Control over a period of 8 years. The opportunity was taken to compare predicted noise levels using the model with actual measured data obtained for three typical cases:

- Wood dust extraction cyclones
- Live amplified music at an outdoor entertainment venue
- A concrete block-making machine.

2.0 METHOD

2.1 Measurement Procedure. The three examples chosen have been investigated by the Division over a period of time and under varying meteorological conditions. Complaints associated with the noise sources were in all cases considered justified by the Division. Most noise assessments included detailed statistical data and in many cases 1/3 octave band spectra recorded at the property line of complainants was available. These measurements were supplemented by additional data taken close to predominant noise sources (within 30 m) or directly outside enclosures.

Weather data (temperature, humidity, wind speed and direction) was obtained from observations on site or from the Capital City Series "The Climate of Brisbane, Queensland" published by the Bureau of Meteorology. In some cases complaints of intrusive noise only arose under worst case conditions (temperature inversions or downwind propagation) and predicted noise levels were adjusted accordingly. Topography for the three study areas was taken from 1:10 000 Orthophoto maps usually with contour intervals of 5 m.

2.2 Measurement Sites. The first case examined was that of a timber manufacturing plant approximately 25 kilometres south west of Brisbane. Complaints were registered up to 1 300 m from the noise source, a wood dust extraction cyclone 15 m above ground level, under temperature inversion conditions.

In the second case predicted noise levels were compared with measured levels from live amplified music at an outdoor entertainment venue 15 kilometres west-south-west of Brisbane. An initial prediction was based on sound pressure levels measured 10 m from two loudspeakers while a jazz band played "Pennies from Heaven". The feasibility of introducing live amplified "modern music" at the venue was also investigated by using "Love is the Drug" by Roxy Music as the source signal.

The third case examined was that of a concrete block-making machine sited inside an inferior acoustic enclosure approximately 95 kilometres north of Brisbane.

3.0 RESULTS

A-weighted octave band sound pressure level data for the various noise sources considered and used as input to the model are presented in Table 1.

Table 1: Input noise data for sources

Noise Source	Distance from source (m)	A-weighted Octave Band Sound Pressure Levels (dB) at Mid-frequencies (Hz)					
		125	250	500	1K	2K	4K
Dust extraction cyclones	193	59	45	43	42	45	38
Jazz Band	10	82	90	87	87	89	93
"Modern Music"	1	90	99	113	114	119	116
Concrete Block-making machine (inside enclosure)	-	97	97	104	103	102	99

Measured and predicted values of overall dB(A) levels at complainants' premises under meteorological conditions experienced at the time of complaint are presented in Table 2.

Table 2: Noise data at complainants' premises

Noise Source	Approximate distance to complainants' premises (m)	Meteorological* Conditions	Overall dB(A)	
			Measured	Predicted
Dust extraction cyclones	940	Temperature inversion 14°C, 65%, calm	46	46
	1 300	Temperature inversion 7°C, 68%, calm	51	49
Jazz band	510	23°C, 46%, 2.8 ms^{-1} N.E.	57	55
Modern Music	510	22°C, 76%, 3.3 ms^{-1} S (downwind)	-	74
Concrete Block-making machine	100	24°C, 75%, calm	62	60
	180	20°C, 60%, calm	58	54

* Meteorological conditions are presented in the order: Temperature (°C), Relative humidity (%), wind speed ms^{-1} and direction.

4.0 DISCUSSION AND CONCLUSIONS

The three situations were selected so that the predicted noise levels related to average or common unfavourable conditions. The majority of predictions (4 out of 5 points) are within 2 dB(A) of the measured levels. This suggests that the procedure adopted for predicting noise is broadly correct. Further attenuation studies using synthetic noise sources are probably required to verify the model. This would have to be done over a period of time so as to cover a representative range of meteorological conditions.

The model does not permit a precise prediction of annoyance or complaint risk but it does give an indication. Calculated and measured neighbourhood noise levels can be correlated in terms of octave band and A-weighted levels. An added advantage is that the program can be run in the field for assessing the environmental noise impact of discrete noise sources in a new plant or the expansion of existing plant at the design stage, thereby enabling the most cost-effective solution to excessive acoustic emission to be obtained.

5.0 ACKNOWLEDGEMENTS

Permission to publish this paper has kindly been given by the Director, The Division of Noise Abatement and Air Pollution Control, Brisbane.

The long hours spent by officers and inspectors of the Division in investigating these complaints, sometimes in the early hours of the morning, is appreciated and permitted the preparation of this paper.

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CONTROL OF NOISE THROUGH THE APPLICATION OF TOWN PLANNING PERFORMANCE STANDARDS

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ABSTRACT

Recently in New Zealand there has been criticism on the inconsistency of local authority ordinances set down under District Planning Schemes to "control" noise from various land uses.

The major type of land use put under control, at least to the extent of setting performance standards in terms of permitted sound levels is industrial, rather than residential or commercial.

It will be argued, that decisions of Planning Tribunals in regard to noise performance standards could also be seen as inconsistent. It will be shown that these problems of inconsistency may arise from definitional uncertainty as to what is "noise" in the particular legislation, and whether in technical terms any such definitions are suitable to control "noise" in the real world. Other problems may be the difficulty of understanding the content of some standards relating to noise; the adversary system and the use of opposing experts in legal tribunals; and perhaps the paucity of evidence as to acceptable levels of sound. A limited survey, undertaken over several years, of sound levels in industrial areas is presented and the extent of the problem examined.

1.0 INTRODUCTION

In New Zealand, district planning is undertaken under the provisions of the Town and Country Planning Act 1977 and every local authority is required to produce district schemes as a basis for planning its area. These schemes have the purposes of providing direction and control of the development of the district in such a way as to promote and safeguard the health, safety and convenience of the people and amenities of the district. Each district scheme must include provisions to bring into effect a number of matters contained in a schedule to the Act. These include, specifically, provisions related to noise such as;

> "the design and arrangement of land uses and building, including ... the provision of insulation from internally or externally generated noise."
>
> and;
>
> " the avoidance or reduction of...nuisance caused by...the emission of noise..." (Statutes of New Zealand, 1977)

Some earlier district planning schemes had introduced noise standards under the provisions of the previous 1953 Act and these were supported on judicial appeal (Williams, D.A.R.,1980). The 1977 act with its explicit requirements led to an increased number of schemes including such noise performance standards. Such standards do not apply to what are described as "existing uses" which are those uses established prior to the district scheme becoming operative. Provisions do exist to enable local authorities to require occupiers to keep objectionable elements, which includes noise, to a minimum. These powers are in addition to those contained in the Noise Control Act 1982. Notice must be served specifying either the cessation of the use, or the reduction by specified means, of the noise. Defences to action under this section have included evidence that the occupier has taken all reasonably practicable steps to prevent such noise. To decide what is reasonably practicable the courts have considered matters of cost and financial resources as well as practicality, and whether the use of the land is seriously interferred with.

The Planning Tribunal under the 1977 Act is a special judicial body with a role that is "appellate and judicial and to some extent inquisitorial" (Williams,B.,1985). It can hear and decide issues that are brought before it by appellants and there are no rights of appeal on planning matters, including noise standards, to the ordinary courts. It largely uses an adversary system with the calling of expert witnesses to provide evidence on both fact and opinion. It can therefore have an extremely important role in confirming or otherwise suggested noise performance standards contained in District Schemes and has done this in a number of cases. Such decisions can have the effect of changing noise performance standards for all industrial zones without adequate evidence being presented on existing, or possible, sound levels in such areas. As more local authorities introduce noise performance standards there has been criticism of their inconsistency, in comparison with other local authority standards, and a national standard is being sought. It appears not to be understood that actual sound levels occurring in any area vary considerably and the search for a fixed level everywhere may be too arbitary under present circumstances.

2.0 METHOD

Fourteen selected sound level monitoring sites were used to take 24 hour sound level measurements during the working week in the years of 1980, 1982, and 1985. The sites were chosen to give a good spread of representation of industrial areas in Christchurch City as well as their accessibility, lack of interference from specific other than industrial noise sources, and for the security of equipment. The original purpose of the survey was to assess whether noise level criteria specified in the District Planning Scheme for proposed industrial uses were being met in practice at existing industrial sites.

The noise level criteria contained in the District Planning Scheme are expressed in dBA L_{95} levels for the hours between 2400 to 0700 hours; 0800 to 1200 hours; 1200 to 1900 hours; 1900 to 2300 hours; and 2300 hours to 2400 hours. In the 1980 and 1982 surveys the noise level analyser was programmed to print out results at the end of each of these periods but in the 1985 survey hourly print-outs were made and the subsequent hourly figures averaged to provide results for each period as above.

All measurements were obtained by the use of a Bruel and Kjaer Type 4426 Noise level analyser wtih a Type 4165 ½ inch microphone coupled to a Type 2312 Alpha Numeric printer. Calibrations were carried out with a Type 4230 calibrator prior to, and following, the measurements being taken. The machine was programmed to measure and print-out the L_1; L_{10}; L_{95}; and L_{eq} values over the period.

The monitoring sites chosen were, as far as possible clear spaces with no nearby reflecting surfaces, and set back from the adjacent roadway to minimise as far as possible the influence of individual vehicles passing the site.

3.0 RESULTS

3.1 Mean Values for Fourteen Sites for the Period 1980 to 1985 The tables below set out the mean sound level, the standard deviation (s.d.) and the range of sound levels over the three years of sampling for each of the time periods and L_n values over the fourteen sites.

Table 1

L_1 Values for Means 1980 to 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	55.4	5.44	67.6 to 49.4
0700 to 1200 hours	65.8	4.80	72.8 to 61.0
1200 to 1900 hours	66.1	3.98	71.9 to 58.0
1900 to 2300 hours	59.1	5.24	68.2 to 54.6
2300 to 2400 hours	55.6	6.00	66.9 to 48.4

Table 2

L_{10} Values for Means 1980 to 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	47.6	3.75	54.6 - 41.1
0700 to 1200 hours	59.5	3.76	64.7 - 53.8
1200 to 1900 hours	59.1	3.60	63.9 - 53.4
1900 to 2300 hours	51.8	3.96	60.3 - 47.1
2300 to 2400 hours	47.8	4.05	56.7 - 42.6

Table 3

L_{95} Values for Means 1980 to 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	36.6	2.90	40.4 - 31.7
0700 to 1200 hours	49.9	2.35	54.3 - 46.6
1200 to 1900 hours	48.3	2.72	52.9 - 44.5
1900 to 2300 hours	41.8	2.14	44.7 - 37.2
2300 to 2400 hours	39.1	3.35	46.5 - 33.1

Table 4

Leq Values for Means 1980 to 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	47.6	5.29	60.2 - 39.0
0700 to 1200 hours	58.0	4.36	63.4 - 50.7
1200 to 1900 hours	57.5	4.26	63.5 - 51.3
1900 to 2300 hours	50.9	4.79	59.6 - 45.0
2300 to 2400 hours	46.9	5.02	55.8 - 40.4

It can be seen that considerable variation exists in measured sound levels over the five year period when the results are examined in this manner. It was decided therefore to undertake a similar analysis of the results of the fourteen sites for 1985 alone and these results are reported below.

Table 5

L_1 Values for 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	58.0	6.94	75.6 - 49.0
0700 to 1200 hours	67.7	5.15	77.0 - 61.8
1200 to 1900 hours	66.7	5.23	77.1 - 60.9
1900 to 2300 hours	61.4	6.48	74.4 - 53.7
2300 to 2400 hours	58.9	8.45	76.8 - 46.3

Table 6

L_{10} Values for 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	49.5	4.95	59.0 - 40.6
0700 to 1200 hours	61.7	3.86	66.9 - 58.0
1200 to 1900 hours	60.5	3.89	66.6 - 55.7
1900 to 2300 hours	54.0	5.49	64.7 - 47.0
2300 to 2400 hours	50.2	6.67	63.0 - 41.0

Table 7

L_{95} Values for 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	40.0	5.02	47.4 - 31.7
0700 to 1200 hours	51.6	2.34	56.8 - 46.6
1200 to 1900 hours	50.5	2.72	56.3 - 46.8
1900 to 2300 hours	43.4	3.63	49.4 - 37.2
2300 to 2400 hours	41.0	6.57	58.8 - 31.8

Table 8

Leq Values for 1985 - dBA

Time Period	Mean	s.d.	Range
2400 to 0700 hours	49.0	6.17	62.8 - 38.8
0700 to 1200 hours	59.6	3.79	65.9 - 54.5
1200 to 1900 hours	58.2	3.89	65.2 - 54.4
1900 to 2300 hours	52.6	5.70	62.3 - 44.4
2300 to 2400 hours	49.4	7.33	61.2 - 38.7

4.0 DISCUSSION

The results of the sound level surveys reveal there is a great degree of variation in sound levels measured at different industrial sites, without, it must be stressed, any apparent industrial sources providing for such variation. The standards in the Christchurch City scheme for industrial sites are set out below.

Table 9

Sound level Criteria - Christchurch City District Scheme

Time Period	dBA L_{95} Monday to Friday	Saturday	Sundays and Public Holidays
2400 to 0700	40	40	40
0700 to 1200	55	55	40
1200 to 1900	55	40	40
1900 to 2300	45	40	40
2300 to 2400	40	40	40

On this L_{95} basis on the basis of the five year average for all sites the Monday to Friday standard would be satisfied and indeed this would be so for the 1985 figures. It is, however, doubtful if some individual sites, if sampled for a brief period, would be seen to comply when the range of L_{95} measures in each case are taken into account. In a number of the measures of noise it would appear that there is less stability in measurements from site to site during the evening and night hours as evidenced by the larger standard deviations occurring in these period. These results reveal a fact well known to persons having undertaken the measurement of noise that considerable variation exists between levels from time to time.

Despite this seemingly well appreciated fact there are pressures to introduce even more specific single figure criteria. A recent review of council noise ordinances, in which 49 cases were taken into account revealed that there were differences in the following matters (Camp, 1985). In the type of measurement involved 31 percent specified a L_{95} restriction only; 16 percent a corrected noise level, 10 percent a L_{95} and L_{10} level; 6 percent L_{10} alone; 6 percent the background plus 5 and either a L_{10} or L_{95}; 4 percent a Leq value, the remainder specifying other measurements or combinations. Camp (1985) suggested the introduction of a national ordinance with a maximum L_{95} for daytime and a maximum L_{95} for nightime together with a maximum corrected L_{10} for residential or rural boundaries.

The Planning Tribunal, and its predecessor the Town and Country Planning Appeal Board, have made a number of, what would appear to be inconsistent decisions. In one case the background level, without a factory operating, ranged from 29 to 34 dBA and the decision allowed a level of 45 dBA at a similar spot. This latter level is from 11 to 16 dBA above the background level and in terms of NZS 6802: 1977 "Assessment of Noise in the Environment" would be considered suitable for abatement. Yet the same body had previously stated that "as a general rule it is undesirable that a particular noise should rise more than 5 dBA above the background noise and if it rises 10 dBA or more above the background it should be abated". In other cases it has been confirmed that a level of 45 dBA was accepted as protecting the sleep of individuals inside (Planning Tribunal, 1985). Evidence was reported from an expert witness that "For typical industry the spread between L_{95} and L_{10} may be taken as 5 dBA so a change from 40 dBA (L_{95}) would for the typical industrial/residential scene have zero impact". The figures from our industrial noise survey show such a statement to have little validity. It would appear that Planning Tribunal decisions, which have if not the force of law outside the particular case a persuasive effect, are based on not totally appropriate evidence in many cases. A wide variation occurs naturally in urban areas in sound levels experienced and it may be that performance standards need to relate to building construction and operations rather than the setting of sound level criteria at some point outside the building or premises.

5.0 CONCLUSION

The setting of arbitary levels of sound which are not to be exceeded (by 1 dBA according to Planning Tribunal decisions) has probably had an effect in ensuring that at least some action is taken by industry to design for noise reduction or attenuation. It is, however, apparent that the wide range of sound levels occurring are not taken into account in setting such standards. More specific and detailed guidelines need to be provided for both measuring and reporting sound levels and indeed for the standards themselves to enable valid and reliable measurements with some consistency to be available. Much longer term measurements must be taken for use in town planning cases rather than the present often short term sampling that appears to be used. It must be always remembered that "noise" is subjective while sound can be objectively measured if not necessarily assessed.

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A NEW APPROACH TO ENVIRONMENTAL NOISE

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ABSTRACT

The Environment Protection Act was passed by the Victorian Parliament in 1970. Since then it has been amended on several occasions in the light of experience and changing community expectations. Major changes were made in 1985 which placed much greater emphasis on the Environment Protection Authority's involvement at the planning and design stage of a project. Classes of industry which represent the larger scale operations and which therefore have the potential to cause significant noise problems are required to notify the EPA of their plans prior to the commencement of works.

The Notification of Works provisions of the Act will be used in conjunction with the State environment protection policies for noise from industry and entertainment premises to enable more effective control of excessive environmental noise.

At the same time as placing greater emphasis on preventing noise problems arising, the EPA will be providing support for other bodies with a role to play in community noise control.

1.0 INTRODUCTION

The noise control legislation operating in Victoria since 1970 has been amended from time to time to take into account experience gained in its use and changing community expectations. The policies now in effect place greater emphasis on prevention of problems than in the past. With the inclusion of the Environment Protection Authority under the Minister for Planning and Environment, the potential exists to go further in this direction. Underpinning this are amendments to the Environment Protection Act in 1985, to require that the EPA be notified of proposed works on premises that have the potential to increase community noise levels.

1.1 Environment Protection Act 1970 The Environment Protection Act was passed by the Victorian Parliament with the majority of its provisions coming into effect in March 1971. As is implied by its title, the Environment Protection Authority has the protection of the air, land and water environments as its objective. Included in this charter is the responsibility for controlling the emission of noise.

This legislation was an important step for pollution control in the State as it clearly placed the responsibility for co-ordinating all activities relating to the control and prevention of noise with one body. It is important to remember that this legislation supplemented responsibilities for community noise control already held by other government and semi-government bodies rather than replacing them.

1.2 State Environment Protection Policy A cornerstone of the Environment Protection Act is the responsibility to develop and declare policies for various segments of the environment. The policies are the means by which environmental objectives are quantified. In the early 1970's work commenced on developing a policy to be used for the control of noise from industry. At that stage it was envisaged that a licensing system would be established to control environmental noise in the State. Australian Standard AS 1055 provided an adequate basis for this purpose but was not definitive enough in some respects to withstand legal argument. A great deal of effort was put into quantifying the subjective aspects of the standard. This program was completed in 1981 and State Environment Protection Policy "Control of Noise from Commercial, Industrial or Trade Premises in the Melbourne Metropolitan Area" No. N-1 was declared by the Government. This contains detailed measurement and assessment techniques as well as the environmental noise objectives. The policy is widely accepted as a fair and objective basis for noise assessment. Although it currently applies to metropolitan Melbourne it has been used to assess noise problems in other areas of the State. It is proposed to formally extend the policy statewide in 1986/87.

A further State environment protection policy for the control of music noise from entertainment premises is due to be declared in the second half of 1986. It will take into account the special difficulties created by predominently low frequency content of music noise.

The development of formal State environment protection policies, although an important aspect of environmental management, is very demanding on resources. With the statewide declaration of the industrial and music noise policies we believe there will be adequate coverage for most cases where detailed measurement and assessment are necessary.

1.3 Noise Licensing and Noise Control Notices The Environment Protection Act 1970 originally contained licensing provisions. However these were not put into effect. Licensing is a useful tool where there is value in computing the net effect of a number of discrete sources. The more obvious application is for the control of discharges to a water catchment or an airshed. Generally noise emissions from a number of sources do not aggregate over a region; their effects are localized. Thus the inventory of noise sources for a region that can be compiled from licensing data is of limited use.

In 1978, the Environment Protection Act was amended to replace the licensing provisions with a system of Noise Control Notices. Under section 47 of the amended Act, the Authority may serve a notice on the occupier of any non-residential premises whose noise emissions exceed limits prescribed by State environment protection policy. Included in these amendments were the requirements to initially serve a preliminary noise control notice and the right of appeal by the recipient of the notice.

A further significant amendment was made to the Act on 1 January 1985. Prior to this, a noise control notice could only be issued if prescribed noise levels were being exceeded.

Now noise control notices may also be issued where:

- the proposed use of the premises is likely to exceed prescribed noise levels
- where a justifiable complaint has been made to the EPA.

In conjunction with these legislative changes there has been a shift in administrative policy. The EPA had been relatively successful in negotiating reductions in noise emissions to policy levels with individual companies. Generally, a noise control notice was issued where the abatement works were to take considerable time, there was a lot of money involved or the company appeared reluctant to undertake the work. Now whilst still being committed to the process of discussion of problems with industry to ensure realistic and achievable objectives are set, noise control notices are issued early in the process. Noise control notices are also being written with a variety of conditions, such as:

- compliance with noise levels
- furnishing of information and reports to the EPA
- specific abatement works to be undertaken

2.0 NOISE CONTROL GUIDELINES

As an alternative to developing formal State environment protection policies, there are a number of noise problems that can be resolved using guidelines. Although they may not have the full weight of a formal policy they do have the advantage of being able to be flexibly applied to take into account local circumstances. This is particularly the case where time of occurrence is as important as the actual noise level.

Guidelines have been produced and circulated for use by councils at the local level. Over the last 2 years the EPA has placed greater emphasis on strengthening relationships with local government and has encouraged the inclusion of noise criteria in planning permits, particularly for the smaller scale problems not likely to be picked up by the notification of works provisions of the Environment Protection Act.

A program of technical training workshops has been initiated by the EPA. Through these courses a greater awareness of noise issues will be created. We believe that planners and environmental health staff have a significant role to play in the State's noise control program and that these courses are a valuable way of increasing the involvement of local government.

In some cases it may be appropriate for the EPA to also include reference to these guidelines in conjunction with an assessment using noise criteria from a State environment protection policy. Adopting this approach will allow us to be more responsive to noise problems that arise in the community. It will also enable the EPA to more readily take advantage of improvements in noise assessment techniques and shifts in public demands and expectations.

3.0 NOTIFICATION OF WORKS

The Act was amended in 1985 to require occupiers of "scheduled premises" to notify the EPA when undertaking work that may increase the level of community noise. Up to this point the EPA's activities related mainly to the resolution of noise complaints from existing premises. A fundamental reason for the shift in emphasis is the EPA's need to be more involved in noise control at the planning and design stage of new plant and equipment.

Prior to 1 January 1985, there was no formal mechanism for EPA input at the planning stage of an industry's establishment or expansion. Indirectly the EPA had a limited input to the planning process through the Victorian Environment Effects Act. However this mechanism only applied to a small number of major or sensitive projects. Through complaints response work,it was obvious that avoidable noise problems were still being created through lack of consideration of noise issues. Clearly there was a need for early and formal EPA involvement.

3.1 Schedule 3 Premises It is not efficient to bring the full weight of the Environment Protection Act into operation for every potential noise problem in the State. Those types of industries that have the potential to emit high noise levels due to the nature of the operations and processes normally carried out have been classified in schedule 3 of the Environment Protection (Scheduled Premises and Exemptions Regulations) 1984. Some examples of schedule 3 premises are petroleum refineries, metal fabrication works, gun and rifle ranges and helicopter landing sites.

Under section 46A of the Environment Protection Act, the occupier of a schedule 3 premises is required to notify the EPA where the alteration of the method of operation or the installation of plant and equipment may give rise to a significant increase in noise levels. Notification must also be made for works that will cause a premises to be included in the schedule 3 list. Notifications must be made at least 60 days prior to the commencement of works. Obviously, in many cases it is highly desirable to discuss the proposals much earlier than the statutory period. Considerable effort was made to publicise these amendments to the Act. However, there are indications that not all possible notifications are being received by the EPA. We will be putting more effort into following these up to ensure that noise emissions are adequately evaluated when new projects are planned and executed.

4.0 CONCLUSION

The EPA's legislation has been changed to place greater emphasis on it being involved at the planning stage of industrial and commercial developments. With the 1985 amendments to the Environment Protection Act, it is now able to ensure noise is considered and State environment protection policy objectives met. Noise control notices can be used to require noise from existing operations to meet government objectives as well as ensuring that new projects do not contribute further to community noise levels.

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COMMUNITY NOISE CONTROL - A PRACTICAL APPROACH

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Community Noise Control - A Practical Approach deals with offensive noise which is only one aspect of environmental noise control. Offensive noise in Western Australia was not controlled in legislative terms in Western Australia until the law was changed in 1981 amending the provisions of the Noise Abatement Act.
This paper outlines what is deemed to be offensive noise as defined by the Noise Abatement Act and how the Noise Abatement Direction can be issued for the various noises that it is capable of controlling.
Community noise control is considered to need a practical approach based on educating people using communication and psychology and that this education be supported by the legislative backing provided by the Noise Abatement Act. Noise Abatement Directions are both efficient and beneficial to the community and have application in all parts of Australia in controlling a common problem.

1.0 INTRODUCTION

The City of Subiaco, Perth, Western Australia was proclaimed a municipal district on 26th March 1897 with 388 houses. Conditions in Subiaco steadily became more comfortable, with earlier arivals progressively improving their personal lots and in a spirit of pioneering neighbourliness helping others do the same. (Spillman K.). In the early history of Subiaco there is no mention of particular noise problems by the Author Ken Spillman. However, times have certainly changed.

Around the 1960s, with the advent of rock bands, stereo music, leisure vehicles and electronic leisure equipment, noise nuisances and in particular offensive noise, began to become an increasingly difficult problem for local authorities to control. The change in lifestyle to communal living by young people added to the increased noise problems.

Noise which generally disturbed the quiet residential environment that Subiaco residents expected was often found by many of the complainants to be offensive due to having their sleep patterns disturbed and lifestyles being affected by people who had lost any signs of acceptable neighbourliness which the City's forefathers had established in the early pioneering days.

2.0 METHOD

Under the provisions of the Noise Abatement Act an authorised Noise Inspector is deemed to be an authorised person under the provisions of Part 1V - Noise Abatement Directions and Inactivation of Audible Alarms. Furthermore, Police Officers have a specific authority to issue a noise abatement direction between the hours of 9.00 p.m. and 6.00 a.m. the following morning and are responsible for dealing with all complaints relating to audible alarms with wide powers. However there is reluctance to act quickly after the 30 minutes prescribed time to inactivate the audible alarm to prevent further complaints.

All inquiries received outside the time when the offensive noise is being emitted and received by a complainant cannot be dealt with at that particular time under the provisions of the Act. However, if a person is aggrieved by offensive noise and makes inquiries that person is fully informed as to their rights and the action that can be taken by an authorised person under the provisions of the Act. Many people request Council's authorised persons to visit a person who is causing the emission of offensive noise to explain the requirements of the Act in an effort to, hopefully, educate that person and to prevent the necessity of complainants contacting authorised persons late at night.

Complaints relating to offensive noise must be received by an authorised person at the time the noise is deemed to be offensive by the complainant. This allows the authorised person to elicit from the complainant the elements of the definition to ensure that the complaint is justified, prior to leaving home or the office.

The provisions of the Noise Abatement Act relating to offensive noise applies to noises which appear to the authorised person in concern to be offensive noise and which are -

(a) on residential premises, generated or amplified mechanically or manually or by air pressure; or

(b) on any premises -

(i) generated by any activity or activities relating to motor vehicles (as defined by the Road Traffic Act 1974) or vessels; or

(ii) generated or amplified electronically or by any musical instrument or musical instruments.

Offensive noise is defined under Section 33A of the Noise Abatement Act as meaning:

"Noise that, by reason of its level, nature, character or quality, or the time at which it is made, or any other circumstances, is likely -

(a) to be harmful to;
(b) to be offensive to; or
(c) to interfere unreasonably with the comfort or repose of,

persons who are -

(d) if the noise is made in premises that are not a public place, outside those premises; or
(e) if the noise is made in premises that are a public place, within or outside those premises."

An authorised person, having elicited the elements of the definition, thus justifying the necessity to take action under Part 1VA of the Act and obtaining full details of the complainant for future reference, may take the necessary action under the Act without reference to the local authority or any other statutory body.

As the Act provides only a definition relating to offensive noise and in the absence of any associated regulations providing regulated noise levels subjective judgement by the authorised person must be used to determine whether it justifies issuing a noise abatement direction. In these circumstances, where the noise is still being emitted from the premises and is considered an offensive noise by the authorised person, action may be taken in issuing a noise abatement direction.

The Act also provides for cases for where the noise has ceased to be emitted from the premises to still allow a noise abatement direction to be issued up to thirty minutes after the noise has ceased.

The authorised person may direct either the person whom he **believes** to be the occupier of the premises to cause the emission from those premises to **cease** or alternatively, may direct any person whom he **believes** to be making or contributing to the making of the noise to cease making or contributing to the making of that noise. It may be necessary on occasions to issue a noise abatement direction to persons of both categories being the occupier and persons whom he believes to be making or contributing to the making of the noise to ensure that the noise deemed to be offensive ceases to be emitted.

In giving a noise abatement direction it may be either verbal or written and, in the City of Subiaco, the majority of noise abatement directions are given in the written form which has been prepared by Council's Solicitors to ensure that all details of the Act are complied with relating to the elements of the offence. It also ensures that the person's name and address is obtained and that they are fully informed as to the offensive noise which must cease to be emitted from the premises. The Noise Abatement Direction written form also advises that the direction remains in force for a period of twenty four hours, unless revoked by the authorised person.

In the case of noise abatement directions given by a police officer, the direction only remains in force from the time in which it is given until 6.00 a.m. next following the time in which the direction was given.

The time given to cease is dependent on each situation and this itself will depend on the amount of co-operation or assistance that is afforded by the occupier or person in charge or **apparently** in charge of any premises. Where a person will not afford any assistance which they are capable of providing, then they commit an offence under the Act and it may be necessary to call police assistance to enforce the provisions of the Act.

3.0 RESULTS

Due to the increased number of complaints, many discussions were held between various local authorities and members of the State Health Department Noise Abatement Section. A Submission was put to the Government for additional Legislation to control offensive noise to provide for immediate relief. In 1981 Part 1VA - Noise Abatement Directions and Inactivation of Audible Alarms was introduced into the Noise Abatement Act to deal with offensive noise, including the Inactivation of Audible Alarms - a source of extreme annoyance.

The West Australian Noise Abatement Act was assented to on the 6th December 1972 to control excessive noise and vibration and to provide for their abatement, and for incidental purposes. This Act of Parliament was found to be generally effective when dealing with noise nuisances in areas away from major traffic thoroughfares, but it was later found that the Noise Abatement (Annoyance of Residents) Regulations 1974 proved inadequate and were subsequently revoked in August 1980. The replacement regulations known as the Noise Abatement (Neighbourhood Annoyance) Regulations 1979 have proved to be far more effective with the ultimate result in providing the necessary basis for having any noise nuisances reduced to within acceptable levels. The Noise Abatement Act, however, did not provide adequate control for reducing what is now defined as "offensive noise". This noise was occurring at regular intervals in which the members of the public demanded immediate relief from to return their neighbourhood to a quiet residential environment.

Since the offensive noise provisions were included in the Noise Abatement Act there have been substantial results in curtailing offensive noise, either as a single entity, or when being dealt with in conjunction with the provisions of a noise nuisance defined under Section 7 of the Noise Abatement Act.

The most significant benefit is that where rock bands are used at public entertainment venues, which may be the subject of separate action under Section 26 of the Noise Abatement Act relating to a nuisance, as regulated by levels set in the Noise Abatement (Neighbourhood Annoyance) Regulations, a Noise Abatement Direction may be issued to provide immediate relief for the surrounding residents. The provisions relating to Section 26 require a resolution of the local authority relating to being satisfied of the existence of the nuisance, issuing of a request to abate the nuisance and, if necessary, issuing of a formal notice to abate the nuisance, then this does take several weeks to have these matters brought before a local authority. The noise abatement directions can be issued to cause the offensive noise to cease being emitted which is the subject of a complaint.

When a noise abatement direction is issued to a licensee of a hotel who refuses to comply with the provisions of Part lVA of the Noise Abatement Act, then a further noise abatement direction can be issued on the persons making and contributing to the making of the noise - in this case, the rock band, directing them to cease causing the emission to be made.

If necessary, noise abatement directions can be issued as often as necessary and as long as the person whom the direction is given to complies with the notice and causes the emission from the premises to cease and not permit the offensive noise to be emitted for a period of twenty four hours, no further action under the Legislation can be taken.

The provisions of the Act allowing a noise abatement direction to be enforced for a period of up to twenty four hours has been recommended to Parliament to be extended to thirty days at the discretion of the authorised person, to allow for circumstances like rock bands in hotels to be controlled more effectively until such time that legal notices can be served under the provisions of Section 26. This matter is still under review.

The authorised person may revoke a noise abatement direction if he considers the matter and finds that the offensive noise is not likely to cause a nuisance, or create further complaint.

Private parties certainly have quietened down, rock bands and other musical groups don't practise in residential areas in Subiaco, people are becoming more aware and educated concerning the Noise Legislation, both from the complainant's point of view and the responsibilities of the person responsible for the emission of noise. This education approach to the practical control of noise is tending to generate more enquiries from persons who are interested in the possible action that may be taken and the effect that it has in controlling offensive noise.

Community awareness in relation to the use of lawn mowers, electric equipment such as jigsaws, bandsaws, grinders, musical equipment, leisure vehicles is ensuring that people consider neighbours prior to using these type of instruments and equipment to the detriment of their environment. Part of the awareness programme is to ensure that members of the public understand that authorised persons are available, on call, to attend to all complaints in strict confidence at any time of the day or night. This has certainly assisted in reducing the number of noise complaints, as often people are informed by a complainant that unless the offensive noise ceases, that they will be left with no alternative but to contact the local authority authorised person so that action may be taken to have them cease the noise emission.

4.0 DISCUSSION

Suburban Subiaco has a high population density which is ten times the metropolitan average. There is a large proportion of elderly residents over sixty years of age and a very mobile younger population. The type of building construction and the size of residential allotments of land all contribute to the environmental noise problems due to the conflict of interests.

Modern household appliances ranging from musical instruments, radio cassette players, washing machines, lawn mowers, small electrical workshop items, air conditioners and leisure equipment all contribute to increased noise levels. Subsequently, increase in complaints and degeneration in community relations have become the major problem for a local authority noise officer.

The Noise Abatement Act is only part of the chain to solving noise problems. Good community relations based on positive communication and psychology skills and a preparedness to investigate all complaints at any time, day or night, all contribute to the understanding of the technical, economical and sociological problems inherent in noise control. Remembering that an authorised person is not primarily a prosecutor using solely the Legislation in which he is empowered, but is also responsible to liaise between the various parties ranging from the legal profession, acoustic consultants, complainants and persons who cause the emission of offensive noise, in an effort to assist all parties in bringing harmony to the community.

Public education, using community newspapers, radio media talk-back programmes, distribution of free brochures and pamphlets and personal contact with both complainants and persons who cause the emission of offensive noise, all helps to resolve community noise problems and reduce anxiety and stress associated with people affected by noise. It is not good enough for a local authority to employ a noise officer who is not prepared to assist in noise control after hours on the basis that they work from nine 'til five. In my particular position, noise complaints are received at any time, day or night, and must be attended at the time of the complaint or within thirty minutes after the complaint has been received, to provide the service that the public demands.

5.0 CONCLUSION

Offensive noise is an inherent problem in inner suburban areas causing disturbances in people's sleep patterns and increasing demands on local authorities and police departments' manpower.

Education based on communication and psychology and the issuing of legal Noise Abatement Directions are considered to be the practical approach to effect the means of controlling offensive noise. The majority of the community will respond to education based on communication and psychology. However, the minority of the community that do not respond, the major deterrent will still be the Legislative control provided by the Noise Abatement Act and its inherent penalties for non-compliance, which in the case of failing to comply with a Noise Abatement Direction, is a maximum penalty of $1,000.

The West Australian Noise Abatement Legislation providing for Noise Abatement Directions and Inactivation of Audible Alarms does have an application Australia wide. If used correctly, it can improve the local authority image as to one that provides a service and assists in providing an acceptable residential environment.

I am informed that the Noise Abatement Act is currently being completely revised with very wide powers to curtail problems of noise and is currently before the West Australian Parliament.

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LAND USE PLANNING FOR NOISE CONTROL

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ABSTRACT

The paper looks at the inter-relationship of town planning procedures and practices in the context of noise.

One of the fundamental objectives of the town planning process is to minimise the impact of new land uses on existing uses and on possible future land uses in the vicinity of the proposal. Achieving this objective is not always practicable since noise impacts are but one of the many factors examined in the consideration of a development application.

The main factors to be considered when dealing with a potentially noisy proposal are outlined. The thrust of the paper, however, is to point out that for applications to be decided quickly, it is imperative that the information needed by the public, planning officers and elected representatives of Local and State Governments is provided fully, at an early stage of the application.

1.0 INTRODUCTION

The objective of every development project is to obtain the necessary approvals as soon as possible and commence operations.

If the expectations and limitations of:-

(i) the role of approving authorities,
(ii) the land use planning considerations,

are fully understood, and can therefore be satisfied, a project can be brought into operation in the minimum time.

In my experience, many applicants for approval do not appreciate the information needs of approving authorities. They are most disappointed and irate, when an application for approval is rejected or more often, delayed while further information is obtained.

The following comments are based on the roles of a local authority and the State Government, in the context of the town planning legislation.

I would suggest however, that the principles involved are applicable to a number of other statutory authorities.

2.0 BACKGROUND

There are numerous instances which illustrate an apparent change in the tolerance to noise of people in the workplace or in a residential locality, over the last 100 years or so. In earlier times the residential environment seems, at least in the more urbanised areas, to have accepted commercial or industrial land uses in close proximity to residential uses.

With the highly mobile transportation systems of today, the expectation which seems to be dominant in the community is that industrial, commercial and recreational uses, expecially those of a potentially noisy nature should be confined to specified localities well away from noise sensitive uses.

Typical instances can be categorised as:-

(i) Residential encroachment on existing commercial, industrial or recreational uses;
(ii) Encroachment of commercial, industrial or recreational uses on existing residences;
(iii) Planned development where noise producing sources are located and designed to minimise impacts on the residential component of the project.

At this stage, it should be appreciated that although the paper concentrates on residential development, the same principles are applicable to the occupants of businesses and industries which are subjected to noise impacts from external business or industrial sources.

3.0 THE LEGAL FRAMEWORK

This part of the paper deals with some of the procedures which are used in the land development process. By understanding or at least being aware of these procedures, a prospective developer and conversely, a prospective neighbour can both be aware of their opportunities and obligations.

In a case where a town planning approval is required, an application has to be approved by the local authority concerned. The first step therefore, is for the applicant to demonstrate to the local authority through the application that no adverse impacts will arise. It is probable that the town planning application will be of a type that requires public advertisement. At this time, any person can object. This will almost certainly be the case if it is not clearly stated in the application that noise sources have been considered and steps taken to minimise their impacts. This information may be in supporting data prepared by the applicant or may be evident from, the site plan or building design and location on the site.

In the event that either the applicant or objectors are not satisfied with the decision of the local authority on the application, there are rights of appeal available for each to the Local Government Court, which hears and determines the matter.

Where the application is for the rezoning of land, the final decision is one for the Governor in Council. At this stage the Minister responsible for the town planning legislation considers the local authority's application to him and has to be satisfied that such factors have been resolved, before he makes a recommendation to the Governor in Council.

It can be seen that there are a number of opportunities for the planning system to assess the proposal at various stages.

A prudent developer who knows his industry will carry out these or similar assessments during his feasibility studies before any firm committment to the project is made. For an application to be dealt with expeditiously, the necessary information should be clear and unambiguous and most importantly, be available at the earliest possible stage of the procedures.

Before leaving this topic, there is one aspect of the planning legislation which needs to be clearly understood - Existing Land Use Rights. Existing uses which may have been established many years ago before a planning approval was necessary, or even a few weeks ago in accordance with the terms and conditions of an approval given under the planning scheme, have vested in them certain rights to use land. These rights are contingent upon the use being lawfully established at the relevant time.

A misconception held by some people is that a local authority, through its planning powers, can "close down" an existing use which has become a source of noise complaints.

The legislation provides no power for a local authority to take this action through its planning scheme. In fact, existing uses are recognised and protected by the Act and are allowed to continue in their present status. Council has an opportunity to consider any proposed changes in land use, alterations or additions however.

4.0 INFORMATION NEEDS

In a paper of this type where there has, of necessity, to be so many generalisations, it is not possible to specify the criteria to be examined in every type of application. The following points commonly arise however.

4.1 Buffer Distances. There are a number of means of minimising the impact of noise on neighbouring uses, one of which is separation distances. Preferably, the buffer distance should be within the site itself. The actual distance required to achieve the reduction in noise level depends upon a range of factors. An expert assessment which can be substantiated in an Appeal Court if necessary should be considered, particularly if there is a chance that the application may be controversial. If this information is available when the application is first submitted to council, it will then be available for public inspection and hopefully will allay any doubts and fears on the part of potential objectors.

Sound propagation is a complex subject, not understood in any objective way by the layman. Because the final decision on planning applications will be made by a person or group of persons who have no specialist knowledge in this field, it is therefore imperative that an appropriate buffer distance be identified and marked on a suitable map. In this way, the decision makers can appreciate the depth of buffering which may be required and also appreciate the extent of any screening, mounding or planting which may be desirable.

4.2 Site Layout. The least cost and easiest method of planning for noise abatement at the design stage, is the location of noise sources within a site away from existing or possible neighbouring developments. There are numerous instances where a noise source is located on a site, obviously without consideration of adjacent uses.

Where a site to be developed has existing neighbours, full consideration of potential noise impacts should be taken into account. There is always a distinct possibility that the neighbouring use will change in the future but in that case the new use would then be expected to consider its neighbouring uses.

A common sense approach to site layout will minimise the chance of objections and complaints and should ensure a straight forward processing of the application.

4.3 Building Design. Closely related to site planning is the design of proposed buildings and structures. The choice of building materials is important, as well as the location of openings in walls.

As a general principle, the alteration of a design at the concept stage to reduce noise impact is by far the "least-cost" option. Once the design has been approved, even if no construction has started, there will be a cost incurred in having the approval amended to suit changes which may be required. Of course once the building has been erected, machinery installed and the use commences, any structural changes to relocate a window opening, or to insulate a wall or a ceiling will involve very considerable cost.

4.4 Land Use Compatibility. The town planning process involves the consideration of a wide range of issues including environmental, transportation, economic, social and political issues. In a particular case, when a final decision is made, economic or other considerations may carry more weight than environmental (noise) matters.

Even though the land use planning objective is to avoid or at least minimise land use conflicts between adjacent uses, it is not possible to ensure that this objective is met in every case.

As a general planning principle, a planning scheme will attempt to segregate land uses which typically generate noise from those uses which find it unacceptable. One of the usual devices is to direct land uses which can tolerate a degree of external noise to lands between the noise generating and noise sensitive uses.

The use of natural features such as ridge-lines or swampy area which are not suitable for urban development, can also be utilised as buffers between incompatible uses. Man-made features such as recreational uses or transportation corridors, when of a significant width, may also be used.

5.0 ROLES OF STATE AND LOCAL GOVERNMENT

Having established the legal principles and some of the information needs of "decision-makers" and officers, it is important to understand the extent of the powers available to each level of Government. It can be very frustrating to find that an innovative project cannot be approved in its original form because it does not comply with a Statute, Regulation, Order in Council or Bylaw of some type.

One of the options available to facilitate approval is to change the "rules". This can be very difficult. Even if it is possible to change the relevant document, it is quite probable that a considerable time will be involved. The other option is to amend the project. In most cases this is the expedient solution.

Local authorities are bound by the provisions of their bylaws, just as private citizens are. A certain amount of discretion to relax or waive provisions is available but only in those circumstances which are specified in the bylaw or planning scheme.

Officers of local authorities have very limited powers to approve. Their main role is to investigate and recommend to the council. Similarly, officers of the State Government carry out an investigation and recommendation role.

Once the roles of officers and elected members of council are appreciated, the application and its supporting information can be prepared accordingly. The officers will need to be satisfied that the statutory provisions of the law have been satisfied by the application. Predicted noise levels, buffer distances, site layout and building design should be clearly set out for a project which includes potentially noisy operations. These and other relevent issues can be readily set down and will assist in the rapid assessment of the proposal.

When the elected representatives meet to decide the application, the council will be guided by the officers recommendation, but will also take into account other factors such as social and political considerations. An applicant might consider acquainting the elected representative for the area with the proposal so that the councillor can (hopefully) support it at the council meeting. Obviously, the more elected representatives who are familiar with the application and support it, the better.

The same principle would apply at State Government level. If the local Member of Parliament can be acquainted with the project at an early date, he may be persuaded to make representations to the responsible Minister in support of the proposal.

An applicant should not anticipate an officer of council "bending the rules" or interpreting the law in a certain manner just to suit this proposal. Complete details, prepared in accordance with legal requirements and the officers guidance, if neccessary, should be in the application.

6.0 CONCLUSION

In my work I receive many enquiries seeking advice on how a specific project might be established without undue delays. A large percentage of these are in relation to moderately sized projects.

The observations in this paper are therefore aimed at those who may be applicants for development, acting for applicants, or who may be in the role of examining or deciding an application where noise is an issue.

In any of these roles, it is important not to lose sight of the information needs of others in the town planning process. The most important points are Buffer distances which must be sufficient to reduce noise generated by the project to locally acceptable levels; the layout of the project on the site to make full use of the site characteristics and take account of adjacent uses; the design of the building and the sensitivity of surrounding land uses in general.

PLANNING FOR NOISE CONTROL

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ABSTRACT

To show the effects which industrial zoning can have on town planning, two recent cases are discussed in a secondary session. These cases are characteristic for industrial zoning in urbanised areas. In both cases the surroundings of the industrial areas are to be reconstructed into mainly residential functions. Opposite goals do meet each other in the designed zones. In both cases emphasis will be laid on the planning aspects of the zoning more than on the acoustical implications. The appendix gives a short explanation of the acoustical basis of the zoning process.

CASE STUDIES

Two case-studies of industrial zoning in Amsterdam.

To show the effects which industrial zoning can have on townplanning, two recent cases are discussed in a secondary session. These cases are characteristic of industrial zoning in urbanised areas. In both cases the surroundings of the industrial areas are to be reconstructed into mainly residential functions. Opposite goals do meet each other in the designed zones. In both cases emphasis will be laid on the planning aspects of the zoning more than on the acoustical implications. The appendix gives a short explanation of the acoustical basis of the zoning process. The acoustical investigations, executed by external consultants on acoustics, by order of the Municipal Executives, are separated in three stages:

Stage 1
Investigations of the existing (or by licence permitted) noise-load of the relevant noise-sources in the area inside the 50 dB(A) contour and caused by the combined installations on the industrial estates together. Investigations of the existing and planned (in official townplans) dwellings and other noise-sensitive premisses within the 50 and 55 dB(A) contours.
After this stage the zoning procedure can be started.

Stage 2
If it appears that in stage 1 there are dwellings with a noise-load above 55 dB(A) a noise-reduction program has to be issued. Source-reduction and dwelling insulation is evaluated in different scenarios.

Stage 3
Detailed measures are designed and calculated. Financial programs, included cost compensations, are made up.

Case 1 "Oostelijke eilanden", description and developments.

The area contains a number of firms active in the metal and machinery industry. The most relevant noise-sources are two test-stations for ship-engines in the North-Western side. At the South-Eastern side there exist large noise-screening buildings (relativly silent).

There are no noise-intensive investment plans for the industries in the coming years. Around the industrial area at the N.W.-side there is an area in reconstruction, based on a designed townplan for new dwellings. In the S.E.-side old dwellings are to be renewed. Along the Northern part there exists a busy railroad track which influence only is inserted in the noise-insulation measures for new dwellings, but according to the Act, not into the calculations on behalf of the industrial zoning.

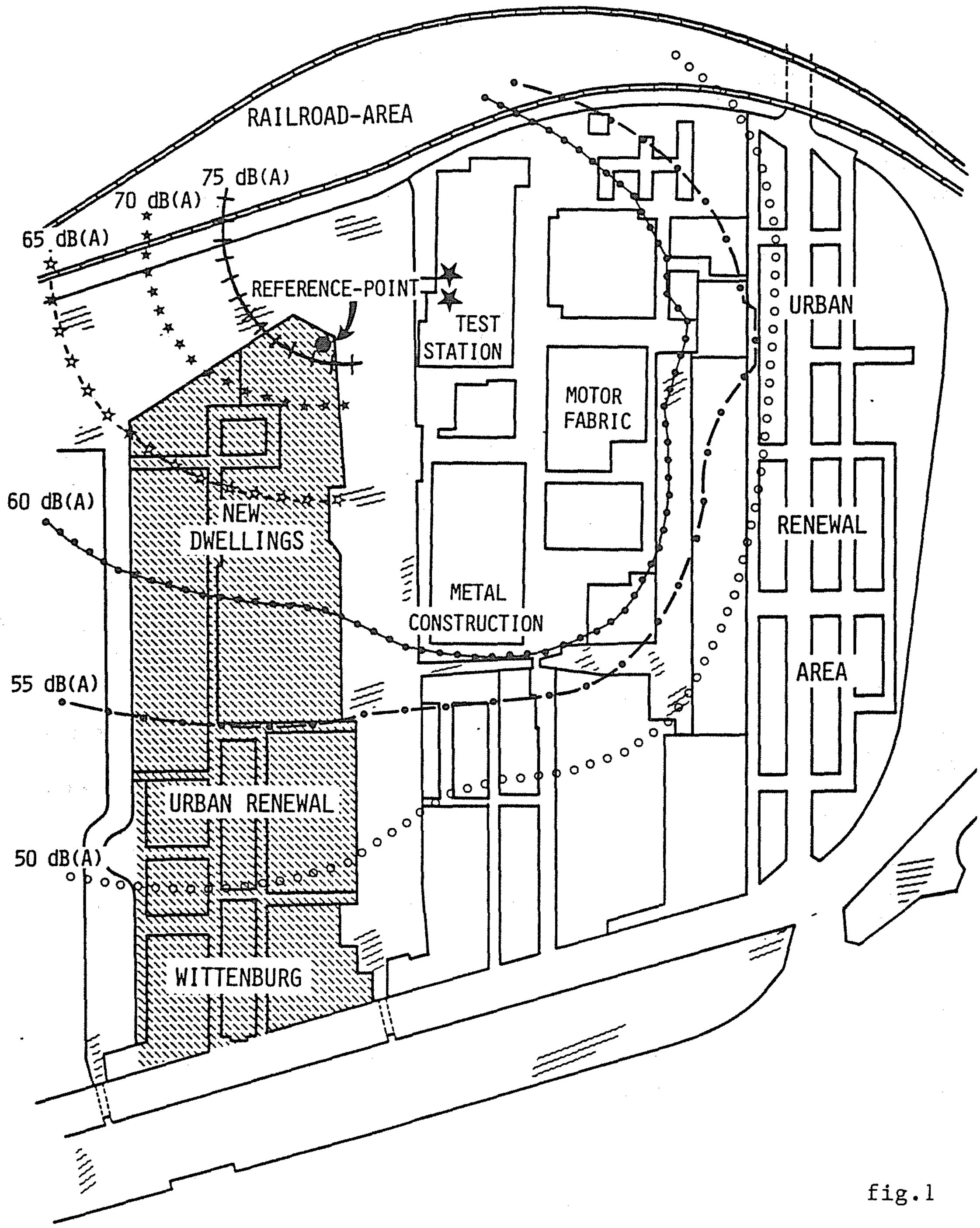

RAILROAD-AREA
75 dB(A)
70 dB(A)
65 dB(A)
REFERENCE-POINT
TEST
STATION
MOTOR
FABRIC
URBAN
RENEWAL
AREA
NEW
DWELLINGS
60 dB(A)
METAL
CONSTRUCTION
55 dB(A)
URBAN RENEWAL
50 dB(A)
WITTENBURG

fig.1

The existing noise-load due to the industry. (fig. 1)

The legal situation is that the maximum noise-load in the reference-point (shown in the accompanying picture) is 65 dB(A). The actual noise-load appears to be 75 dB(A) in a representative working condition with a 24-hours test-program (full continuous) of simultaneously two test units. The actual noise-load exceeds the permitted noise-load with 10 dB(A). This fact is important in the later discussed cost evaluation in behalf of the noise-reduction program.

New developments in the surrounding area.

In the S.E.-area existing dwellings are situated between 50-55 dB(A) contours. The Act does not impose more obligations than to provide sufficient insulation of the facades (noise-limits inside buildings). In the N.W.-area (Wittenburg) the building of dwellings is planned with Governmental approval. According to the Noise Abatement Act however the 55 dB(A) contour may not be tresspassed by the building of new dwellings, so without measures at the source there will be a building embargo in this part of the area.

This restriction made the development of new dwellings on "Wittenburg" problematical. The political decision was made, that everything had to be done to draw back the noise-load in the reference point to at least 55 dB(A) in favour of the new dwellings.
Scenarios had to be worked out concerning:

a) Measures at source as required according to the licences of the firms involved, giving a noise reduction of ± 10 dB(A).
b) Supplementary measures at source to achieve an additional reduction of at least 10 dB(A).
c) Garantees for financial support as far as it concerns the supplementary measures.
d) Approval of the Provincial Authorities to built new dwellings within a noise-contour of maximally 55 dB(A), after the noise-reduction program is implemented.

Realisation.

A management team was installed (± 1983). The parties involved are:
- The Governmental executives
- The Provincial "
- The Municipal " (chairman)
- The industries
- The consultants (specialists on acoustics and construction)

After a period of investigations on acoustics and constructions a scenario was drawn up for necessary measures to reduce the total noise emission with ca. 20 dB(A).
The rather complex combination of the observance of the licence prescriptions and the supplementary measures required a long period of negotiations and consultations.
The results of the financial agreement are shown in the following picture. (fig. 2)

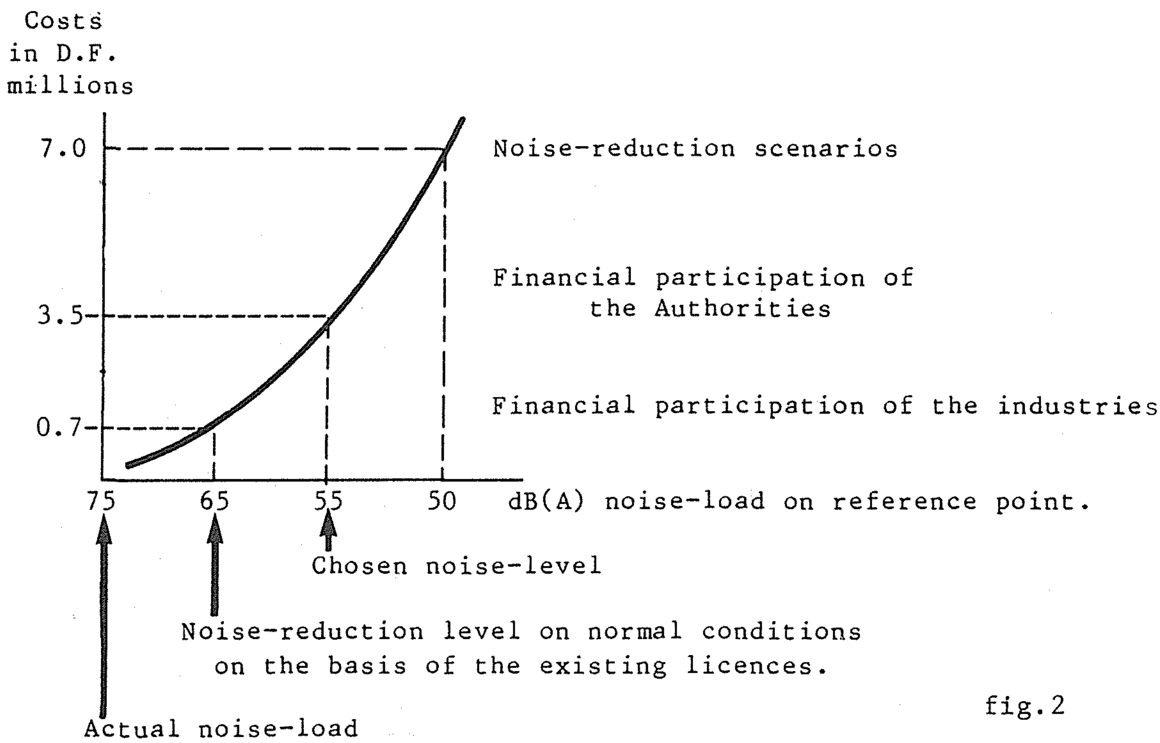


fig.2

The contribution to the financial budget by the industries was related to the legal obligations. The contribution by the Authorities was related to the minimum effort necessary to receive a noise-load of 55 dB(A) in the reference point which made it legally possible (according to the Act) to build dwellings. The cost of compensation in behalf of the supplementary measures were indirectly financed by budgettary provisions on the budget of the dwellings involved.
The calculated acoustical results are shown in the following picture.
The measures at the source and the estimated noise-limits are laid down in a revised licence for the test-station.
Financial garantees, in case of disappointing results and the eventual need of additional measures are given by the Central Government.

The actual situation, after the measures have been taken place, will be finally laid down in a physical plan for the "Oostelijke eilanden" area. According to the planning, measures will be executed at the end of 1986 just before the start of the building of dwellings on Wittenburg. (fig. 3)

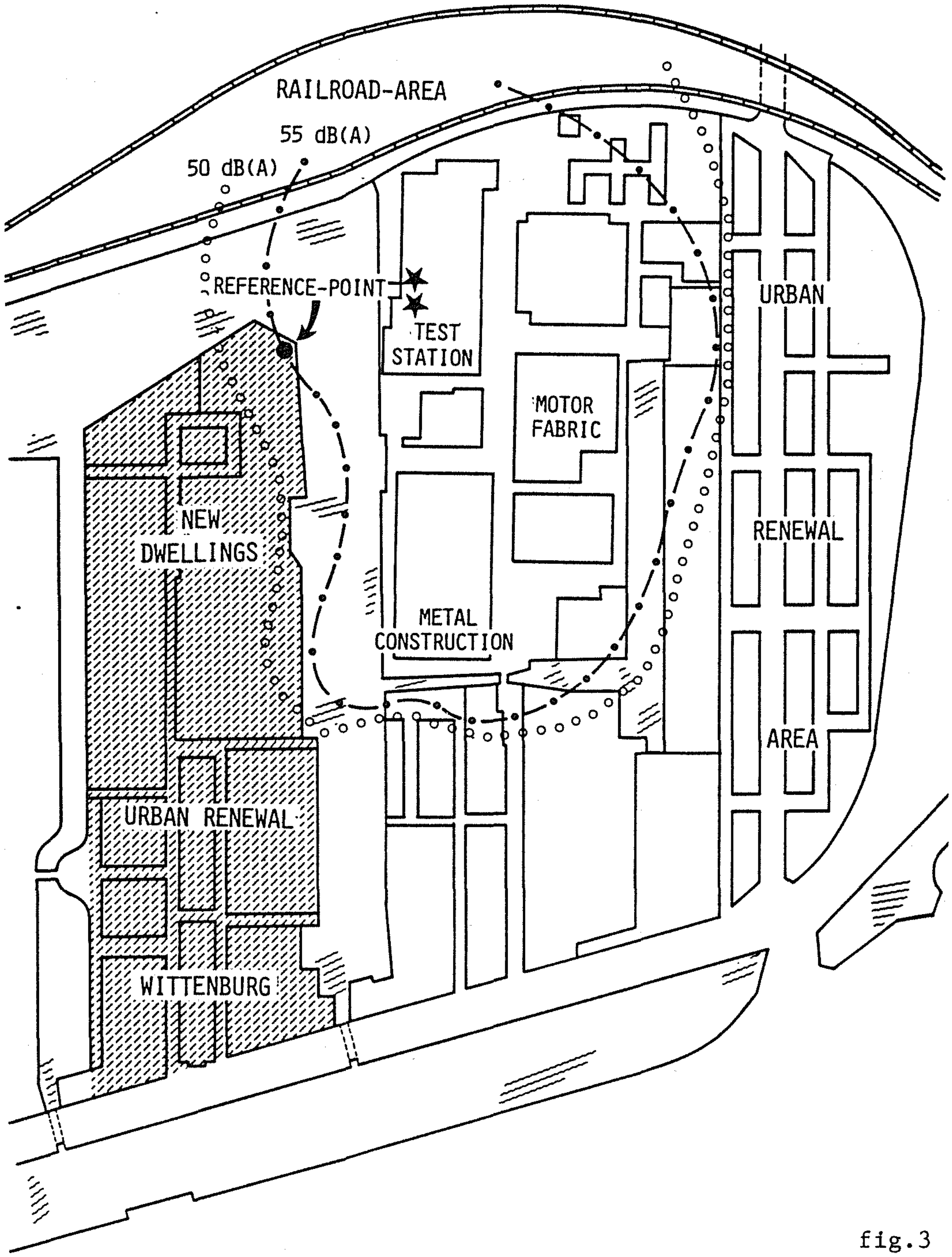

RAILROAD-AREA
55 dB(A)
50 dB(A)
REFERENCE-POINT
TEST
STATION
MOTOR
FABRIC
NEW
DWELLINGS
METAL
CONSTRUCTION
URBAN
RENEWAL
AREA
URBAN RENEWAL
WITTENBURG

fig.3

Case 2 "Johan van Hasseltkanaal Oost".

Description and developments.

The area involved contains a hundred industrial firms (over a ± 60.000 m 2) such as shipyards, construction-firms, chemical industry etc. The industrial area is surrounded by busy traffic roads, waterways and residential premisses as shown in fig. 4. In the South a development (townplan) is going on for the building of ± 10.000 dwellings and infrastructure. This area used to be the old harbour of Amsterdam which activities are mainly displaced to the Western area of Amsterdam.

The existing noise-load of the total industrial area on its surroundings.

The investigations on acoustics in behalf of the zoning started with public hearing and explanation. Employers and public were informed by the management team, appointments were made and the inventories and measurement programs were started.
Relevant noise-sources, screening objects, working hours and all other necessary characteristics which can influence the noise-contour are catalogued. Developments on the industrial area are discussed with the employers and, if realistic, taken into account. So was the present legal situation as far as it concerned permitted noise-emission (licences). The not operating, but legally permitted, parts of the industries were calculated by use of "distinguishing values" for representative noise power levels in dB(A)/m 2.

Zoning procedures.

The selected data were discussed for approval with the concerning firms and after mutual consent inserted in the computer-model (the standard transmission model for short range measurements and extrapolation calculations, chosen because of high background noise-levels in the area) for the drawing up of the noise-contours. This process proved to be rather complicated and time consuming because of the fact that the employers were not always very clear in presenting information about the existing or wanted situation in the factories. The check on the legally permitted situation and "wishful thinking" made the discussions sometimes like "heavy sea".
Finally, after the representative working conditions were accorded with all concerning parties, the results of the investigations were reported and had to be approved by the Provincial Authorities and the Inspectorate for the Environment.
In the ne·t stage the zone was designed and, according to the legal obligations,(appendix 3 of the first paper) deposited for the public hearing and consent. Claims for some expansion in the Eastern part of the zone are in consideration.

Policy and planning consequences of the zoning.

What could have been expected is that the space for expansion on the industrial area in this urbanised part of the city is rather small. On the other hand the noise-contours do show that residential developments in the near surroundings have to be tempered.

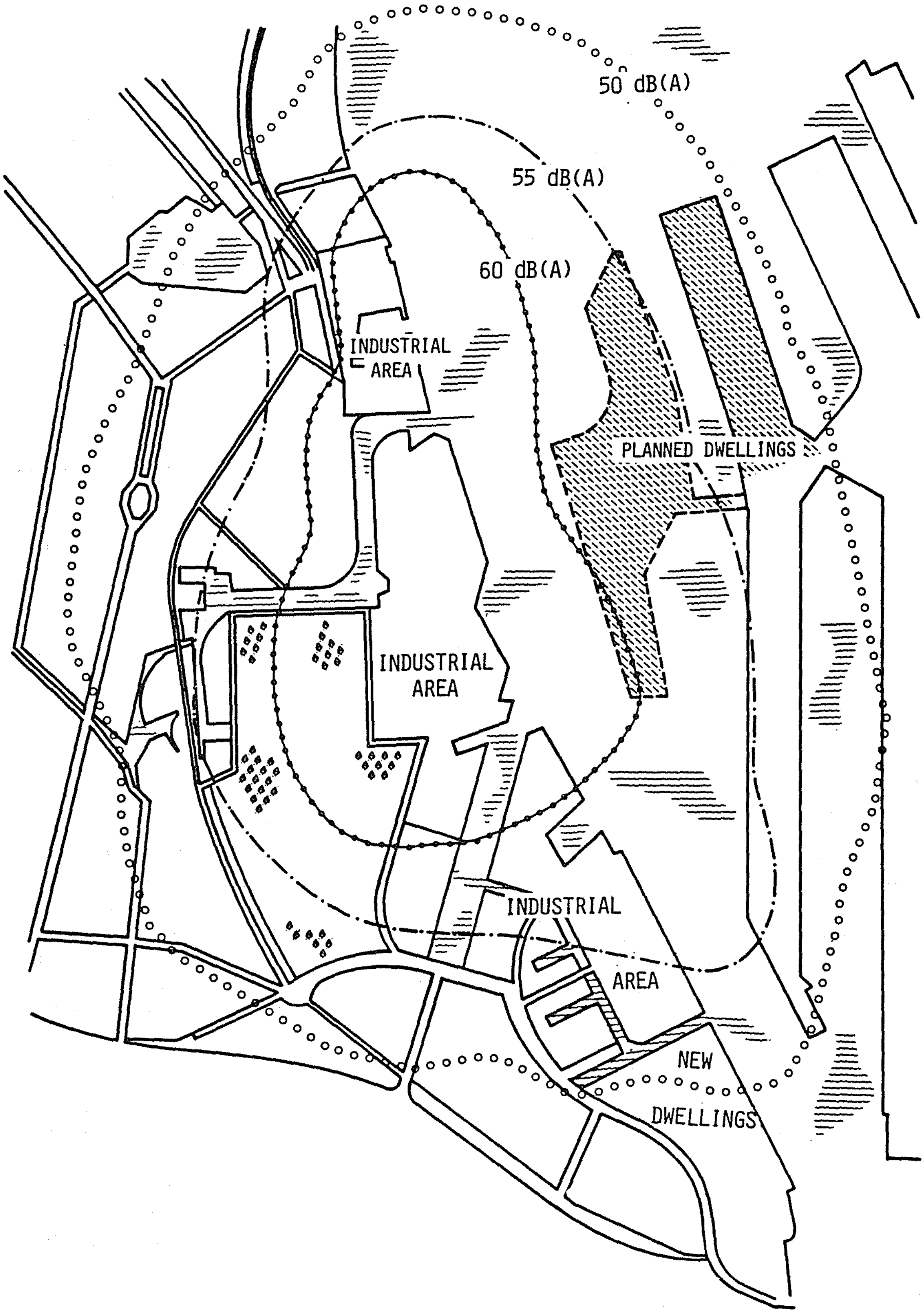

50 dB(A)
55 dB(A)
60 dB(A)
INDUSTRIAL AREA
PLANNED DWELLINGS
INDUSTRIAL AREA
INDUSTRIAL
AREA
NEW DWELLINGS

fig.4

In the North-West corner of the area the noise-load of the adjacent dwellings exceeds the 55 dB(A)-level. A noise-reduction program has to be drawn up. In the Southern part of the zone the development of the new dwelling area is heavily frustrated. According to the legal rules the building of new dwellings within the 55 dB(A)-contour is forbidden. Source-reduction investigations have pointed out that the costs would have been extremely high and could not legally be compelled. The preliminary choice is, to take insulation measures at the facades of the dwellings involved. Besides that, other environmental aspects made it not sensible to build dwellings on short distance of a large chemical plant. So a part of the mentioned dwelling development has to be cancelled concerning ± 1500 dwellings. In fact it is due to the Noise Abatement Act provisions that on this occasion townplanning was heavily influenced by the obligatory zoning of this industrial area.

APPENDIX

Basic rules for zoning around industrial areas

The noise load from an industrial area

The noise load from an industrial area is the cardinal factor for zoning within the framework of the Noise Abatement Act. This is defined in the Noise Abatement Act as "the twenty-four hour value of the equivalent noise level in dB(A) occurring at a certain place, caused by the combined installations and appliances on the industrial estate; not including the noise of motor vehicles not belonging to normal operating conditions".
In continuation, the following initial points apply:

1. The noise emission concerns the equivalent noise level over the day, evening and night periods in question. (Noise proceeding from public roads on the industrial estate is not included).
2. The variations in the transmission of noise as the result of changeable weather conditions are taken as average from an energy point of view.
   This is satisfied by the use of the system preferred meteo-conditions (meteo-restrictions).
3. The contribution of reflections against a facade lying immediately behind the immission point is left out of consideration when measuring. Should these reflections make any contribution, an adjustment, is made for this.
4. The measuring height is 5 metres.

The zone must encircle the whole area which will obtain a noise level of 50 dB(A) or more due to the industrial estate. In this the following are not taken into consideration:

- incidental rises in the noise level as a result of operating indisposition.
  In general, regularly re-occurring work breakdowns are not included in this. Whether an increase can be considered as a disaster or falls within the range of typical operating conditions, must be judged by the Authority granting the licence.
- exceptional sounds that are not typical for operating conditions.
  The amount of the maximum permissible rise as well as the operating conditions and the sources which cause these, must be stated separately in the licence.

In zoning procedures, contrary to licencing procedures, no account needs to be taken of the eventual tonal or impuls-like character of the noise.

The noise load of the facade

For noise-sensitive objects which lie within a noise zone, the maximum permissible noise-load of the facade should be determined

The same initial points apply to this as to the "noise-load from an industrial area". The noise-load of the facade is determined at the most sensitive point of the facade.
In general a measuring height of 5 m can be taken for this.
If, however, it can reasonably be expected that, at a different height on the facade, the noise-load will be considerably higher (e.g. in the case of screening objects between source and receiver), the noise-load at that height will be the criterion. The meteo-adjustment is taken at the facade height. If the highest point of the facade of the dwelling is lower than 5 metres a correspondingly lower measuring height can be maintained.

Reproducibility and representativeness

Reproducibility.

One of the most important conditions for carrying out sound measurements and calculations is that the results can be reproduced. This means that should the measurement or calculations be repeated at any other time at random and/or by other people with different equipment, the same results should be obtained within the set accuracy margin and naturally within the conditions of the method. No value can be placed on results which do not satisfy these conditions.

For the sake of the required reproducibility, agreements should be reached with regard to the conditions under which the measurements are made and/or to what the calculations refer.
It is important to differentiate between:
- representative operating conditions
- representative noise transmission.

The operating conditions are the determing factor for the noise production.
A factory is able to influence this. The variations in the noise-transmission are, where the distances are long, accidental and erratic. Attempts must be made to separate the variations in the noise production as much as possible
- both quantitatively and qualitatively - from those in the transmission.

Representative operating conditions.

Measurements in an industry must be carried out as far as possible in representative operating conditions, that is to say, the results of the measuring/calculating must be characteristic of the noise situation over a day, evening or night period. With each measurement of a sound source, therefore, a technical description is also required. The detailedness of this description is determined by the purpose of the measurement and the information available. The description of the operating conditions often forms, in practice, the weakest link in the measuring of noise. The operating conditions, the measuring position and the measuring conditions form, together with the measured noise levels, one entity. If one of these items is excluded then, in general, the result cannot be used.

As a rule the following belongs to the factors which have to be determined:
- the number and type of separate sources belonging to the industry to be investigated,
- geometrical dimensions,
- the operating conditions such as the installations in operation, power, if any, number of revolutions (rpm), production capacity used, etc.,
- the operating periods.

But other data, too, relevant to the noise production have to be determined because the noise emission from a work can sometimes alter considerably without alterations in operating conditions. It often happens that the personnel from the industry in question say that everything has remained normal whilst the noise production has indeed changed. A typical example to such a case is the opening of doors and windows in typical transmission limiting walls.

The measuring period should be such that the result is not influenced by the choice of the time when measuring begins. The measuring period depends on the type of noise. It will often be unnecessary to measure during the whole of the day, evening, night period. It will be sufficient to make one measurement during a short period under representative operating conditions.
If, during the day, evening, night period, more and different operating conditions arise, then the assessment data can be established by means of a few additional calculations from the measuring results per separate operating condition.

In very large or complex works (petrochemical, steel works, sugar factories) it may occur that separate operating conditions cannot be established as separate entities. In these cases measuring can be done on the random test system. It is also advisable in such a case to describe, as far as possible, the operating conditions during the measurement.
The measurements are usually taken "close to source" because of high background noise level. The noise-contours are usually calculated and plotted by means of computers, plotters, etc. If possible, the contours are checked by noise immission measurements on clearly defined reference-points.

Interpolation conditions.

Noise-contours are often required for planning purposes. A noise-contour is a line which connects points of the same sound-level with each other (at a given measuring height). When a contour is constructed from measuring data consisting of a limited number of points it is necessary:
- to take into account the way in which the noise propagates (spherical, plane, screening effects),
- to make no interpolations for points for which the transmission differs strongly from the nearby other measuring points.

Linear interpolation can also be made between a number of measured or calculated immission-points provided the following conditions are observed:
- the difference in sound level between the points must be less than 5 dB
- the distance from the new point to the source area, must be greater than the distance between the two points between which interpolation is made.

BUFFER ZONES FOR NOISE CONTROL

Warren D. Renew

Division of Noise Abatement and Air Pollution Control

ABSTRACT

In order to assist Local Authorities in planning for noise control the Division of Noise Abatement and Air Pollution Control has prepared certain guidelines. Appropriate buffer distances between developments and residential areas are a necessary factor in these guidelines. This paper discusses the bases on which buffer distances are prepared and presents a table of buffer distances for typical developments in rural and suburban areas.

RECOMMENDED BUFFER ZONES FOR NOISE CONTROL

1.0 INTRODUCTION

If we lived in a Utopian world, we would not be bothered by environmental noise. Road, rail and air traffic would not annoy us because, by a combination of engineering design and proper location through town planning, noise from these sources would be almost inaudible. Similarly, industries would be located in industrial areas sufficiently far removed from residences, hospitals, schools and the like. The problem is that noise annoyance cannot be entirely eliminated: many of society's basic needs involve plant and equipment that emit significant levels of noise. There is thus a conflict between competing land uses: developers seek to establish profitable enterprises (for example factories, sports centres) which generate noise in some fashion, while residents seek to preserve the amenity of their neighbourhood and the value of their properties. It is the responsibility of the town planner to address and solve this problem.

2.0 STATUTORY REQUIREMENTS

There are so many facets of industrial noise that its control requires the involvement of local government as well as central government. For this reason, the Queensland Noise Abatement Act provides for the responsibility of noise abatement in the planning stage to be shared between Local Authorities and the Noise Abatement Authority. Under Section 13 of the Act, Local Authorities are required to consider the noise aspects of any development proposal made to them. If a Local Authority decides that excessive noise is likely to result from the implementation of any proposal, it is required to refer that proposal to the Authority for its decision. The Authority has the power to issue a Noise Abatement Order or Licence in respect of the proposal.

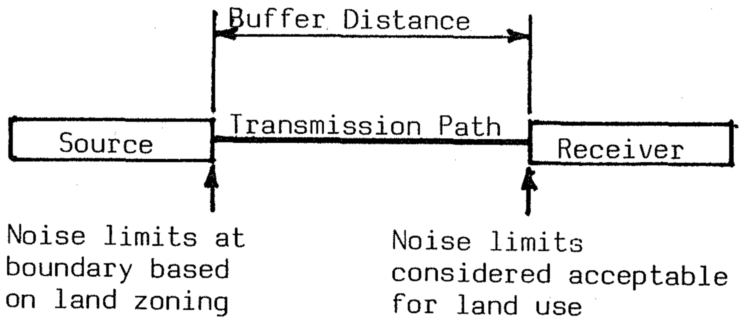
3.0 TOWN PLANNING

Land use can be controlled by several means (Clawson M.): zoning (the most important), subdivision regulations, building codes and health requirements. The aim of the town planner is to restrict intrusion of discordant land uses, particularly into residential areas. Zoning is a means of delineating areas having different land uses. Its use as a noise control tool is in grouping noisier enterprises together and separating them from noise sensitive areas by appropriate buffer zones. It is recognised that certain enterprises produce comparatively high noise levels which cannot readily be attenuated.

The establishment of Crown Industrial Estates has assisted in locating such enterprises in areas dedicated exclusively to industry. Complaints have been received about noise from several Industrial Estates, so it is essential that they are situated at a sufficient distance from residential areas. Planning within the Estates should be aimed at locating noisier enterprises towards the centre so as to take advantage of the shielding effect provided by surrounding buildings. One factor which must be kept under surveillance is the background (i.e. L_{90}) noise level in the area around an Industrial Estate. If the Local Authority does not give continuing consideration to the expected noise emissions from additional enterprises in an Estate, the background noise level will gradually rise and lower the amenity of the area. Noise zoning, as practised in countries such as the United Kingdom and the Netherlands, is aimed at preventing creeping background noise.

4.0 THE NOISE SYSTEM

4.1 Relationship Between Components. The noise system shown in Figure 1 has three components: the source, the transmission path and the receiver.



The equation employed for effecting the calculation for a source at ground level may be written:

$$L_p = L_w + D - 20 \log_{10} r - 8 - \Sigma R \quad \text{dB}$$

where L_p = the sound pressure level at the receiver
L_w = the sound power level of the source
R = the sum of the other losses in the system due to meteorological effects, barriers, ground attenuation.
r = the distance between the source and the receiver (metres).
D = a directivity index for the source

It is evident that the value of the noise level at the receiver can be reduced to an acceptable level by proper selection of the transmission distance. However, this method of noise control can be rather restrictive in terms of the use of the surrounding land, particularly if the land is suitable for residential development. In practice, an acceptable noise limit can be attained by a combination of noise control measures affecting the three components of the noise system. Table 1 summarises the possible means of noise control and the areas of involvement of responsible parties. It is apparent that it is only by co-operation between the developer, the Local Authority and the Noise Abatement Authority that the development can proceed, in many instances, without creating annoyance in the surrounding areas.

TABLE 1

Involvement of Parties in Noise Control

Noise System Component	Noise Control Measures
Source	Developer: 1. Equipment selection 2. Process design 3. Silencers 4. Enclosures 5. Building design 6. Orientation of buildings
	Local Authority: 1. Permit conditions 1.1 Noise limits at boundary of site. 1.2 Hours of operation 1.3 Building design
	Noise Abatement Authority: 1. Labelling of equipment 2. Advise on noise abatement
	Receiver: 1. Object to development
Transmission Path	Developer: 1. Location of activities and buildings on site 2. Orientation of plant 3. Erect barriers
	Local Authority: 1. Specify buffer distances in Town Plan 2. Preserve any natural barriers
	Noise Abatement Authority: 1. Recommend buffer distances in guidelines 2. Advise on barrier design

Noise System Component	Noise Control Measures
Receiver	Developer: 1. Purchase affected houses 2. Pay for acoustical treatment of houses
	Local Authority: 1. Advise residents on layout and design of houses 2. Refer proposal to Noise Abatement Authority

Noise Abatement Authority:
1. Advise Local Authorities on noise abatement
2. Issue Orders or Licences
3. Investigate complaints

Receiver:
1. Complain to Noise Abatement Authority
2. Complain to developer
3. Upgrade acoustical properties of house
4. Erect acoustical barriers

4.2 Source Noise Levels

Noise levels measured in the vicinity of typical noise sources which produce annoyance in the community are shown in Table 2. For comparison purposes the values of sound pressure level are expressed at a distance of 100 m. It is evident that there is a considerable difference between the maximum and minimum values in each noise category. Such differences are the result of factors such as size and design of plant, level of activity, operational methods and effectiveness of noise reduction measures.

TABLE 2

Noise Levels of Typical Noise Sources at 100 m

Noise Source	Sound Pressure Level (dB(A)) $L_{av\ max\ adj}$ *
Quarries	65 - 74
Concrete batching plants	50 - 68
Timber mills	61 - 74
Shopping centres	40 - 58
Engineering workshops	52 - 83
Joinery works	44 - 58
Concrete block works	67 - 73
Squash centres	39 - 47
Indoor cricket centres	42 - 57

* Values of sound pressure level have been adjusted where appropriate for tonal and impulsive character.

4.3 Acceptable Noise Levels. Before a suitable buffer distance can be estimated for a given noise system, it is necessary that an acceptable noise limit be prescribed at the receiver. As Table 1 indicates, this prescription can be made by the Local Authority or the Noise Abatement Authority. The acceptable level in any given situation may be contained in regulations or in guidelines which indicate levels that the Noise Abatement Authority considers to be achievable, due allowance having been taken of factors other than noise. The Division has issued guidelines in connection with several types of noise source (extractive industries, standby generators) which are intended to produce a consistent approach to noise control.

A set of desirable or target noise levels, on the other hand, represents noise levels which are considered appropriate in the long term when they could be included in regulations. For example, a typical set of target noise levels has been used by the Division over the last five years for assessing development proposals and complaint situations (Renew, 1984). These levels, which are expressed as values of L_{10} and L_{90}, are based upon noise levels generally recorded in the various land use areas. A similar set of recommended outdoor background (L_{90}) levels is contained in the Noise Control Manual used in New South Wales (State Pollution Control Commission). Certain Local Authorities in Queensland have incorporated in their town plans a set of noise limits applied at the boundaries of premises in several land use zones. Certain organiisations in Australia favour the use of energy-based noise criteria.

A set of acceptable noise limits is based upon the results of community noise surveys. An analysis of the results of such surveys in Australia has recently been reported (Renew, 1986). This study indicates that, in recent surveys in Brisbane and Adelaide, measured values of L_{90} are generally lower than those contained in Australian Standard AS1055, which are for use in situations where the background level cannot conveniently be measured. Table 3 indicates target at acceptable values of L_{10} in general residential areas.

TABLE 3

Target and acceptable L_{10} outdoor noise levels [dB(A)]

Period	Target Level	Acceptable Level
Day (7.00 am - 6.00 pm)	50	55
Evening (6.00 pm - 10.00 pm)	45	50
Night (10.00 pm - 7.00 am)	40	45

4.4 Buffer Distances for Planning Purposes. The chief cause of noise problems is the location of noisy enterprises too close to residences. To assist Local Authorities in deciding whether certain proposals should be permitted, a set of generally suitable buffer distances would appear to be an invaluable guide. Such a guide is presented in Figure 2 which is a set of distances which have proven sufficient in normal situations to attenuate noise from typical sources to acceptable levels.

Because there is often considerable variation in the levels of noise emitted by certain sources, Figure 2 contains zones of acceptable distance. The width of a zone depends upon factors such as: the sound power level of the source, the effectiveness of any silencers, enclosures around the source and barriers in the transmission path, the nature of the terrain separating source and receiver and meteorological effects. A suitable buffer distance for a particular industry will be considerably lengthened if evening and night operations are to be carried out. If, say, a factory intended to operate up to 10.00 p.m., so that the acceptable noise level for the area would fall by, say, 5 dB(A), the required buffer distance would need to be increased by a factor of about 1.8. However, if noisier activities are avoided or if doors and windows are kept shut, work could proceed at the site without the acceptable noise level being exceeded. In a similar manner, any pronounced tonality or impulsivity in a major noise source would attract an adjustment of up to 5 dB(A) which would necessitate an increase in the buffer distance.

CONCLUSION

A set of buffer distances has been presented to assist town planners in forestalling many of the noise problems that result from the location of development projects too close to residential areas.

ACKNOWLEDGMENT

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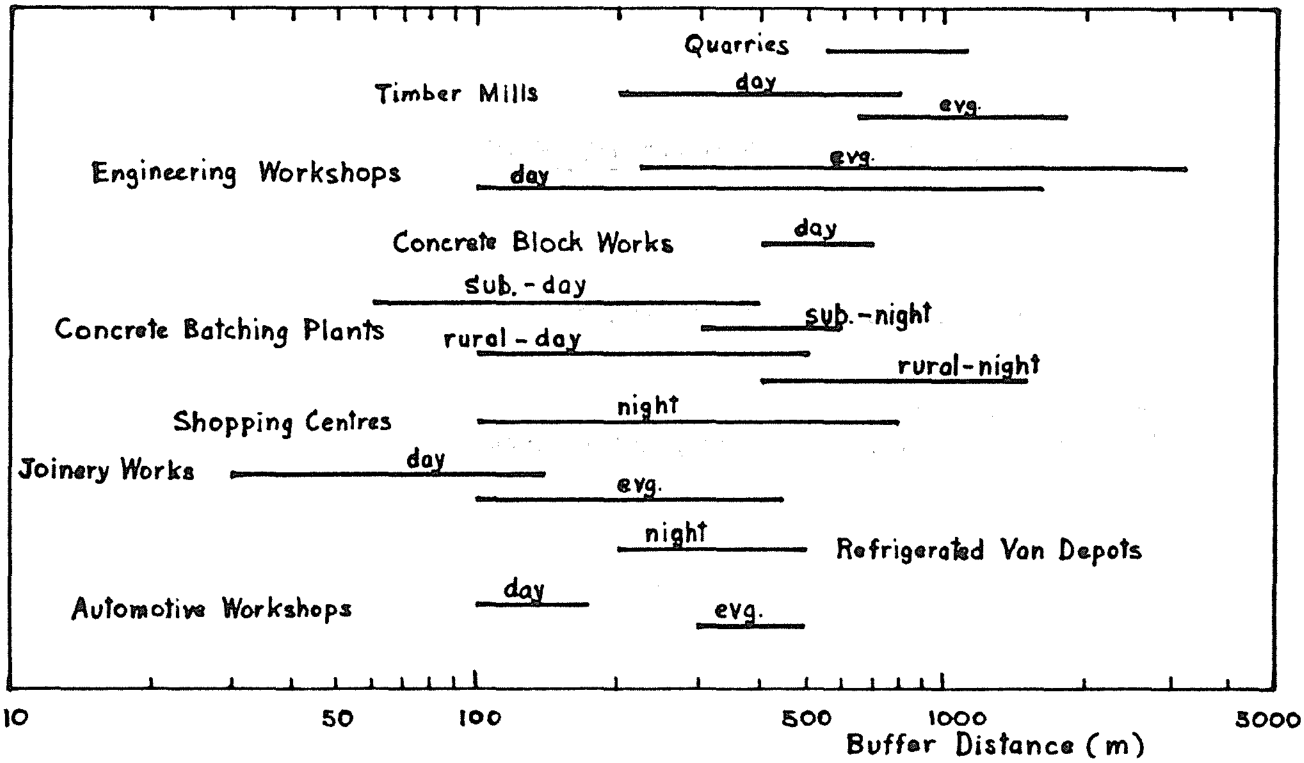

Fig. 2(a). Buffer Distances for Industry

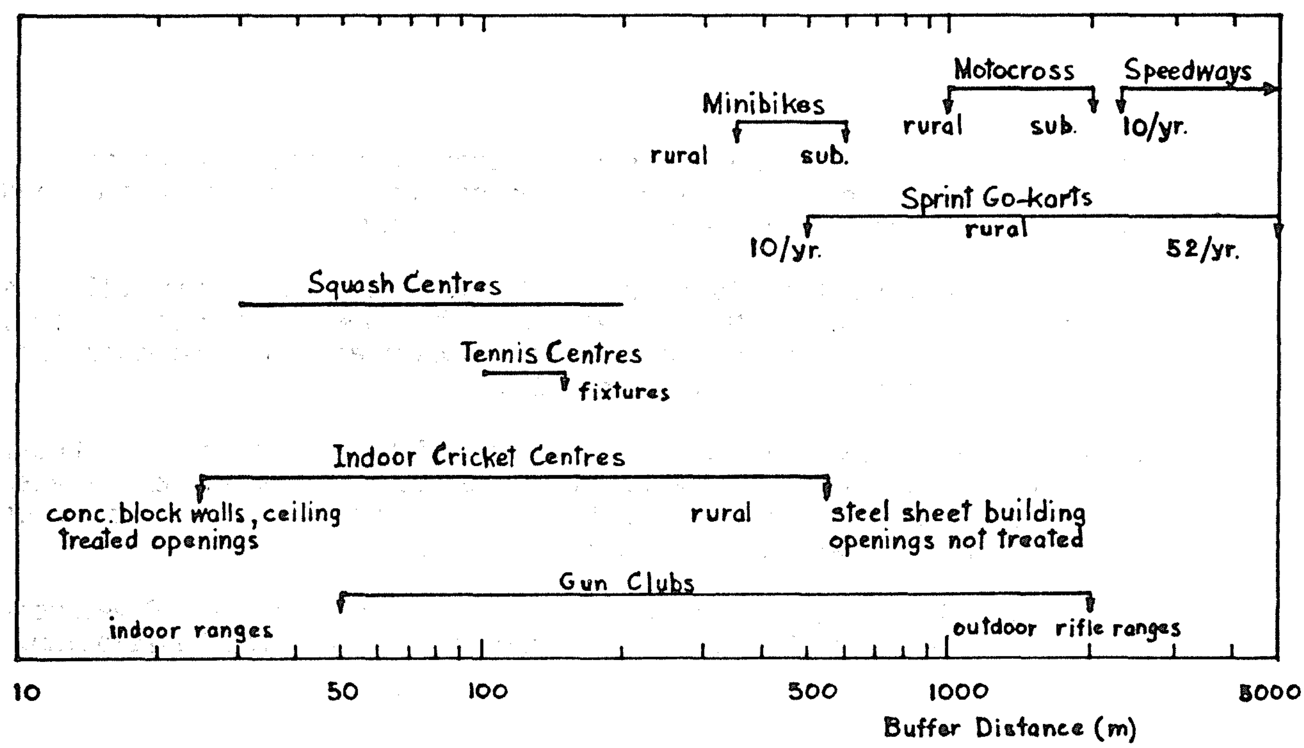

Fig. 2(b). Buffer Distances for Sporting Centres

NOISE CONTROL - A LOCAL AUTHORITY VIEWPOINT

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ABSTRACT

The viewpoint of a Queensland Local Authority's Health Department is given to the structure, control and enforcement of Noise Control and legislation as it exists in Queensland at present.

The paper examines the distribution of noise control responsibilities between the Division of Noise Abatement, The Queensland Police Force, The Queensland Licensing Commission, Department of Harbours and Marines and Queensland Local Authorities.

Delegation of authority from the Division of Noise Abatement to Local Authorities with regard to sections of the Noise Abatement Act is also discussed from the Local Authorities viewpoint and a breakdown of noise complaint investigations results is tabled.

The discussion will be of value to Local Authorities, Government Departments and individuals in the field of Noise Control Legislation.

1.0

DIVISION OF NOISE CONTROL RESPONSIBILITY

Noise Control and Legislation in the State of Queensland is currently enforced by five different State Government bodies, the Division of Noise Abatement, the Licensing Commission, the Police Force, the Railway Department and the Department of Harbours and Marine, one Commonwealth Government Department, the Department of Aviation and the Shire, City and Town Councils spread throughout the area.

The main Noise Control Legislation in force in Queensland is the Noise Abatement Act 1978 - 1983 and this is enforced by the Division of Noise Abatement, The Queensland Police Force and by Local Authorities using delegated powers from the Division of Noise Abatement under Section 9 of the Act.

Queenslands Division of Noise Abatement is responsible for the control of noise emission from commercial and industrial premises such as factories, quarries, workshops, tennis and squash courts, large construction and demolition sites and refrigeration and air-conditioning units in commercial premises.

Local Authorities can use delegated authority from the Division of Noise Abatement to deal with these matters in their local areas and this will be discussed further, later in this paper.

The Police Force in Queensland is responsible for administering the sections of the Noise Abatement Act dealing with excessive noise from musical instruments and rowdy premises and this gives them powers of seizing, removing, rendering inoperable, locking or sealing any property used to produce excessive noise

Noise from vehicles on roads is controlled by the Police under the provisions of the Queensland Traffic Act and noise from off road vehicles is also controlled by the Police under the requirements of the Noise Abatement Act. The Police are also required to control the excessive noise from audible alarms under the Audible Alarm Regulation of the Noise Abatement Act.

Control of noise such as amplified music from licensed clubs, hotels, restaurants and motels is carried out by the Queensland Licensing Commission under the provisions of the Queensland Liquor Act.

Responsibility for the control of noise from waterways, lies with the Department of Harbours and Marine, Local Port Authorities or Harbour Boards while the control of noise from rail traffic and air traffic comes within the auspices of the Queensland Railway Department and the Commonwealth Department of Aviation respectively.

This leaves only noise from domestic or residential premises. The control of such noise excluding amplified music and rowdy behaviour, as detailed earlier, is the responsibility of Queensland Local Authorities within their Local Authority areas. Domestic noise is noise emitted from private residences, recreation grounds, public places, reclamation sites, churches and halls and is controlled by the provisions of the By-laws of the Council of the area.

2.0

REFERRAL OF DEVELOPMENT APPLICATIONS AND DELEGATION OF AUTHORITY UNDER NOISE ABATEMENT ACT 1978 - 1983

Under Section 13 of the Noise Abatement Act 1978 - 1983 Local Authorities are required to refer any applications for development which they consider may give rise to excessive noise to the Noise Abatement Authority.

In Maroochy Shire the referral is carried out after the approval of Council is given and it is a requirement of Council's approval that all noise control measurements recommended by the Authority become conditions of Council Development approval.

It is considered that in this way, future excessive noise problems from such developments can be controlled and more desirable living standards can be attained for the benefit of all Shire residents and visitors.

Section 9 of the Noise Abatement Act allows the Noise Abatement Authority to delegate all or any of its functions, authorities, duties, powers and discretions under the Act to a Local Authority with the consent of that Local Authority.

Maroochy Shire Council was given delegated power from the Noise Abatement Authority in August, 1981 for the investigation of excessive noise complaints under Section 10 of the Act. This power was extended in October 1982 to give Council the authority to restrict hours of operation on commercial construction sites and to issue Noise Abatement Orders relating to these premises without the requirement of a Show Cause hearing.

These delegated powers have enabled the Council to deal with local excessive noise problems from commercial and industrial premises more quickly and more conveniently than if the complaints had to be referred to the Authority. In dealing with these complaints at a local level, an inspection of the complaint can be carried out at most times by Council's Health Surveyors and therefore does not require the Authority's inspectors to travel long distances to carry out the same inspections.

The following table is a summary of noise complaints received by Maroochy Shire Council and those dealt with under delegated authority from the Authority.

Noise Complaints 1984 - 86

	Complaint Source	Number
1.	Animals	116
2.	Refrigeration Motors	28
3.	Power Tools	51
4.	Other	82

No. Referred to Division - 10

3.0

NOISE CONTROL - IS IT EFFECTIVE

Having set out earlier the method of Noise Control available to Local Authorities it is perhaps more relevant to examine whether the system works. Firstly "Does the Noise Abatement Authority obtain results" - from our experience the answer is definitely yes, but in many cases, over far too long a time span. By a narrow margin, the most common complaint received by my Council for which the Authority has responsibility is noise from refrigeration motors associated with local or neighbourhood shops. (The problem seldom arises from large shopping centres as they are usually not close enough to houses to matter).

My Council under delegated authority is able to inspect the premises quickly (as demanded by the complainant) and usually the offender is advised of the existance of a nuisance and requested to remedy same. At this early stage a preliminary assessment of the complaint is completed and forwarded to the Authority for record purposes. Non compliance with notice results in my Council requesting the Authority to take the matter up formally and directly with the offender. This can take some time as the Authority has considerable demand placed on its time. With a not too tough approach, the Authority pursues the matter until a result is achieved. Because considerable time is taken the complainant believes that no one is doing anything for them.

It is worthy of consideration for the Authority to expand the scope of delegation and allow Local Authorities to serve an initial or preliminary order on offenders. This could be subject to the preliminary assessment being examined and considered to be reasonably sound by the Authority.

Final proof and Court action would remain the responsibility of the Authority. It is recognised that established procedures would need to be followed and that Local Authority Staff Training be adequate to support the Authority in any resulting Court action. It is my belief that the power to impose orders on behalf of the Noise Abatement Authority would considerably speed up results in many cases.

It was mentioned earlier that my Council has this extended authority relative to building sites and whilst building has been quiet of recent years, the power given to my Council was used on two occasions with complete effect.

The next area of most common complaint is noise from extractive industry and its by-products - regrettably not usually machines on the site but trucks going to and from quarry sites. In our area during busy times many complaints arose from empty trucks bouncing along roads to quarries as early as 3.00 a.m. to get in line for loading. These complaints are genuine as are complaints arising from large truck motors being started up in pre-dawn hours in quiet residential areas. There is little that can be done about these matters at the present time under the Noise Abatement Act and some would argue that there is no need to make further laws in this regard, nonetheless it is an area of considerable complaint and causes discomfort in our society.

My Council enjoys a close working relationship with the Noise Abatement Authority and in the majority of cases that we have shared over recent years, satisfactory results have been obtained on all but a few.

The majority of people seem to be aware that any excessive noise from a party or amplified music is a problem for the Police and because we have easy access to local Police Officers, most complaints are remedied within a reasonable time. Those that are not, arise from extremely selfish people aware of the limitations of lawful remedies and the need only to turn the appliance down when Police are in the near vicinity. Unless the noise is heard by the Officers and deemed to be excessive, action is seldom taken.
The area in which my Council finds our Police Officers to be a little reluctant and far less successful is in noise complaints arising from vehicles other than on a road. Noisy motorbikes being ridden by under age riders on private property on weekends pose problems for both Police and Council . Usually Police strength is lower on weekends when the demand occurs and more important tasks require their attention. As well, bike riding in rough country not easily accessible by car make offenders difficult to catch, and even more difficult to do something positive about as the offenders are minors seeking only to have a good time. The solution to this problem is not known, some argue that bikes should be confiscated, others will maintain that such activity is desirable and that Council should provide areas in which bikes can be ridden so as not to cause nuisance.

In any holiday area revelry and rowdy behaviour occur, most commonly in licensed premises particularly those having entertainment lasting into the early hours of the morning. Complaints arise from several areas - Loud bands or disco music - Crowd noise from patrons leaving the premises (perhaps after too much to drink) and from motor vehicles arriving at or leaving the premises. The Licensing Commission accepts responsibility for such premises and if complaint can be justified, the Commission usually responds by refusing late licences or imposing conditions that ensure a reasonable result. It is possible to deal with the level of entertainment noise arising from a premises, but people noise after the premises are closed causes some concern and is best controlled with the assistance of Local Police.

My Council's only real problem in regard to noise from licensed premises is that once again the power base for action is in Brisbane and by the time responsible Officers are able to assess the complaint the holidaymakers, unit occupiers or the like have left the area with an unfavourable opinion. It is believed that both the Police and the Local Authority could receive more positive delegated authority from the Licencing Commission to assist in dealing with these complaints. Licencees have much to lose if they fail to respond to a reasonable order for Noise Abatement.

Since the implementation of the Noise Abatement Act, very few complaints have arisen from water based activity, therefore, I do not propose to enlarge further on this aspect of Noise Control.

The last major role for discussion is that of the Local Authority. To a large extent the success or otherwise of noise control rests with the whim of the elected representatives. Our most common complaints arise from the keeping of animals, e.g. dogs and roosters.

To a lesser extent the backyard hobbyist or businessman causes problems. We find noise complaints from animals by far the most difficult to solve. "No ones dog barks too much and the crowing of a rooster surely couldn't bother anyone". People are sensitive about their pets and a great deal of time is used arriving at satisfactory results from these complaints. My Council has NOT yet adopted the Model Noise By-law but operates on objective opinion if a noise "disturbs the quietude of the neighbourhood" then it is a nuisance, I regret to say that while successful in the past this approach is losing credibility. It now appears necessary that Officers need to measure the sound level and duration of noise before it can be sutstantiated as a nuisance, experience shows that better results are achieved when offenders can be shown on a noise meter that their dog barks at say, 70 decibels, than by an Officer saying that in his opinion the bark of a dog is a nuisance. It is surely a sign of the times that hard copy is more credible than opinion.

Maroochy Council has had considerable success with animal noise complaints in its own area of responsibility, I believe because it takes the time to recognise that a complaint has been made, to investigate that complaint and to follow it through to prosecution if necessary. We have had less success with power tool noise complaints despite the same attention, our biggest problem in this regard appears to be that such noise is made outside normal working hours and is difficult to catch offenders in the act.

Despite publicity elsewhere, few complaints arise from swimming pool motors, lawn mowers or air conditioners. Some problems arise from residential construction but are usually remedied by one inspection and advice to builders of By-law requirements.

It is fair to say that the Noise Abatement Act of this State has proved to be workable and with only a few changes provides the means for prompt and permanent resolution of Noise Complaints.

ACOUSTICS FOR TOWN PLANNERS : A COOKBOOK APPROACH

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ABSTRACT

This paper presents a simple, reasonably accurate procedure for carrying out noise planning calculations. It assumes no detailed knowledge of the subject, each aspect of the calculation being explained in simple terms.

The technique employed is a cookbook approach, with the parameters being presented in a series of graphs and tables.

The calculations are performed using an A-weighted (dBA) format. To make allowance for the different attenuation rates occurring for different frequencies, the paper characterises noise sources according to their dominating frequency content. The various attenuation parameters are then plotted for each type of noise source.

An example is used to illustrate the procedure.

1.0 INTRODUCTION

Planning for noise control has become an accepted and significant part of Town Planning. This adds acoustics to the already large repertoire of scientific and professional skills that the Planner is required to master.

He can always call on the assistance of a Consultant. In many instances, this may be prudent, even necessary. But what of the small job that cannot justify the expense of a Consultant? What of the preliminary project where it is to early to call in the troops?

It is necessary for a Town Planner to have some degree of self-sufficiency in acoustics. The object of this paper is to fulfil this need without requiring the Planner to reach for his textbooks. It provides a simple, reasonably accurate calculation procedure, using a series of graphs and tables; a cookbook approach.

1.1 The object of noise planning is to match the noise exposure at each location to the proposed use of the area and thereby avoid noise annoyance. This can apply to the planning of a new development or to the replanning of an existing situation of noise conflict; the principles aad procedures involved are the same.

The procedure includes two distinct stages. Stage I is the calculation of the noise level perceived at each significant location, taking account of the various noise sources affecting the site and geometrical factors such as distance, topography, vegetation and barriers. Stage 2 involves establishing an acceptable noise criterion for the particular location and comparing this with the perceived level calculated in Stage I.

If the perceived noise level is unacceptably high, changes can be made to any or all of the planning parameters until the conflict is resolved.

2.0 METHOD

2.1 The Planning Equation. The noise planning parameters can be expressed in the form of an equation:-

$$L_P = L_W - A_O - \Sigma A_N$$

where:- L_P is the perceived noise level
L_W is the sound power level of the source
A_O is the distance attenuation
A_N are additional attenuation caused by barriers, enclosures, vegetation and climatic conditions.

For simplicity all of these parameters are expressed as A-weighted decibel quantities (dBA).

The above equation has four terms. Any three of the four can be chosen independently, but once values are allocated to these three, the fourth becomes a planning constraint.

For example, if the sound source is fixed (L_W), the distance to neighbouring properties is set (A_O) and the added attenuation (A_N) determined by geometry, then the planning constraint becomes the perceived noise level (L_P). The use of the adjoining property must then be allocated so that the perceived noise level is consistent for that use. It becomes a *Consistent Adjacent Zone Constraint.*

Similarly an *Allowable Noise Source Constraint* is the case when A_O, A_N and L_P are defined. The sound power emitted from the source (L_W) must then be regulated to be acceptable.

Separation or Buffer Zoning Constraint occurs when only the distance A_O remains uncommitted.

The use of added attenuation A_N in the form of plant enclosures, barriers, fences, mounds and plantings could be realistically called *Conditional Approval.* This last category has an obvious application to existing lawful non-conforming uses where these infringe on existing residential zonings.

3.0 NOISE PLANNING DATA

3.1 Planning Parameters. To achieve the desired simplicity of use, the planning parameters (L_P, L_W, A_O, A_N) have been reduced to the form of tables and graphs. An A-weighted (dBA) format is used for all data so that the calculations can retain the form of simple additions and subtractions.

This use of the 'dBA' format introduces a minor complication because it communicates no information on the frequency composition of the noise. Two noises with the same A-weighted noise level could have widely different frequency composition. In general, high frequencies attenuate more easily than low frequencies so the various noise abatement measures (A_O, A_N) would be more effective on the high frequency noise.

To incorporate frequency information into the data, a spectral representation would be required, such as the octave band spectrum. Using such spectra in the calculation is undoubtedly more rigorous, but also increases the complexity of the calculations manyfold. To avoid this, three basic noise types have been defined:-

Type 1 - Low-frequency dominated noise such as low-speed diesel engines, air-cooled refrigeration condensing units, domestic air-conditioners, rock music.

Type 2 - Mid-frequency dominated noise such as high-speed engines, electric motor whine, reciprocating compressors.

Type 3 - High-frequency dominated noise such as squeaking brakes, dry bearings.

This classification is a compromise between accuracy and simplicity. A rounding off error is introduced but in most cases would be within 2 to 3 dBA; adequate for planning purposes. If an instance should arise where a noise does not clearly fit into any single noise type, it should be placed in the lowest likely category so that any error will be conservative. For example, if a noise could be either Type 1 or Type 2, consider it as Type 1.

3.2 The Sound Power Level (L_W) emitted by a noise source can be determined from simple measurements, using the technique described in AS1217 - 1972 - Section 3 "Methods of Measurement of Airborne Sound Emitted by Machines". This method entails the measurement of noise levels at various prescribed positions surrounding the source, from which L_W is calculated using the inverse square law of sound propagation.

The A-weighted sound power levels of some representative noise sources and their appropriate noise type classifications are listed in Table 1, produced from a number of personal investigations and measurements. This is not intended to be an exhaustive list, but more in the nature of a "starter kit". With time, it could be added to, each new measurement carried out by the health surveyors or noise inspectors adding a new piece of data.

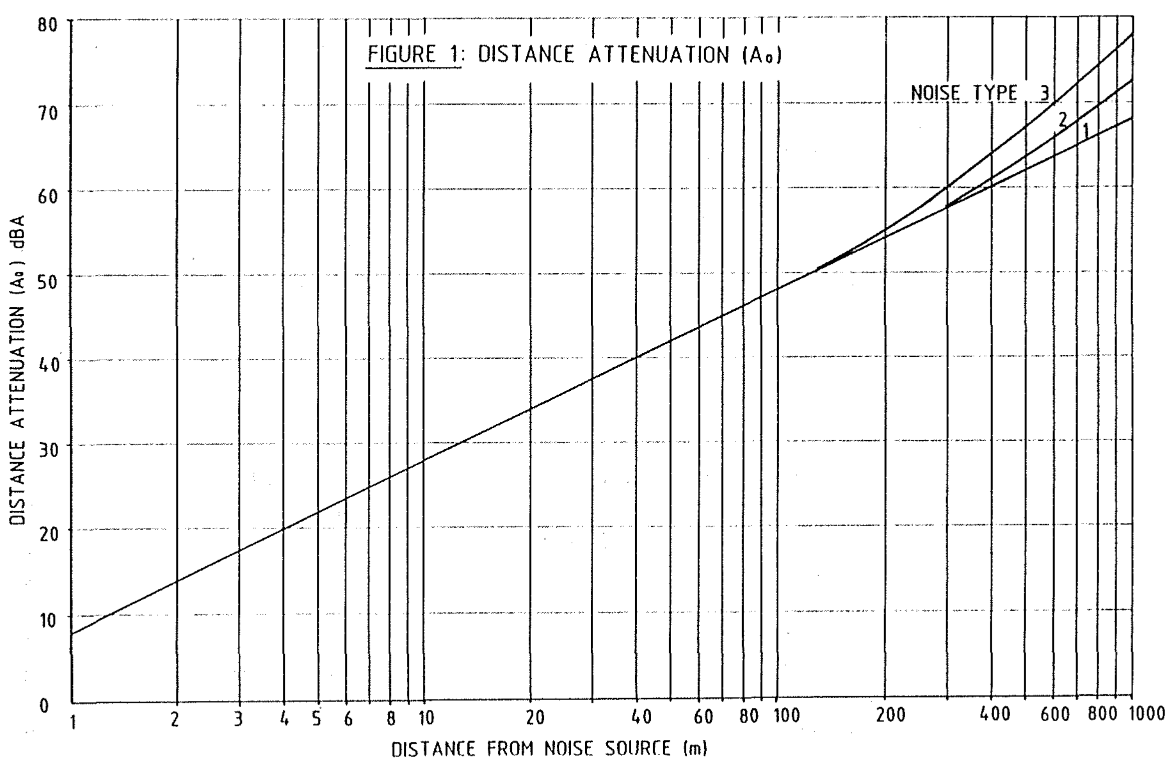
Table 1: Sound Power Levels and Noise Type Classification of Various Sources

	Noise Source	L_W (dBA re 10^{-12} watts)	Noise Type
Industrial:	Pneumatic chipping	123	2
	Hammering steel plate	110 - 120	2
	Grinding steel plate	105 - 120	2
	Arc-air gouging	125	3
	Oil furnace	95	1
	Sand blasting	100	1
Quarrying:	Rock drilling	125	2
	Crushing plant (jaw or cone)	110 - 115	1
	Screening plant	110 - 115	2
	Front-end loader (2 stroke)	120	2
	Diesel truck	110	2
Woodworking:	Circular saw	120	3
	Planer/thicknesser	105 - 120	2
	Router/edger	110	2
	Moulder	110 - 120	2
Commercial:	Outdoor entertainment	100 - 120	1 or 2
	Outdoor advertising/music	95 - 105	2

3.3 Distance Attenuation (A_0) is plotted in Figure 1 as a function of the distance from the noise source. This graph follows an inverse square law close to the noise source, but diverges at greater distances due to the effects of air absorption. These absorption corrections have been calculated in the manner recommended by (Beranek).

Figure 1 assumes a theoretical *point source* of sound, a condition that many practical sources do not fulfil. Figure 1 can be used with larger sources, for example the open doorway of a large factory building, providing the separating distance is much greater (eg 20 times) the dimensions of the source.

Figure 1 applies only to outdoor propagation, with no significant vertical reflecting surfaces occurring in the vicinity. A significant surface is one of dimensions greater than the sonic wavelength, which for practical purposes can be taken as 1 to 2 m. Sound can reflect from such a surface in a manner similar to the reflection of light by a mirror. So, depending on the size, location and orientation of a reflecting surface, it can add as much as 3 dBA to the perceived noise level.

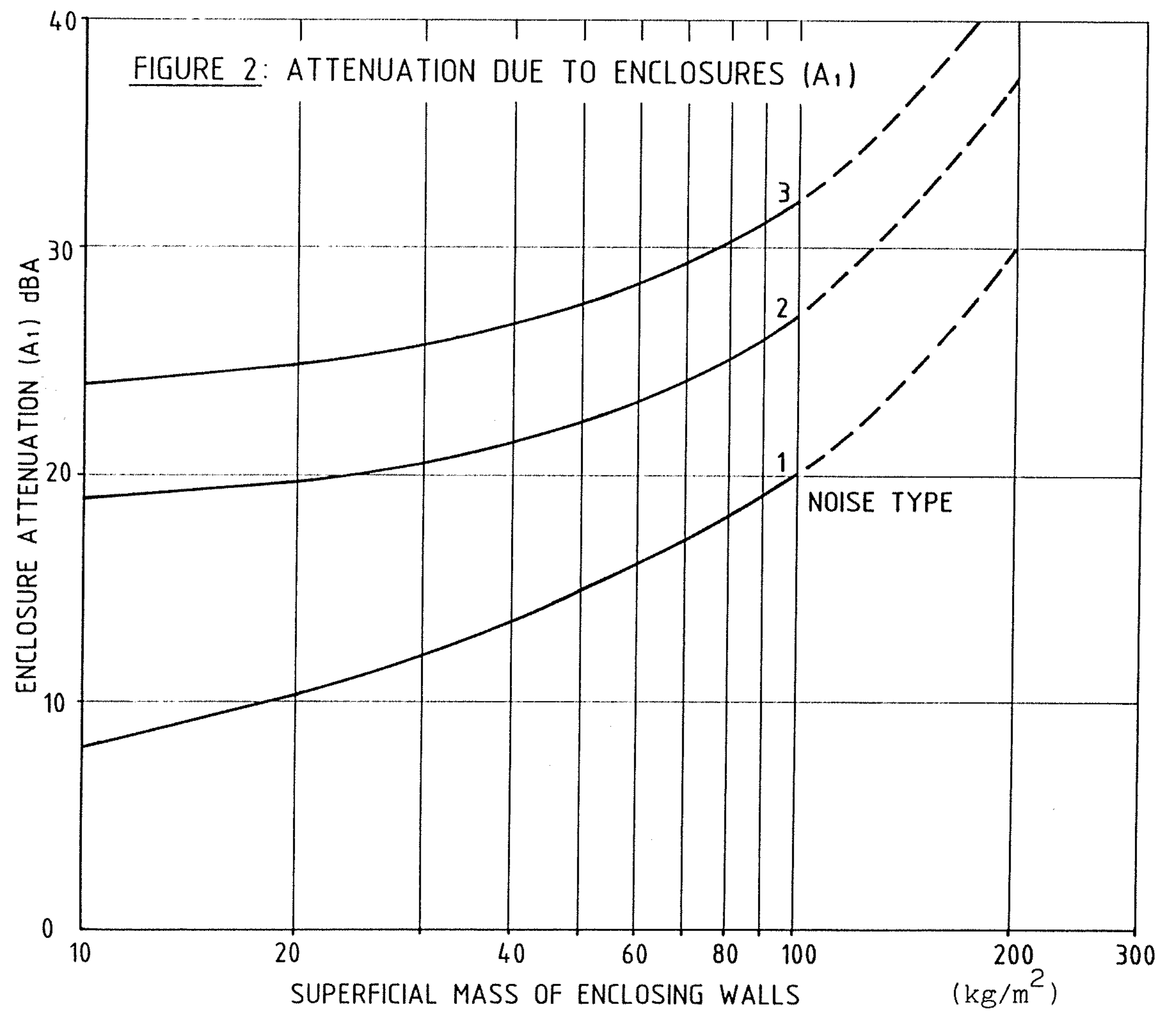


3.4 Attenuation Due to Enclosures (A_1) either surrounding the noise source, or surrounding the noise recipient, is given graphically in Figure 2, produced from transmission loss data published by (Weston et al).

Of all the noise planning parameters, this is the most difficult to generalise. The attenuation produced by an enclosure depends on many variables, including the size and orientation of the enclosure, the amount and disposition of sound absorbing material inside the enclosure, the mass per unit area of the enclosure structure and the existence of any weakness in the acoustical envelope such as windows and doorways.

To retain the required simplicity only 'typical' enclosures have been considered; up to 500 m^3 in volume, having no acoustical absorption treatment internally and having a distance of separation from recipients at least 10 times the maximum dimension of the facing wall. Non-conforming cases would need to be calculated independently.

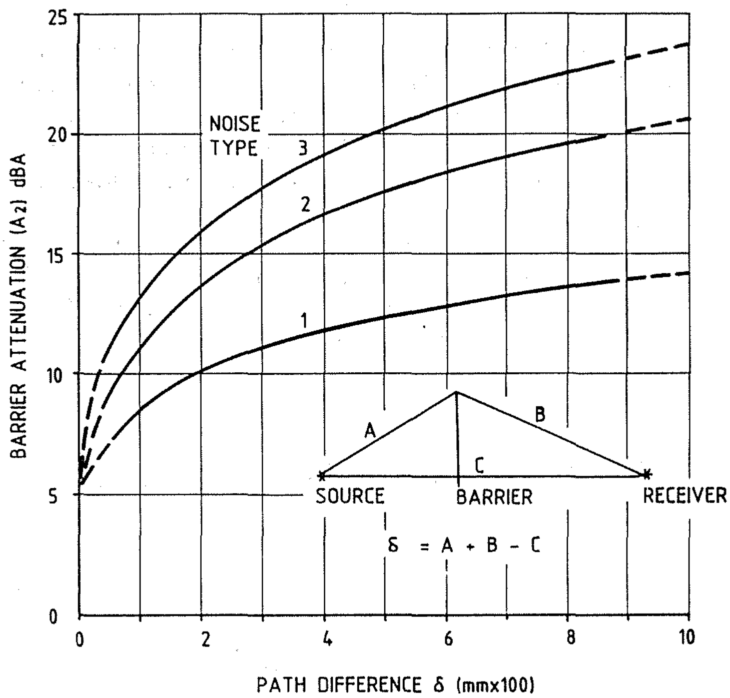
To use Figure 2, one first determines the superficial mass of the enclosure walls. If composite constructions are used, the weakest section is considered. The attenuation is then read from the graph according to the particular noise type.



3.5 Attenuation due to barriers (A_2) is to be found in Figure 3 which has been developed from the classical diffraction theory and the work of (Maekawa and Foss).

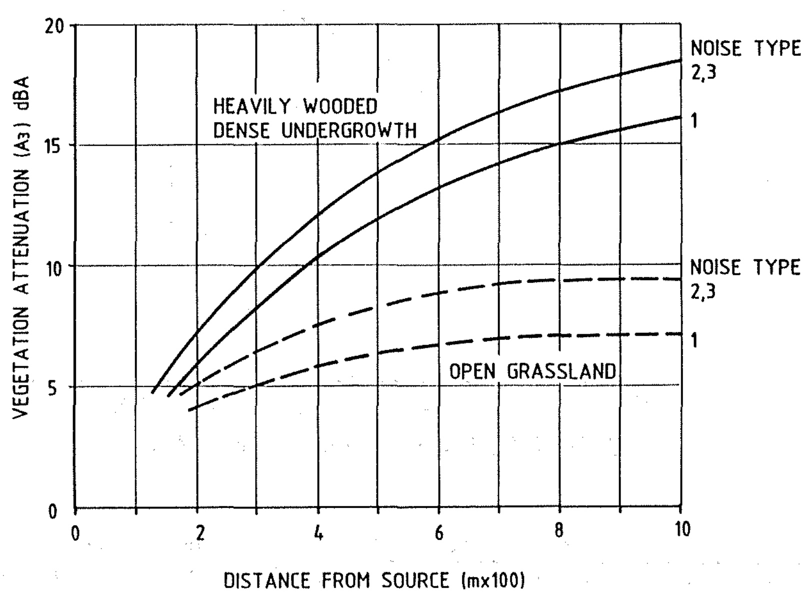
The attenuation (A_2) is expressed as a function of the noise path difference caused by the introduction of the barrier. The path difference is calculated geometrically and the corresponding attenuation read from the graph.

FIGURE 3: BARRIER ATTENUATION (A_2)



3.6 Attenuation Due to Vegetation (A_3) Figure 4 is self-explanatory, the added attenuation being expressed as a function of the depth of vegetation for the various noise types and for various vegetation types.

FIGURE 4: ATTENUATION DUE TO VEGETATION (A_3)



3.7 Attenuation Due to Climatic Conditions (A_4) Barometric pressure, temperature, relative humidity and wind all affect the propagation of sound, but the changes are only significant at distances greater than 1 km. All of these factors can produce vertical gradients in the air which can cause bending of the normally straight sound rays. This re-direction, if towards the ground, can reinforce the noise level and conversely, if away from the ground can produce a *sound shadow*.

In the case of wind, it is not as popularly believed the wind blowing the sound along, but a re-direction caused by wind gradients. A *shadow zone* is created upwind and a *bright zone* down wind.

The changes to the perceived noise level depend on the frequency of the noise as well as the atmospheric factors, with high frequencies being affected more.

Typical figures for low frequency Type 1 noise would be ± 5 dBA, that is 5 dBA added attenuation in the shadow zone (upwind) and 5 dBA added sound level in the bright zone. For Type 2 and Type 3 noises the figure could be as high as ± 15 dBA.

3.8 Acceptable Noise Levels are usually defined by local by-laws or regulations. In the absence of statutory limits, (AS1055) defines techniques for assessing an acceptable noise level criteria both for existing developments and for proposed future developments.

3.9 Multiple Noise Sources can be readily handled using the techniques already described. Each individual noise source is treated separately as if it alone was contributing to the perceived noise level at the recipient site(s). The combined noise level is then found by the logarithmic addition of the various individual contributions. This calculation is simplified in Table 2.

For example, if there are two sources with individual level contributions of 50 dBA and 55 dBA, their level difference would be 55 - 50 = 5 dBA. From Table 2, the corresponding adjustment is found to be 1 dBA. This is added to the larger of the two sources, giving an effective combined noise level in this case of 56 dBA.

When there are more than two noise sources, the same tables can be used. The individual L_p's are first listed in descending order. The bottom two are combined into one using the previous method and this *running sub-total* is combined successively with the next on the list until all sound sources have been included.

Table 2 - For Combining Sound Sources

Level Difference (dBA)	Adjustment (dBA) (added to greater level)
0 or 1	3
2 or 3	2
4 to 9	1
10 or more	0

4.0 EXAMPLE - HYPOTHETICAL CASE STUDY - BRINGING IT ALL TOGETHER

A contemporary gravel crushing/screening operation is proposed within 1 km of a residential development, but is screened by medium density vegetation. The acceptable noise level according to by-laws is 40 dBA at the residential boundary. The noise sources are:-

(a)	Crushing Plant	L_W = 115 dBA, Type 1
(b)	Screens	L_W = 115 dBA, Type 2
(c)	Front-end Loader	L_W = 120 dBA, Type 2
(d)	Diesel Truck	L_W = 110 dBA, Type 2

Planning Equation: $L_P = L_W - A_0 - \Sigma A_N$

For source (a) alone :	$L_W(a)$	= 115 dBA	
A_0: Distance attenuation for 1 km, Type 1		= 68 dBA	Figure 1
A_3: Attenuation due to medium vegetation, Type 1		= 12 dBA	Figure 4
Other attenuation, enclosures, barriers		= 0	

Therefore, perceived level due to source (a)

	$L_{P(a)}$	= 36 dBA
Similarly for others:	$L_{P(b)}$	= 27 dBA
	$L_{P(c)}$	= 34 dBA
	$L_{P(d)}$	= 24 dBA
Combined Total		= 38 dBA
Acceptable Noise Level		= 40 dBA

Conclusion: Proposed development should not produce noise annoyance.

5.0 CONCLUSION

The aim of this paper has been to present a simple method of carrying out noise planning calculations.

It may attract some criticism because of the approximations used and non-adherence to conventional terminology. However, this was necessary in the interests of simplicity.

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AN INFORMATION CAMPAIGN DESIGNED TO INFLUENCE BEHAVIOUR

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ABSTRACT

The past decade has seen the development in the Netherlands of a legislative framework designed to reduce noise pollution from what are known as "non-personal" sources. However, there have been no such measures to deal with noise-generating behaviour by individuals, which is the main cause of "neighbour noise" in and around the home. Information is seen as the best means of dealing with such behaviour, which is the second most serious source of noise pollution in the Netherlands.

The NSG (Dutch Noise Abatement Society), which is a private organization, has been waging a publicity campaign, with government support, to promote noise-conscious behaviour. In addition to expertise on noise control, expertise on mass communications was brought in through the involvement of professional advertisers.

The outlay on the campaign to date has been just over US$ 4 million, which is a fraction of the expenditure allotted to control the greatest source of noise pollution in the country, namely road traffic. The measurable effects of the campaign are already sufficient to justify such an outlay for the control of neighbour noise.

This paper describes why and how the campaign was launched, and what the results have been so far.

1.0 INTRODUCTION

In the 1960s the realization grew, in the Netherlands and elsewhere, that noise pollution is a serious environmental problem in its own right, and that government intervention is desirable. In the Netherlands this led, in the 1970s, to the updating of existing legislation and the promulgation of the Noise Abatement Act.
The intention was that in the 1980s and 1990s the main "non-personal" sources of noise in the Netherlands (road traffic, aviation, industry, recreational establishments and rail traffic) should be suitably modified, by "cleaning up" existing instances of noise pollution and preventing the development of new ones.
Regarding the second greatest source of noise pollution, neighbour noise, the then environment minister saw information as the answer. Legislation was in general seen as impracticable and undesirable. There was a definite conviction that what was really needed was a change in attitude, and that this would also enable the legislation on non-personal sources to function more smoothly. On the one hand, it was felt that laws can only work properly if they are backed up by a general sense of justice and fairness. On the other hand, individual behaviour can counteract the effects of technical, legal and organizational measures designed to limit noise pollution in general. This is particularly true with regard to neighbour noise.
In view of all this, the NSG decided to call in an advertising agency to devise a publicity campaign which would promote noise-conscious behaviour particularly in and around the home. The NSG was unique in the Netherlands in already having years of experience with public information on noise pollution. Futhermore, a campaign designed to influence behaviour would come across as less paternalistic if launched by an independent body such as the NSG rather than the government. Acting with government support, the NSG was able to launch a large-scale information campaign in 1977.

2.0 METHOD

The campaign was organized in three phases:

1. drawing public attention to the issue of noise pollution, and introducing the NSG as the national information centre on noise problems;
2. bringing about a change in attitude, involving acceptance of the need for noise-conscious behaviour and for discussion between annoyed and noise-causers;
3. translating the positive attitudes of those Dutch people who are prepared to take action or are otherwise well-intentioned into actual noise-conscious behaviour.

Such a campaign can only function optimally if research is carried out into the effects. In this way, the design of the campaign can if necessary be altered halfway. Information is also periodically provided about the current phase of the campaign and about how to proceed further. Specific details can also be periodically adjusted so that the optimal effect is achieved.

<u>2.1 Phase 1.</u> In this initial phase, it was decided that the campaign should introduce the topic with suitable caution. Since noise pollution is not considered a major issue by those not directly affected, it was necessary to avoid a shocking, accusing, peremptory or paternalistic approach. The subject was broached in a roundabout way:"Nuisance is always caused by someone else. And, if you're on the receiving end, you may wonder if it would be rude to say something about it." Our intention was to create in our target audience willingness to think about the subject, perhaps even to realize that they too might be responsible for causing some kind of nuisance.
For our media campaign, we deliberately chose a broad rather than a deep approach. The size and frequency of advertisement were kept low-key, again so as to avoid creating any discrepancy between the importance of the subject and the attention paid to it. The advertisements were published in daily newspapers and weekly magazines. Use was also made of free publicity. Posters and a leaflet were available on request (fig. 1 and 2).

fig. 1. One of the first posters.

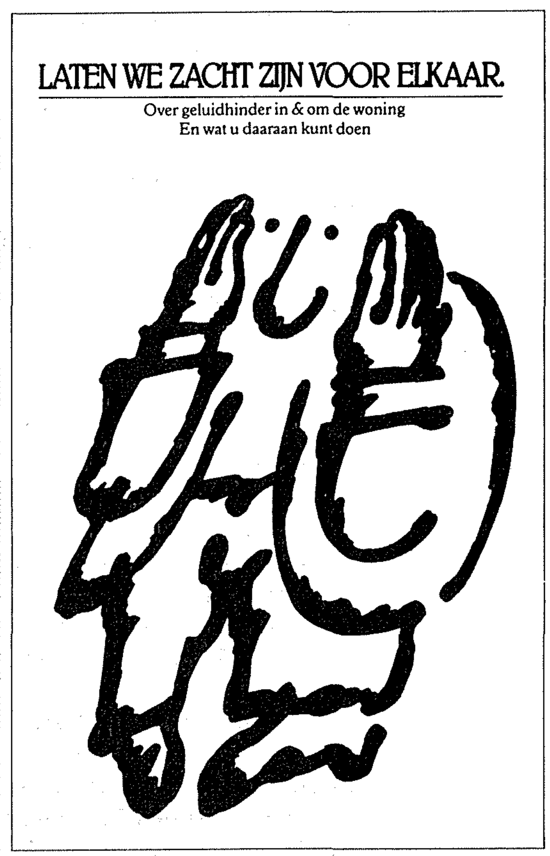

fig. 2. A leaflet with further information.

2.2 Phase 2. Phase 1 was designed to create a fertile soil for a change in attitude. In Phase 2 our goals were as follows:
- establishing a direct link between the annoyed and the noise-causer
- hinting at the willingness of others to discuss their own noise-generating behaviour
- creating greater self-recognition on the part of the target audience
- creating awareness that everyone occasionally behaves in such a way as to cause nuisance, and that everyone should therefore be prepared to discuss the nuisance they cause. And conversely that everyone should feel free to raise the subject with anyone else.

The second phase therefore included more specific identification of normal everyday noise situations (see fig. 3).
As regards the media, we again deliberately chose a broad rather than a deep approach, although rather less so than in Phase 1. For the same reasons as in Phase 1, the size and frequency of advertisements were kept unobtrusive. This time, however, the range of different media was expanded. In addition to advertisement in dailies and weeklies, use was made of radio and television advertising. The NSG regularly had stands at major exhibitions, and a PR man was employed to handle free publicity.
Stickers (fig. 4) were made available in addition to the existing posters and leaflet.

fig. 3. Advertisement about an every-day situation.

fig. 4. Stickers; "Noise is nasty", "Honking makes crazy", etc.

<u>2.3 Phases 2 and 3.</u> By the end of 1979 a clear pattern had begun to emerge in the target group.

About one-third of the total target group could be considered as unbenevolent and/or indifferent. In addition to a large category (about 60%) of passively well-intentioned people, there was also a definite "well-intentioned" group.

Although Phase 2 was not yet completed, the development of subgroups within the target group made it necessary to make a start with Phase 3. For a number of years, therefore, the campaign operated halfway between Phase 2 and 3.

Differing approaches were chosen to deal with the different target groups.

A so-called "emotional campaign" was devised for the "unbenevolent and/or indifferent" category. Here the subject was presented in a dramatic/emotional manner in press and TV-advertisements (see fig. 5). The press advertisements appeared mainly in so-called "gossip magazines", as well as in various appropriate family magazines.

Small advertisements were also published on the editorial pages of national and regional newspapers; these were chiefly aimed at the "passively well-intentioned" group. With this group the principal of "out of sight, out of mind" applied, and it therefore proved necessary to repeat the essentials of the message in order to help bring about a change in attitude. What this meant in practice was that Phase 2 was simply continued as far as this first and second group were concerned. Finally, the still small "well-intentioned" group was now ready to put

fig. 5. An emotional advertisement.

fig. 6. Range of aids.

into practice its (altered) views regarding noise pollution. This group had therefore to be provided with behavioural models, alternatives, and other assistance. This made it necessary to commence Phase 3. A start was therefore made on what were known as "small-scale" activities, mainly to help this group. A series of booklets on specific topics, a teaching package for use in schools, and a mobile stand (for exhibitions, schools and local authorities) were developed and made available free of charge (see fig. 6).
Following the American example, an ECHO (Each Community Helps Others) project was started especially for activists in community associations, pressure groups, political parties and local authorities. This enabled authorities and action groups to exchange knowledge and experience on similar noise pollution problems.

2.4 Phase 3. By the end of 1981 it was apparent that practically the entire population of the Netherlands was not only aware of the problems regarding noise, but was also familiar with our campaign. There was also greater willingness to take action, and accordingly it was decided to move on to Phase 3, without however neglecting Phase 2 altogether. Since 1982 the campaign has therefore been based on a twofold "communication target", with increasing stress on the second element:
(a) continued efforts to influence attitudes and behaviour;
(b) concrete back-up in the form of behavioural models and provision of assistance.

This is in accordance with the phasing of the campaign as decided at the outset. Back then, in 1977, we started with the following mild reaction from the annoyed: "They're making a noise, should I say something about it?" For some years now we have been at the stage where the annoyed has started to stand up for himself and speak his mind: "I'm easygoing as a rule, but I'm not going to stand for that noise". This development can be detected not only in the words used, but also in the visual methods adopted: from caricatures of noise-causers (fig. 1), through dramatic and lifelike portrayals of the annoyed (fig. 2), to pictures showing both causer and the annoyed. (fig. 7)

fig. 7. Relaxed atmosphere for solving the problem together.

The campaign logo and slogan were adapted accordingly. In 1984, the rather "soft" approach reflected in the slogan "Be quiet with each other" (In Dutch also = "Be gentle to each other") was replaced by a tougher, shorter, more direct and therefore clearer message: "You can't live with noise".
The original all-in-one strategy has given way to a segmented approach, with separate messages geared to specific target groups. This results in highly concrete information and attitude modification with regard to various noise pollution problems, on the premise that each noise pollution situation involves two sides: the annoyed and the causer.

3.0 RESULTS

The requests for information and advice received by the NSG in the course of the campaign reveal the following:

- as the NSG became better known, the annual number of requests at first rose rapidly, then decreased again and eventually stabilized;
- during the first few years the requests were more for information, but in recent years the percentage of requests for advice (which are more difficult to answer) has been increasing;
- in recent years people with noise problems have had a clearer idea of how to get in touch with the NSG, even in the absence of messages in the mass media;
- the percentage of requests for information and advice from noise-causers has significantly increased (currently around 35%).

Measurements of the effects over the last few years shows:

- that practically the entire population of the Netherlands (over 90%) is aware of the problems regarding noise (in mass communication terms this is the maximum);
- that a large majority (60-70%) of Dutch people agree with us that discussion is the most appropriate initial response to neighbour noise;
- that complaints about excessive noise are considered to be socially acceptable behaviour, although most people prefer not to react at once;
- that in over 40% of instances of neighbour noise, there is discussion between causer and annoyed;
- that some 60% of noise-causers approached claim to have taken (a great deal of) account of the complaints;
- that in over 60% of cases where discussion has taken place, the noise problem has been (partially) eliminated;
- that over the last 5 years neighbour noise in the Netherlands has been reduced by about one-quarter.

4.0 DISCUSSION

An information campaign such as the one under discussion, is considered, not only in the Netherlands but internationally, as a low-cost noise pollution control measure. To date our campaign has cost just over US$ 4 million. This can be set against an observed decrease of around 25% in the number of persons annoyed by their neighbours, although the question remains to what extent this is the result of the campaign.

No recent figures are available concerning the extent of noise pollution caused by road traffic, aviation and industry in the Netherlands. The only possible comparison between the measures adopted to control noise pollution from these sources and the information campaign to reduce neighbour noise is therefore a financial one. Thus, for example, an annual sum of between US$ 8 and 16 million has been set aside merely to prevent in the Netherlands new instances of noise pollution from road traffic.

5.0 CONCLUSION

Since behaviour by individuals is a major, if not the major, factor in neighbour noise, technical measures (such as improved sound insulation in and between dwellings) would appear to be inadequate, and (additional) legislative controls ineffective and perhaps undesirable. Our experience shows that, from the cost-benefit point of view (inter alia), an information campaign designed to modify individual behaviour trough the mass media is a valid alternative means of limiting neighbour noise.

We consider the following essential to such a campaign:

- a professional approach to both mass communications (involvement of advertising and PR experts) and the content of the information, supported by good follow-up in terms of individual information and advice;
- periodic measurement of the effects by means of sociological research.

Influencing behaviour is a lengthy business, in which the same message has to be got across gradually, if necessary in different packaging. A maintenance campaign (entailing less effort) will be necessary in the long term in order to ensure that the message is not forgotten and that the results are not allowed to slip away after so much has been put into achieving them.

TRAINING OF AUTHORISED OFFICERS AND THE ENVIRONMENTAL NOISE CONTROL MANUAL

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ABSTRACT

The Noise Control Act was modified in 1984: to extend the powers of authorised officers; to enable their 24-hour operation when required; and to delineate the responsibilities of the State Pollution Control Commission, the Police, local government and the Maritime Services Board.

Training and authorisation of these officers takes place through various special courses which will be outlined in the paper.

A training document entitled "Environmental Noise Control Manual" was prepared for instruction purposes. Details will be given regarding the production, review process, content and use of the manual.

THE NOISE CONTROL ACT

The Noise Control Act was introduced into New South Wales legislation in 1975. The Act placed certain responsibilities on local government and the Maritime Services Board for the control of noise.

The State Pollution Control Commission provided a program to train officers from these authorities as a prerequisite to authorising them under the Act. Authorised officers have power to enforce various sections of the Act and its Regulation.

In 1984 the Noise Control (Amendment) Act was passed, substantially increasing the powers and responsibilities of local government and authorised officers.

AWARENESS OF THE 1984 AMENDMENT

The magnitude of the amendment made it necessary to familiarise those authorised officers who may be engaged in noise control work with the changes introduced by the new Act.

Towards the end of 1984 a series of 24 one-day seminars was held at various centres throughout the state: 22 for local government officers and one each for Police and Maritime Services Board officers. By this means a total of over 700 officers were made aware of the details of the amendment.

TRAINING SCHEMES

Training courses were also revised to encompass the changes in the amended Noise Control Act.

Police, Maritime Services Board and local government officers have different powers under the Act. Consequently, training courses designed for them are different for each, varying in complexity according to their requirements.

Police

Members of the Police Force are empowered by the Noise Control Act to issue noise abatement directions for the immediate control of noise on a short term basis.

Police Officers exclusively now have power under the amendment to forcibly enter premises in order to issue or enforce a noise abatement direction. Prior to the amendment the power of forcible entry was also held by officers of other authorities.

Licensing Police are concerned with the control of noise from licensed premises. Action is usually taken under the Liquor Act or the Registered Clubs Act. The Commission provides technical support if noise measurement or assessment are required by the Police for presentation in court.

A half-day course conducted by the Commission is incorporated in Police training or refresher courses.

Maritime Services Board

Some clauses of the Noise Control Regulation apply specifically to the control of noise from machinery or people on vessels in navigable waters. These clauses are included in a one-day course for Boating Service Officers of the Maritime Services Board. Over 40 officers have attended this course.

The Commission also conducts a two-day course for Port Authority Inspectors in the major ports of Sydney, Newcastle and Wollongong. This course contains instruction on the issuing of noise control notices under the Act. Field training in noise measurement is also included. Twelve officers of the Board have been authorised after attending the two-day course.

Local Government

The range of operations and degree of competence required by authorised officers of local government are much wider than those of other authorities.

The Commission authorises these officers after attending a comprehensive five-day course which includes visits to industry and practical exercises in noise measurement.

The course is available at two centres. The Department of Technical and Further Education incorporates a noise control option as part of the Associate Diploma course in Health and Building Surveying. Hawkesbury Agricultural College has the same option as part of the Batchelor of Applied Science (Environmental Health) course. Both of these options are conducted mainly by Commission staff.

This year 120 students of Sydney Technical College and 30 students of Hawkesbury Agricultural College will complete the course.

To date over 700 Health and Building Surveyors employed by local councils throughout the state have been authorised by the Commission.

ENVIRONMENTAL NOISE CONTROL MANUAL

Even with the background of a comprehensive training course, authorised officers have had difficulty in assessing equitable noise levels and times of operation for noise control purposes because of the wide range of variables involved. Noise sources could range from helipads to hotels and from speedways to swimming pools.

From the community viewpoint the officer should reduce any particular noise to an acceptable level during acceptable times, while from the polluter's viewpoint he must provide a fair solution which is economically feasible.

The results of local and overseas experience and research were not readily available for authorised officers to make decisions regarding development applications, building approvals, town planning or the investigation of noise complaints.

The Environmental Noise Control Manual was initially developed by the State Pollution Control Commission to fill this need and provide guidelines with respect to noise levels and times of operation for many specific noise sources.

The Goals of the Manual

A number of goals were established at the beginning.

- To write mainly for local government authorised officers, but, at the same time, bear in mind the needs of consultants, industry and the general public.

- To provide guidelines on noise levels, times of operation and general policy applicable to particular situations.

- To ensure consistent action by authorised officers and from council to council.

- To explain and interpret in plain English the Noise Control Act and its Regulation as well as other legislation where reference is made to noise.

- To supply a text for training purposes including the basics of acoustic theory.

- To make reference material available.

Editing

The manual was written by many members of the Noise Control Branch of the Commission. Considerable editorial rewriting was required to ensure consistency of form and style. A dedicated editorial panel of three people proved to be essential. A larger number was found to be too unwieldy.

The creation of the manual from initial concepts to publication in draft form took 18 months.

Review Period

The manual remained in draft form for a review period of 12 months, during which time comment was invited on its form and content.

Useful comment was received from Commission staff, including regional officers, from other government departments, local government, universities, industry, sporting associations and consultants.

There was not always agreement and some arbitrary decisions had to to be made but the comment received enabled ambiguities to be eliminated, complex chapters to be clarified and errors corrected.

The review period was found to be a very fruitful and important part of producing the manual.

At the end of this period the manual was modified where necessary and released for publication in its first edition.

Form of the Manual

The content of the manual is divided into three major segments:

. Noise Control Policies and Responsibilities;
. Noise Control Practices; and
. Reference material.

Each of these segments is divided into parts and each part into chapters.

Indexing

Effectively the manual is indexed in three ways.

. A contents list at the beginning of the document enumerates 131 chapter titles. (A copy of the contents list is included as an appendix to this paper).

. Each of the 13 parts of the manual has its own index in which the chapters of that part are further subdivided into paragraph headings.

. There is also an easy reference chapter indicating the authority responsible for control of noise from various particular noise sources, listing the sections and clauses of the legislation which apply and the chapters of the manual which refer to control of the particular noise source.

Expansion

The manual was intended to be dynamic in the sense that a 90% document was to be produced in loose-leaf form with an updating service to improve and expand the work in accordance with future needs.

Expansion is catered for by individual numbering within each chapter and by provision of unused chapter numbers reserved at the end of each part. Chapters may thus be rewritten and further chapters may be added in each part.

The name and address of the current holder of the manual is registered and new pages will be despatched whenever rewriting becomes necessary. This will occur when the

Act or Regulation are changed or when clarification or additional material are required.

Distribution

The first printing of a thousand copies has been issued; about 700 to authorised officers and most of the remainder to consultants and industry. Other states have shown interest and copies have been requested from New Zealand and France.

Relevance of the Manual

The manual is used extensively throughout the state as a standard reference in the field of noise control by authorised officers, consultants and industry.

It has been presented and accepted in court a number of times as evidence of the Commission's stated policy.

It is used exclusively as text for the training of authorised officers.

Comment received to date has been very favourable.

SUMMARY

Training of authorised officers was necessary from the earliest days because of the complexities of noise control.

Training schemes differ according to the needs of the officers being authorised.

The Environmental Noise Control Manual is fulfilling its purpose of training for the increased responsibilities brought about by the Noise Control (Amendment) Act of 1984.

It is used to provide a statewide consistent approach to noise control.

The manual has proved to be an extremely worthwhile document.

APPENDIX

CONTENTS

COMPUTER PREDICTION OF SYDNEY RESIDENTS AFFECTED BY TRAFFIC NOISE WITH CHANGING MOTOR VEHICLE NOISE EMISSION STANDARDS

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ABSTRACT

Motor vehicle noise emissions are a major source of noise pollution, particularly in urban areas. Quantification of the extent and impact of traffic noise is a complex task. This paper presents a method for predicting the number of people exposed to traffic noise at their residences.

A computer model has been developed to calculate traffic noise exposure of residences in any given area using simple regional data on human and vehicle populations, total road length and vehicle kilometres travelled. Other inputs to the model are vehicle noise levels, the lengths of various categories of road and frequency distributions of traffic counts and traffic speeds in each road category.

Results of the application of this model to Sydney over the years 1965 to 2015 are presented. It is estimated that the number of people seriously affected by traffic noise (i.e. by levels above 65 dBA 24hr Leq) has risen from 142,000 in 1965 to 335,000 in 1985, with the number of people affected by 55 to 65 dBA increasing from 740,000 to 1.2 million over that period. As to the future, if no further motor vehicle controls are introduced then the number of people seriously affected will rise to 734,000 in 2015. For comparison, the results of modelling an alternative, more stringent, control scenario are also presented. In this scenario it is assumed that the standards due for introduction in the European Economic Community (EEC) over 1986 to 1989 are adopted as from 1/1/1990. The number of people seriously affected would be almost halved in the year 2000 to 285,000 and be 390,000 by 2015.

1.0 INTRODUCTION

Traffic noise has been shown to be the major noise pollution problem in developed countries, (OECD and AEC) and there is increasing concern in the community that further controls be adopted.

Some estimates of the numbers of people seriously affected by traffic noise in Australian State capital cities have been made. (The noise level at which people are seriously affected is taken to be 65 dBA on a 24 hour Leq basis as suggested by the OECD, who classify such areas as "black", or unacceptable, while noise levels between 55 and 65 are classified as "grey" or undesirable). For Sydney in 1975 Carr and Wilkinson estimated that about 600,000 people were seriously affected but this was based on an over-simplified approach. For Melbourne in 1983 the AEC (1985) estimated 250,000 people seriously affected. These estimates, being for only one year, could not be used for prediction nor for comparison between scenarios for vehicle controls.

A previous model developed by Stewart and Rogers (1984) in the State Pollution Control Commission (SPCC) was based on regional data of vehicle kilometres travelled (VKT) being converted into a nominal average traffic count, which was used to calculate a notional average noise level for traffic in the region. Changes in VKT, vehicle mix and vehicle noise standards that had previously occurred or that might occur in the future, were then used to calculate and predict the relative <u>change</u> in Sydney's traffic noise levels (on average) over the years 1960 to 2000. The appeal of this model was its simplicity, the ready availability of respected VKT projections (available from air pollution modelling (Stewart et al 1982)) and the way it overcame the fundamental problem of translating vehicle noise measurements (done at a <u>point</u>) into traffic noise (a <u>line</u> source) and further into <u>area</u> - wide overall effects.

This model was useful for comparing the effects of various control scenarios against a background of growth in traffic volumes and was used by the Australian Environment Council (AEC, 1985) for these purposes. It was recognised, of course, that this model was not designed to predict actual noise levels (for comparison, for example, with criteria such as health standards or environmental goals) nor the numbers of people that might be adversely affected.

The model described in this paper (and its attendant database of inputs) was developed in an effort to allow calculation of noise levels, both historically and predictively. The model also enables comparisons to be made of the costs and effects of "vehicle-based" control scenarios with the costs and effects of "non-vehicle-based" scenarios, although this aspect is not reported in this paper.

2.0 METHOD

The model is based primarily on traffic count data. It also uses as inputs: vehicle noise levels, road lengths, VKTs, data on human and vehicle populations and traffic speeds etc. The model manipulates these inputs to estimate the numbers of people affected by traffic noise of various levels at their residences. A schematic flowchart of the model is shown in figure 1 on the next page, and for a more detailed description see SPCC (1986 a).

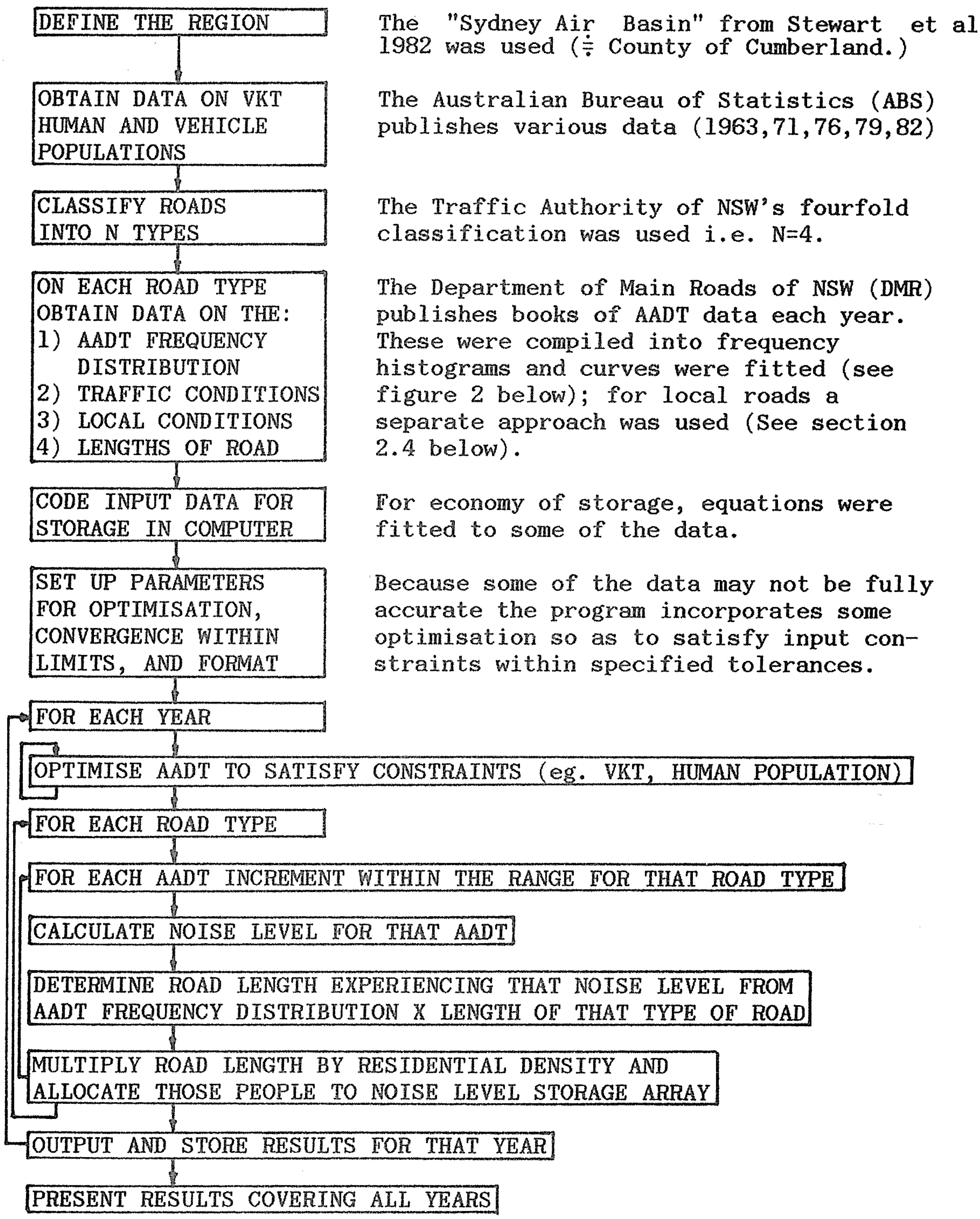


FIGURE 1: SCHEMATIC FLOWCHART OF THE COLLATION OF DATA INPUTS AND THE COMPUTER PROGRAM

2.1 Traffic Count Data in the form of annual average daily traffic (AADT) counts were obtained from the NSW Department of Main Roads (DMR). In order to simplify the analysis of the large number of data points (about 1500 for each year) only data for 1965, 1971, 1977 and 1983 were used, and these were assumed to represent trends from 1965 to 1985. The data points were characterised by fitting equations, the coefficients of which were found to vary in an orderly way with time. This orderliness permitted projections of AADT frequency distributions with some degree of confidence. The AADT data histograms, the curves fitted to them and projections for the years 2000 and 2015 are shown in figure 2. There is potential to improve the fitting of the curves to the data.

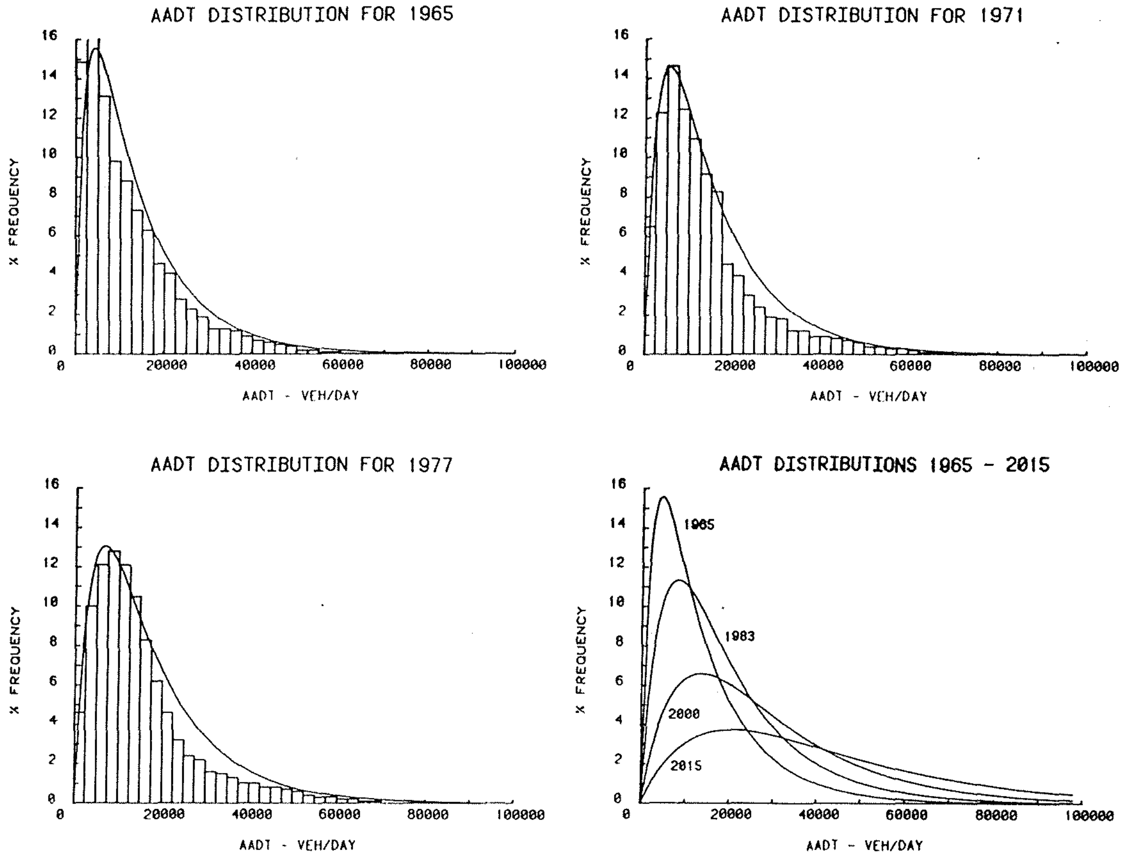


FIGURE 2: AADT FREQUENCY DISTRIBUTIONS

2.2 Road Classification System Enquiries indicated that many criteria are used by authorities for the classification of roads in Australia. The Traffic Authority of NSW has recently (1985) published criteria, summarised in table 1.

Type of Road	Traffic Volume (AADT)	No. Of Lanes	Peak Hour Parking	Right Turn Bays
Local	0-2000	> 2	Yes	No
Collector	2001-10000	> 2	Yes	No
Sub-Arterial	5000-20000	> 4	No	Preferred
Arterial	> 15000	> 4	No	Yes

TABLE 1: FUNCTIONAL CLASSIFICATION OF ROADS - NSW TRAFFIC AUTHORITY

The model has been structured to use any road classification system for which data exists, but for the calculations presented here the classifications shown in table 1 were used, and the conditions estimated to occur on these roads are shown in table 2.

Road Type	Mean Speed (V)	% Heavy Vehicles (P)	Distance to Kerb (D)	Lengths of Road 1983 km	1965 km
Local	35	0	10	11875	9625
Collector	55	2	15	1350	1070
Sub-Arterial	60	5	20	1275	735
Arterial	70	12	25	875	385

TABLE 2 TRAFFIC AND LOCAL CONDITIONS USED AS INPUTS TO THE MODEL

2.3 Determining road lengths for the various road types In 1983, according to the Department of Local Government, Sydney had 1920 km of roads funded either wholly or in part by the DMR and there were 13,438 km of Council-controlled roads. The traffic count distributions on DMR roads were compared to those on Council roads, and it was evident that, whereas the average DMR road carries much more traffic than the average Council road, many Council roads carry substantial traffic flows, and that the lengths of road functioning as arterials and sub-arterials are more than 1920 km. On analysing available data and consulting the DMR and Department of Local Government, the estimates in table 2 above were made for 1983.

Similar estimates were made for 1965 and the points for 1965 and 1983 were joined with simple straight lines and extrapolated to give estimates for years forward to 2015. Due to the lack of available information on the likely extent of road-building activity over the period to 2015 (NAASRA, 1984, covered only the period to 1991) no better than a simple straight line relationship could be posed at this stage. Obviously, there is scope for refinement in this area.

2.4 Consideration of traffic counts on local roads The DMR consider that their AADT data give an accurate representation (i.e. individual AADTs within 10% of true values) of the traffic on arterials and sub-arterials, a reasonable representation of traffic on collector roads but a poor picture of what happens on local roads. The obvious reason is that their primary interest is in the efficient traffic flow and safety of "main" roads. It was thus necessary to consider some alternative way of characterising the frequency distribution of traffic counts on local roads, bearing in mind: a) local roads generate only a fraction of overall VKT; b) traffic counts are so low that noise levels are usually below 55 dBA anyway.

The Traffic Authority (1985) defines local roads as "sub-divisional roads within a particular developed area ... used solely as local access roads...". and having "no through traffic". AADTs were modelled by considering a street closed at one end; the AADT would vary from about zero at the closed end up to a figure at the open end that is related to the dwellings per kilometre of road,the trip generation rate per dwelling and the length of the road. These factors, and the situation on local roads open at both ends, have been modelled (SPCC, 1986 b) to give a frequency distribution of: $p(x) = a \exp(-bx)$, where x is the traffic count and a and b are related to cars per person and residents per km (which change slowly each year).

2.5 Vehicle noise control scenarios Scenario 1 involves no change from the current vehicle standards. For the purpose of modelling an alternative it is assumed as scenario 2 that the standards being introduced in the EEC are implemented from 1/1/90. (These standards are also being canvassed within the UN Economic Commission for Europe (ECE) but no final position has been determined.)

2.6 Calculation of Noise Level was done using the UK's "Welsh Office" method for a position one metre from the building facade. No allowance was made for stop/go driving or for gradient effects. The model's output was desired in the form of a 24 hr Leq average, a form of unit favoured by the OECD. In typical traffic situations the 24 hr Leq average is about 3 dB less than the 18 hour L_{10} level so this conversion was used.

3.0 RESULTS

For scenario 1 the percentage of Sydney residents estimated to be in the "black" and "grey" areas (as defined above) are presented in figure 3, while figure 5 shows the overall frequency distribution. The actual numbers of people in the "black" are presented in figure 4 for both scenarios.

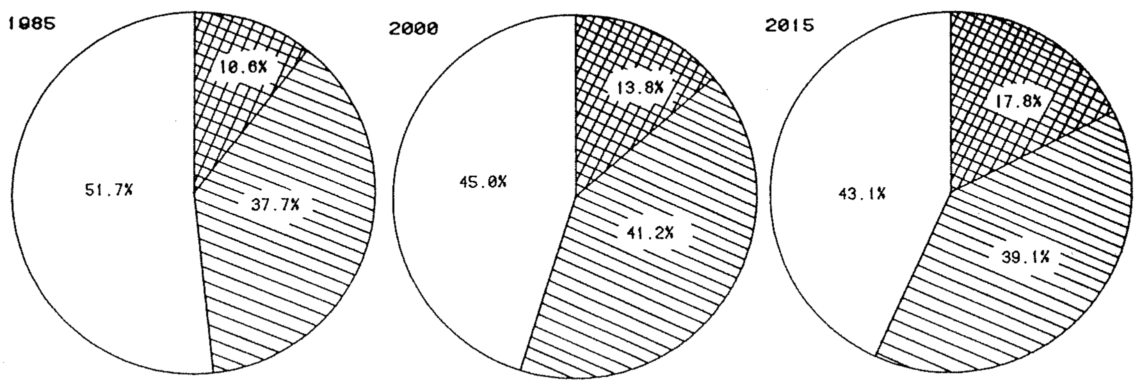
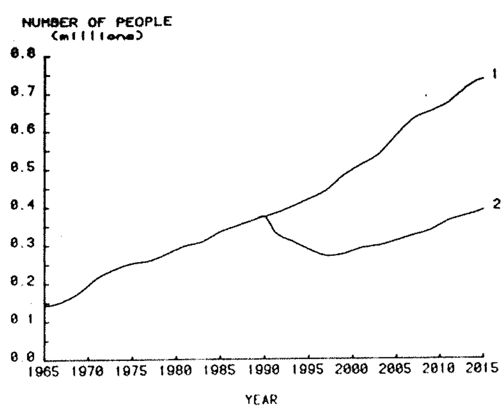


FIGURE 3. PERCENT OF POPULATION EXPOSED TO ROAD TRAFFIC NOISE



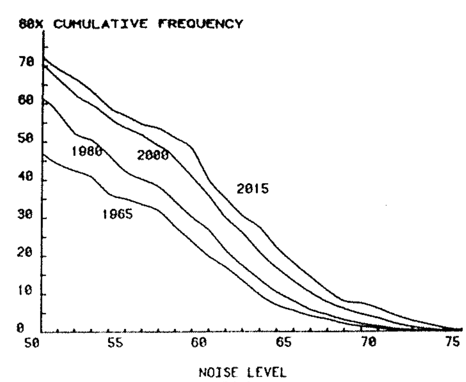


FIGURE 4: NUMBERS OF PEOPLE EXPOSED TO ROAD TRAFFIC NOISE ABOVE 65 dBA 24 HOUR Leq

FIGURE 5: CUMULATIVE FREQUENCY OF PEOPLE EXPOSED TO TRAFFIC NOISE

4.0 DISCUSSION

The model involves some assumptions, which cannot be adequately discussed here and probably underestimates noise levels and the numbers of people affected. These matters are discussed in a more detailed report (SPCC 1986 a).

A number of cross checks are performed in the computer programme: The VKTs calculated before any optimisation was performed varied from the data input by +1.1% in 1965 to -10.5% in 1975 and up to +12.6% in 2015. The slight waviness in figures 4 and 5 is due to the iterative optimisation and the rounding errors involved in storing continuously varying functions in arrays of finite length. The calculated human population differs from the data input by less than 1/2%. Drivers per car varied from 2.39 in 1965 to 1.22 in 2015. The average kilometres travelled (AVKT) per car increased from 12842 in 1965, to 13859 in 1985 and to 15044 in 2015. The proportion of VKT done on local and collector roads varied from 30% in 1965, to 17% in 2000 and to 13% in 2015; it is made to agree within about 25% in 1971 (SATS data) and within about 21% in 1981 (NAASRA data).

Further work could usefully be spent in refining the model and the data inputs; for example although it is an acceptable simplification to combine the relatively few km of freeways at present in Sydney into road type 4, it may be necessary for accurate modelling beyond say 2000 to adopt 5 road types.

It is not yet known if the results of this model can be directly compared with similar calculations done in Europe due to the different methodologies involved. It is interesting, however, to note OECD figures for 1985:

	USA	Denmark	Greece	Norway	Sweden	This paper
> 65 dBA	7%	12%	20%	8%	11%	11%
55-65 dBA	30%	26%	30%	24%	27%	38%

TABLE 3: POPULATIONS EXPOSED TO TRAFFIC NOISE IN OECD COUNTRIES

5.0 CONCLUSIONS

The model appears to be a useful tool for assessing the impact of road traffic noise on a regional basis, although both it and its related data inputs could be refined further.

If the results of the model are correct then the numbers (or percent) of people in Sydney affected by road traffic noise would be as follows:

Thousands of People	1965	1985	2000 Scenario: 1	2000 Scenario: 2	2015 Scenario: 1	2015 Scenario: 2
> 65 dBA	142	335	500 (13.8%)	285	734 (17.8%)	390
55-65 dBA	740	1,190	1,480 (41.2%)	1,540	1,610 (39.1%)	1,860

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A MODEL NOISE BY-LAW IN QUEENSLAND

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ABSTRACT

In 1978 the Queensland Parliament enacted the Noise Abatement Act to provide for the abatement of excessive noise.

Such Act empowered Local Authorities to include in their By-laws, by-laws in relation to the abatement of excessive noise.

To assist Local Authorities and to have some degree of uniformity throughout the State a "Model" By-law was prepared.

No matter where we go in modern society, noise seems to intrude, more than it did in years past, whether it be that trail-bike across the creek, a power boat, a jet overhead, or the heavy footed neighbour leaving early for a big day at the coast.

Many more areas of our lives are being regulated and it should not be surprising to anyone that some control is being placed on the "level of noise" being made in our society.

Queensland is a modern society and it too is meeting the same problems as other states and countries. The result is that special legislation has been introduced which makes provision for By-laws to be made to control noise.

People tend to go about their business sometimes without realizing that what is merely a noise to them could be a nuisance to others.

Without presenting any statistical data, I believe I would find some support in the argument that many people would agree with the proposition that noise, or rather, excessive noise requires attention to prevent it becoming another pollution.

It is my intention not to burden you with boring moments of legal jargon. I feel it is more important to explain to you the Queensland By-Law. However, when considering noise as a nuisance, I am reminded of a case some 100 years ago which touched on the duty of care. Bramwel L.J. said in Hayn v. Culliford (1) the following:-

"It may be asked where is the duty of care? I answer that duty exists in all men not to harm the property of others. This is not a mere non feasance which is complained of, it is a misfeasance and an act and wrongful."

Can this concept be applied to the problem of excessive noise in our society? Surely we all have a duty to respect and not to invade the amenity of others with our own excessive noise, and that our own duty of care extends to a duty to refrain from excessive noise in those situations where that noise will have an effect on others?

Noise as a nuisance has received judicial consideration from time to time and it may be of interest if I refer to some of them.

As far back as 1872, in the early days of the steam-engine, neighbours Gaunt and Fynnay apparently fell out over the noise from new hissing steam-engines. After putting up with it for some five years the sufferer, who had a horse stable next to these "offensive" machines, made a complaint to a Court to halt the contraptions. Unfortunately for him, no injunction was granted in that instance.

However, about the same time, there was a court case, Heather v. Pardon (2) which concerned printing machinery. After being used for some years this machinery was then reconditioned. This work resulted, (perhaps surprisingly) in an increase in noise and vibration. An injunction was granted by the Court restraining the use of the machinery so that there was no increase in noise and vibration.

Even here at home, in Queensland, in 1930, the Court considered the question of crowing cocks. On the evidence it was impossible to determine the real degree of noise caused by the Defendant's birds during the relevant period, and, consequently, the Court held that the Plaintiffs had not established a nuisance.(3)

In 1976, in Victoria, the Court held, to establish a nuisance, it must be shown that there has been a substantial degree of interference with the enjoyment of the use of premises. What constitutes a substantial degree of interference must be decided according to the reasonable standards for the enjoyment of those premises. What are reasonable standards must be determined by common sense, taking into account relevant factors, including what the Court considers to be the ideas of reasonable people, the general nature of the neighbourhood, and the nature of the location at which the nuisance is taking place, and the character, duration and time of occurrance of any noise emitted and the effect of the noise.(4)

In another case of Bankstown Municipal Council v. Berzins (5) the meaning of the word "noise" when used in an Act of Parliament was considered Manning J. stated that "the word "noises" where used in (the section) involves the noise of a substantial degree of loudness and that they are of a nature which would materially interfere with the ordinary comfort and convenience of residents of the neighbourhood."

The Act has been amended a few times since 1978 and its present citation is the Noise Abatement Act 1978-1985.

Finally, I refer to the case of Lesley v. The City of Essendon (6). This case was in relation to one of the By-laws of the Essendon City Council concerning prohibiting or minimising noises in any public highway, including the prohibition or regulation of the use on vehicles of brakes which are calculated to cause noises. In endeavouring to come to grips with the definition of noise Sholl J. said -

"Volume amounting to loudness, I think, is alone involved in the conception of a noise once one limits it so as not to include all audible sounds."

Perhaps then we should now clarify what is meant by "noise", for the purpose of our discussion. We need go no further than the Noise Abatement Act. This Act, passed by the Queensland Parliament in 1978, came into operation on the 28th September of that year.

Before proceeding any further, let us briefly have a look at this Act. The Act, as is explained in the Preamble is "to provide for the abatement of excessive noise, to repeal a section of the Vagrants Gaming and Other Offences Act 1931-1971 and for related purposes.".

The Act is divided into eight (8) Parts. Parts I, II, VI and VII are Parts which set up the Act, so to speak. They are as follows:-

PART I - PRELIMINARY;
PART II - ADMINISTRATION;
PART VI - NOISE ABATEMENT AUTHORITY;
PART VII - MISCELLANEOUS PROVISIONS;

The remaining Parts contain what I would refer to as "the meat" of the Act. They are as follows:-

PART III - ABATEMENT AND REGULATION OF EXCESSIVE NOISE FROM COMMERCIAL AND INDUSTRIAL PREMISES;
PART IV - ABATEMENT OF EXCESSIVE NOISE AFFECTING RESIDENTIAL OR COMMERCIAL PREMISES;
PART V - ABATEMENT OF EXCESSIVE NOISE FROM MOTOR VEHICLES;
PART V(A)- PORTABLE ALARM SYSTEMS;

"Noise" has been defined by this Act as meaning "any sound capable of prejudicially affecting the health of or occasioning annoyance, distress or irritation to any person" (section 6).

Additionally, "excessive noise" has been defined as meaning -

(a) any noise that is prescribed under this Act to be excessive noise or, where not so prescribed either at all or in respect of a particular noise, that is considered to be excessive noise in the opinion of any person authorized by or under this Act to form such an opinion, either by reason of the level of such noise or the nature thereof; and

(b) in relation to noise of a description such that its abatement, when excessive, is by this Act entrusted to Local Authorities, any noise that is prescribed by a by-law or ordinance of a Local Authority to be excessive noise or, where not so prescribed either at all or in respect of a particular noise, that is considered to be excessive noise in the opinion of any person authorized by a by-law or ordinance of a Local Authority to form such an opinion, either by reason of the level of such noise or the nature thereof.".

The particular Part of the Act I would like to discuss is Part IV. This Part has been further divided into two (2) divisions.

Division I is headed "Excessive Noise from Machines Etc." and is the Part of the Act that provides that By-laws may be made by Local Authorities in relation to excessive noise. It is this particular Division that I will discuss with you today.

This Division is comparatively small consisting of but three (3) sections as follows:-

"28. Local Authorities may legislate on excessive noise. (1) The power conferred on Local Authorities by the Local Government Act 1936-1984 or the City of Brisbane Act 1924-1984 to make by-laws or ordinances includes power to make by-laws or ordinances in relation to the abatement or regulation of excessive noise that -

(a) is emitted from or audible in any residential premises;

(b) is emitted from premises being used solely in connexion with the erection, demolition or renovation of a single residential unit or two residential units;

(c) is or is likely to be emitted from premises while thay are being used as a venue for the presentation of an open-air concert."

(2) Without limiting the power referred to in subsection (1), for the purposes of by-laws or ordinances referred to in that subsection a Local Authority -

(a) may prescribe excessive noise;

(b) may authorise any person or class of person specified therein to form an opinion of what is excessive noise, either by reason of the level of such noise or the nature thereof; and

(c) may provide that noise emitted from any machine, appliance or equipment specified therein shall be presumed to be excessive noise if it is emitted within hours specified therein or, as the Local Authority thinks fit, outside hours specified therein.

29. Restriction on Local Authorities' power to abate noise. It is not competent to a Local Authority to provide, by by-law or ordinance, for the abatement of excessive noise emitted by any means or in those circumstances is provided for by this Act and in particular for the abatement of excessive noise emitted from commercial or industrial premises.

30. Private rights of action to be preserved. The making of by-laws or ordinances referred to in section 28(1) shall not be taken to prejudice the right in law had by any person to be granted relief or to recover damages in respect of noise."

You will note that Parliament has extended the powers of a Local Authority, including the Brisbane City Council, to make By-laws or Ordinances in relation to the abatement of particular types of excessive noise.

You will further note that the power is limited to excessive noise, that -

"(a) is emitted from or audible in any residential premises;

(b) is emitted from premises being used solely in connexion with the erection, demolition or renovation of a single residential unit or two residential units;

(c) is or is likely to be emitted from premises while thay are being used as a venue for the presentation of an open-air concert."

By Section 29, Parliament has restricted the power of Local Authorities. This Section provides that it is not competent to a Local Authority to make By-laws for the abatement of excessive noise emitted by any means, or in any circumstances if the abatement of such noise emitted by those means, or in those circumstances is provided for by this Act, and in particular for the abatement of excessive noise emitted from commercial or industrial premises.

By making By-laws, other rights or persons are not taken away. In fact, Parliament has made this situation patently clear. Section 30 provides that the making of By-laws under this Division shall not prejudice the right of any person to be granted relief or to recover damages in respect of noise.

Queensland is a vast State. It covers some 1,727,000 square kilometres. There are 134 Councils (or Local Authorities). The Councils vary in the size of area they administer as well as population. Thus, they have varying needs.

Insofar as the varying needs are concerned, I might mention some of the different types of Councils in Queensland. Leaving aside the Brisbane City Council, which has its own special legislation, there are city councils such as Redcliffe and Townsville, which have large residential areas. Queensland has other councils such as Cairns and the Gold Coast, with a somewhat floating population due to tourism. Mount Isa is a huge mining town. Many of the rural councils cover huge areas of Queensland, and there are numerous rural shire councils with small scattered communities.

Consequently, it will be readily understood that the same noise in a close residential suburb may not be the same "nuisance" in spacious, lightly populated rural communities.

Notwithstanding this diversity some years ago it was considered that there were a sufficient number of common provisions which could be included in by-laws and the Noise Abatement Authority determined to prepare a model By-law for use by Local Authorities. This would give some guidance for Local Authorities who proposed to make By-laws pursuant to the powers provided by this Division of the Act.

The model By-law (attached) is the document which was settled for that purpose.

Being a model, the By-law had to be both general enough to cater for varying needs but still succinct enough to be workable.

The By-law was drafted in such a way that would allow the councils to have a degree of flexibility and independence, whilst still retaining the concepts contained in the draft, in determining their own levels of standards etc. This was effected by the use of Schedules to the By-law.

Additionally, the use of Schedules enables the By-law to be conveniently amended, by replacing the Schedules if the content is required to be changed to meet any change in council's requirements as time goes on.

The model consists of eight (8) By-laws plus three (3) Schedules.

By-law 1 is in four (4) clauses.

As is nearly always the case with legislation, there is a definition clause. One of the definitions is "excessive noise". You will see that this definition then has two (2) components. It allows for specific noises to be prescribed. It also allows an "authorised officer" to determine if any noise (that is, one not prescribed) is excessive. This determination is made only on reasonable grounds and calculated in accordance with the prescribed parameters which are set out in paragraph (c).

You will note that the parameters are objectively phrased. The decision which is to be made can then be made on consideration of objective criteria rather than the subjective feelings of the person who has to make the decision.

By-law 2 prescribes which noises are excessive.

You will note that a time has been inserted. As this is a model, this time could be amended to suit the particular requirements of the council. For instance, a council may decide to have a longer or shorter time.

The second category are those noises emitted within the hours specified in the Schedule.

By-law 3 prescribes further excessive noises being those emitted from a machine, appliance or equipment specified in a Schedule if emitted within hours corresponding to the machinery in the second column of the Schedule.

By-law 4 sets up a procedure to be followed for a person who wishes to make a complaint concerning an alleged excessive noise. He may do so to an authorised officer. Such complaint should be in writing or verbally, but, if made verbally should be reduced into writing as soon as possible thereafter.

You will observe that the authorised officer has been defined. This gives to the council the latitude to determine which officer is to carry out these duties and may be changed to meet the council's needs.

By-law 5 sets out the procedure which the authorised officer should follow on receiving a complaint regarding an alleged excessive noise.

By-law 6 provides the action that should be taken by the authorised officer following the receipt by him of a complaint and following the action he should take under By-law 5.

By-law 7 provides that a person may obtain a permit from an authorised officer, authorising the emission of a noise in accordance with conditions laid down in the permit so granted. The By-law sets a procedure for obtaining such a permit. The holder of such a permit is then not guilty of an offence if the noise is emitted from the premises in accordance with the permit.

By-law 8 contains the penalty provisions in relation to this particular By-law. The penalty is shown as $500.00. This amount could be varied downwards to suit the council.

The Schedules are self explanatory but I do emphasize that the times, hours and the machinery have been inserted as a guide only, and it is for the relevant council to determine the appropriateness of those particular entries.

To conclude, let no-one be under any belief that legislation will be the ultimate panacea. There will still be differences of opinions - some ending in Court hearings.

MODEL BY-LAW

AB SHIRE COUNCIL

Department of Local Government, Brisbane, ,198 .

HIS Excellency the Governor, acting by and with the advice of the Executive Council and in pursuance of the provisions of the Local Government Act 1936-198 , has been pleased to approve of the following By-laws made by the Council of the Shire of AB.

R.J. HINZE

WHEREAS by the Local Government Act 1936-19 and the Noise Abatement Act 1978-19 , a Local Authority is empowered to make By-laws for all or any of the purposes in the said Acts mentioned, and it is further provided that a By-law may be amended or repealed at any time by the Local Authority. It is hereby resolved by the Council of the shire of AB, with the approval of His Excellency the Governor in Council, that the following By-laws for the general good rule and government of the Area and its inhabitants, and which the Council hereby determines are necessary for the proper exercise and performance of the functions of Local Government and the powers and duties of the Council, shall be in force from the date of publicatio hereof in the Gazette.

The By-laws of the Council of the Shire of AB published in the Gazette of as amended from time to time, are hereby further amended as follows:-

By inserting the following new Chapter:- "Chapter Abatement of Excessive Noise

1. (a) In this Chapter, the terms used shall have the meanings respectively assigned to them by Section 6 of the Noise Abatement Act 1978-198 and unless the contrary intention appears -

"animal" includes a bird or a fowl;

"Australian Standard" means a standard rule, code or specification of the Standards Association of Australia;

"Authorised Officer" means an officer or servent of the Council from time to time to do any act matter or thing under these By-laws;

"Council" means AB Shire Council

"residential construction site" means any premises which are being used solely in connexion with the erection, demolition or renovation of a single residential unit or two residential units.

"excessive noise means" -

(i) any noise prescribed by these By-laws as excessive noise; or

(ii) where not prescribed, any noise that is in the opinion of an Authorised Officer formed on reasonable grounds, having regard to clause (c) of this By-law, considered to be excessive noise either by reason of the level of such noise or the nature thereof;

(b) A reference in any By-law to any standard, rule or specification shall be taken to be a reference to any document that supersedes that document or to any document that supersedes a previous superseding document.

(c) Where for the purposes of this Chapter an opinion is to be formed as to whether a noise is excessive noise regard shall be had in the formation of an opinion on the question to such of the following matters as are assessable by the person required to form the opinion and as are, in his opinion, relevant -

(i) the second pressure level of the noise;

(ii) the type and characteristics of the noise and in particular whether it is a continuous noise at a steady level or whether it is of fluctuating, intermittent or impulsive nature;

(iii) the frequency components associated with the noise;

(iv) the degree of interference that the noise is likely to cause to the conduct of activities ordinaril carried on on premises other than those from which the noise is emitted;

(v) the nature of the lawful uses permitted for premises in the neighbourhood of the premises from whic the noise is emitted and the dates of establishment of particular lawful uses;

(vi) the topographical features of the area in which are situated the premises from which the noise is emitted;

(vii) the number of complaints received concerning the alleged excessive noise;

(viii) other noises ordinarily present in the neighbourhood of the premises from which the noise is emitted;

(ix) if the complaint on which the person required to form the opinion is acting has been made by an owner or occupier of premises who has become such owner or occupier at a date subsequent to the date when the noise complained of first came to be emitted, the action taken in relation to such premises to limit the effect of noise emitted from other premises in the neighbourhood.

2. For the purposes of this Chapter the noises prescribed as excessive shall be -

(i) a noise made by an animal for at least ten minutes in any period of one hour, provided that such noise occurs more than once;

(ii) a noise which -

(A) exceeds an adjusted measured sound level of 45 dB(A) determined in accordance with Australian Standard 1055-1984 (Acoustics - Description and Measurement of Environmental Noise) by means of a sound level meter -

(1) complying with at least the specifications of a Type 2 sound level meter in accordance with Australian Standard 1259-1982, Sound Level Meters; and

(2) used in accordance with Australian Standard Miscellaneous Publication MP44, Part 1 - 1979 Guide for the use of Sound Measuring Equipment, Portable sound Level Meters; and

(B) is emitted within the hours specified in Schedule 1;

(iii) a noise which -

(A) exceeds a sound level of 5 dB(A) above the background when both the adjusted measured sound level and the background level are determined in accordance with Australian Standard 1055-1984 (Acoustics - Description and Measurement of Environmental Noise)by means of a sound level meter

(1) complying with at least the specifications of a Type 2 sound level meter in accordance with Australian Standard 1259-1982, Sound Level Meters;

(2) used in accordance with Australian Standard Miscellaneous Publication MP44, Part 1 - 1979 Guide for the use of Sound Measuring Equipment, Portable Sound Level Meters; and

(B) is emitted within the hours specified in Schedule 2.

3. For the purposes of this Chapter noise emitted from a machine, appliance or equipment specified in Column 1 of Schedule 3 shall be presumed to be excessive noise if it is emitted within the hours corresponding in Column 2 of Schedule 3.

4. A person desirous of making a complaint concerning alleged excessive noise that is -

(i) emitted from or audible in any residential premises;

(ii) emitted from any residential construction site, may do so to the Authorised Officer. Such complaint may be made in writing or verbally but, if made verbally, shall be reduced into writing as soon as possible thereafter.

5. (a) If the Authorised Officer, having regard to all the circumstances, considers that a complaint made under By-law 4 is of a frivolous or vexatious nature he may reject the complaint and take no action in respect of it.

(b) Subject to clause (a), the Authorised Officer shall investigate a complaint made to him under By-law 4 and -

(i) by whatever means he considers adequate assess the noise to which the complaint relates; an

(ii) inform the occupier of the premises from which the noise is being emitted that a complaint has been made concerning such noise and the nature of the complaint.

(c) Where the Authorised Officer considers it desirable to do so he may cause a further assessment of the noise to be made before proceeding to deal with the matter of the complaint as provided by this Chapter.

6. Where noise is -

(i) emitted from or audible in any residential premises; or

(ii) emitted from any residential construction site,

if the Authorised Officer following the procedure prescribed in By-law 5 considers that noise is excessive noise, he shall direct the occupier by notice in writing to abate the noise forthwith, or within such time as specified in the notice.

7. (a) Notwithstanding any other provision of this Chapter, a person shall not be guilty of an offence against these By-laws in relation to noise emitted from any residential premises or residentail construction site if a permit authorising the emission of such noise is first obtained from the Authorised Officer and the conditions of the permit are complied with in every respect.

(b) An application for a permit shall be made to the Authorised Officer not less than days prior to the day on which it is intended to emit the noise.

(c) The Authorised Officer, on application being made to him by an occupier of any residential premises construction site, may -

(i) grant a permit; or

(ii) grant a permit subject to such conditions as he sees fit,

if he considers that there exists sufficient reason to permit the activity responsible for the emission of the noise.

8. (a) A person who in any respect contravenes or fails to comply with any of the provisions of these By-laws shall be guilty of an offence and shall be liable to a penalty not exceeding Five hundred dollars ($500.00).

(b) Where any person under the authority of an express provision of these By-laws directs anything to be done or forbids anything to be done by another person then if that other person fails to do the thing directed to be be done or, as the case maybe, does the thing forbidden to be done, that other person shall be guilty of an offence against these By-laws.

(c) In the case where the contravention or failure to comply is of such a nature that it may be committed from day to day, in any case, a person shall be liable in addition to any other penalty to which he is liable pursuant to these By-laws to a penalty not exceeding Fifty dollars ($50.00) for each day during which it is continued as from the date of its occurrence until the date on which he is convicted of the offence or until the date on which the default is rectified, whichever date is earlier.

Schedule 1

Specified Hours - By-law 2(ii)

Monday to Saturday (other than Public Holiday) -
6.00 a.m. to 7.00 a.m.
6.00 p.m. to 10.00 p.m.
Sunday and Public Holiday -
7.00 a.m. to 8.00 a.m.
6.00 p.m. to 10.00 p.m.

Schedule 2

Specified Hours - By-law 2(iii)

Monday to Saturday (other than Public Holiday) -
before 6.00 a.m. and after 10.00 p.m.
Sunday and Public Holiday -
before 7.00 a.m. and after 10.00 p.m.

Schedule 3

By-law 3

Column 1 Machine, appliance or equipment	Column 2 Specified Hours
Part A- Residential Premises (to be completed by respective Council)	
Part B- Residential Construction Site (to be completed by respective Council)	

ANNEXURE 2

SCHEDULE 3

Column 1 Machine, Appliance or Equipment	Column 2 Specified Hours
Part A- Residential premises	
Lawnmowers	10.00 p.m. - 6.00 a
Power Tools (limited to Saws, Drills, Jack Hammers, Riveters, Sanders, Grinders, Edge/Weed Cutters)	10.00 p.m. - 6.00 a
Hammer	10.00 p.m. - 6.00 a
Part B- Residential Construction Site	
Air Compressors	10.00 p.m. - 7.00 a
Concrete Equipment	10.00 p.m. - 7.00 a
Powered Tools (limited to Saws, Drills, Jack Hammers, Riveters, Sanders, Grinders, Edge/Weed Cutters)	10.00 p.m. - 7.00 a
Vibratory Equipment	10.00 p.m. - 7.00 a
Hammer	10.00 p.m. - 7.00 a

REFERENCES

(1) (1879) 4 C.P.D. 182 & 185

(2) (1877) CL.393

(3) Ruthning v. Ferguson (1930) St.R.Qld 325

(4) Oldham v. Lawson (no. 1) 1976 V.R. 654

(5) (1963) 8 L.G.R.A.

(6) (1952) VLR 222 1 231 & 232

(7) (1984) 54 LGRA 179

JUDICIAL SUPERVISION OF NOISE CONTROL

Delivered at the Conference on Community Noise at the Darling Downs Institute of Advanced Education, 1-3 October 1986

Judge K.F. Row B.A., LL.B.(Qld.)
Judge of District Courts of Queensland
Judge Local Government Court

ABSTRACT

The paper considers the appeal rights against a decision of the Noise Abatement Authority by statutory control and other non statutory controls that may be available.

Under Section 16 of the Noise Abatement Act 1978-1983, the Noise Abatement Authority may issue a noise abatement order, requiring a person to whom it is directed to abate the excessive noise referred to therein in the manner indicated in the order where the authority is of the opinion that a noise investigated under Section 10 of the Act is an excessive noise and there is no good reason that the noise should not be abated forthwith. A further power exists where the authority is of the opinion that the implementation of a proposal which is the subject of an application to a local authority for its approval, consent, permission or authority and which has been referred to the Noise Abatement Authority under Section 13 of the Act is likely to give rise to excessive noise or, where the authority is of opinion that sufficient cause has not been shown to a noise abatement notice issued under Section 15 of the Act why a noise abatement order should not issue to the occupier of the premises concerned.

Under Section 10 of the Act a person desirous of making a complaint concerning alleged excessive noise may make such complaint in writing to the authority. The authority, unless it considers the complaint frivolous or vexatious,is obliged to investigate the complaint. Under Section 13 of the Act a local authority when considering any application made to it pursuant to any Act for which approval, consent, permission or authority for the implementation of a proposal shall take into consideration whether the implementation of the proposal would be likely to give rise to excessive noise. If the local authority considers that the implementation of a proposal is likely to give rise to excessive noise it shall refer the proposal to the Noise Abatement Authority, which is obliged to consider the application.

Division 4 of Part III of the Act empowers the Noise Abatement Authority to issue licences to people to carry on operations which nevertheless involve excessive noise. It is further provided that the Noise Abatement Authority may grant exemptions from compliance with one or more of the conditions of a licence or otherwise.

Judicial supervision of the decisions of the Noise Abatement Authority in the above cases is provided in Section 27 of the Act which provides as follows:-

> "A person ... being -
>
> (a) a person to whom is directed a noise abatement order;
>
> (b) the occupier of premises to which a licence relates;
>
> (c) an application for exemption from the conditions to which a licence is subject; or
>
> (d) a person to whom the exemption is granted,
>
> who is aggrieved by a decision made by the Authority with respect to such order, licence, exemption or his application may appeal against the decision in accordance with this section to a District Court or to a Magistrates

> "Court exercising jurisdiction in the Magistrates Court District in which the premises to which the decision relates are situated."

The appeal Court is invested with jurisdiction to hear and determine every such appeal duly made and may make therein such order as the Court considers just, including an order as to the cost of the appeal.

The statutory provision simply states that an appeal will lie; there is no specific guidelines as to what form such an appeal takes. Appeals to an appellate body may be of a varying nature. Appeals stricto sensu are normally found in appeals from one Court to another. An appeal stricto sensu proceeds on the basis that the Appellate Court will determine how the tribunal of first instance should have decided a point on the facts and on the law then available to that original tribunal. Appeals de novo proceed on the basis that the appellate body will decide the matter anew as if it were being decided for the first time. The facts relevant on a rehearing de novo are the facts as exist at the date of the appeal. The appellate body is not limited to the facts as they existed before the original tribunal. The law applied on a rehearing de novo is similarly the law as it exists at the date of the appeal. This type of appeal is more usual where the tribunal appealed from is an administrative body.

A discussion of the distinction between these varying types of appeal is contained in the decision of the High Court in Builders Licensing Board v. Sperway Constructions (Syd.) Pty. Ltd. 135 C.L.R. 616. In the course of the judgment of Mason J. it is said:-

> "An appeal is not a common law proceeding. It is a remedy given by a statute. Upon an appeal stricto sensu the question considered is whether the judgment complained of was right when given, that is whether the order appealed from was right on the material which the lower Court had before it. ... Where a right of appeal is given to a Court from a decision of an administrative authority, a provision that the appeal is to be by way of rehearing generally means that the Court will undertake a hearing de novo, although there is no absolute rule to this effect. ... But in the end, the answer will depend on an examination of the legislative provisions rather than upon an endeavour to classify the administrative authority as one which is entrusted with an executive or quasi judicial function, classifications which are too general to be of decisive assistance. Primarily it is a question of elucidating the legislative intent, a question which in the circumstances of this case is not greatly illuminated by the Delphic utterance that the appeal is by way of rehearing."

Which type of appeal is provided by Section 27 of the Act was the subject of judicial determination in Havill & Ors. v. Noise Abatement Authority (1982) Q.P.L.R. 1. The District Court in that case decided that the appeal is one by way of rehearing de novo, having regard to the provisions of the Act. The Court further ruled that in such circumstances the Noise Abatement Authority carries the relevant onus of proof and is obliged to adduce evidence in order to discharge that onus. As the party carrying the onus it presents its evidence first and is obliged to satisfy the Court of all the statutory matters of which it had to be satisfied before making its decision or in the formation of its opinion.

While the Court on appeal is essentially placed in the shoes of the Noise Abatement Authority and considers the matter anew, the procedure followed by the Noise Abatement Authority may vary significantly from the procedures followed by the Court on appeal. Section 27(3) of the Act provides inter alia, that the hearing of the appeal shall be had on the best evidence available. The District Court in any proceedings before it is obliged to act in accordance with the rules of evidence. On the hearing of an appeal the District Court proceeds on the acceptance of the adversary system (i.e. the Court cannot enquire into matters itself - it acts on what is put before it by the parties). In this regard, Section 27(3) states one of the rules of evidence which the Court would be bound by in any event. The Noise Abatement Authority is, by contrast, not a Court but an administrative body and hence is not prima facie bound to apply and to act according to the rules of evidence or to act in accordance with the adversary system. The aspect of the absence of the application of the rules of evidence was recognised in Havill's case (supra) pages 2-3 where it was said:-

> "There is no statutory provision for a hearing before the Authority or for a record to be made of what takes place there. The Authority does not appear to be bound by the laws of evidence."

The power of the Noise Abatement Authority with regard to its process in reaching its decision should not be taken too far. There exists another extra statutory remedy which may be available to an aggrieved party, namely that of judicial review by the issue of a prerogative writ. Where the rules of natural justice which generally are designed to ensure a fair hearing apply to the decision making process of an administrative body have been breached, a Superior Court (in Queensland the Supreme Court of Queensland) may quash the decision of the inferior body and command that body to make a decision according to its statutory duty.

The rules of natural justice may apply where the decision of an administrative body affects the rights of a person. The requirements of natural justice were defined by the Privy Council in <u>Byne v. Kinematograph Renters' Society</u> (1958) 2 All E.R. 579 at 599 in the following words:-

> "First, I think that the person accused should know the nature of the accusation made; secondly, that he should be given an opportunity to state his case; and thirdly of course that the tribunal should act in good faith."

In <u>R. v. Secretary of State for the Home Department Ex parte Santillo</u> (1981) 2 All E.R. 897 Denning M.R. at p.919 said:-

> "The rules of natural justice, or of fairness, are not cut and dried. They vary infinitely."

Given the existence of the above remedy, the Noise Abatement Authority should bear in mind the rules by which a Court is bound are not meaningless or valuless. The rules of evidence may seem legalistic but to completely ignore them may prove fatal to a decision. As was pointed out by the High Court in R. v. War Pensions Entitlement Appeal Tribunal Ex. parte Bott (1933) 50 C.L.R. 228 at 256 in the dissenting judgment of Evatt J. as follows:-

> "Some stress has been laid by the present respondents upon the provision that the Tribunal is not, in the hearing of appeals, 'bound by any rules of evidence.' Neither it is. But this does not mean that all rules of evidence may be ignored as of no account. After all, they represent the attempt made, through many generations, to evolve a method of inquiry best calculated to prevent error and elicit truth. No tribunal can, without grave danger of injustice, set them on one side and resort to methods of inquiry which necessarily advantage one party and necessarily disadvantage the opposing party. In other words, although rules of evidence, as such, do not bind, every attempt must be made to administer 'substantial justice'."

It is important to note that noise control is not exclusively covered by the Noise Abatement Act and related remedies. The law has always recognised the tort of nuisance and granted relief where noise constitutes a nuisance. One remedy used in such cases by Superior Courts is the discretionary remedy of injunction which protects against a recommission of the civil wrong. It should be borne in mind however that not every noise will constitute a nuisance. In this regard attention is drawn to the words of Stanley J. in Kidman v. Page (1959) Qd.R. 53 at 55 where he said:-

> "In these days of mechanised living, even a country resident cannot expect his home to be a soundproof sanctuary, or an idyllic retreat where the loudest sounds are the ordinary noises of nature. The growing suburbs of any expanding city inevitably become noisier than they used to be, and, sooner or later, new problems in the law of nuisance will arise. Their solution is not made easier because there must be reasonable give and take in the manner of noisy living."

An injunction to restrain a noise nuisance will not be granted unless the effect complained of is substantial. Luscombe v. Steer (1867) 17 L.T. 229 and it generally will not be granted to restrain a temporary situation. Cleeve v. Mahany (1861) 25 J.P. 819. The factual circumstances that may produce noise which is excessive or unreasonable that interferes with the amenity of other people are as many as the grains of wheat on the Darling Downs. Noise created by, for example, amplifiers, music, motor vehicles and even church bells have been held in certain circumstances to constitute actionable nuisance.

The exercise of noise control powers by local authorities has been the subject of criticism by Hunt J. (Supreme Court of New South Wales) in Paul Dainty Corporation Pty. Ltd. v. Sydney City Council (1893) 2 N.S.W.L.R. 147 at 154 in the following:-

> "Without intending any disparagement, I recognise the undoubted fact that such authorities may often be prevailed upon by a small group of local residents to act in relation to noise in such public places in a way which is inimical to the interests of the public as a whole who may seek to use that place."

Such words are doubtless apposite to the exercise of its powers by the Noise Abatement Authority.

As was said by Watkins J. in R. v. Fenny Stratford Justices Ex parte Watney Mann (Midlands) Ltd. (1976) 1 W.L.R. 1101 at 1103:-

> "It is well known to anyone who has been concerned with applications for injunctions in nuisance cases referable to noise, that the terms of such injunctions have, after the making of them, given rise to considerable perplexity and difficulty. It is also well recognised that excessive noise is one of the curses of the modern age. One of the reasons why this is so is that somebody invented the amplifier, which serves at least one purpose, namely, very nearly to blast out the eardrums of anyone within its proximity."

Perhaps one may feel some concern for the person who was subject to an injunction granted restraining him from continuing a course of conduct comprised of singing, shouting, whistling and sometimes using unseemly words, in his own premises, in the street and in a public park, when his conduct affected the amenity of tenants of a house on the opposite side of the street. Vincent v. Peacock (1973) 1 N.S.W.L.R. 466.

As is said by the learned author in Kerr on Injunctions 6th Edition p.185 "mere noise alone will, on a proper case of nuisance being made out, be a sufficient ground for an injunction".

The use of a decibel reading to assist in the provision of certainty relating to the terms of an injunction or to other regulatory matters is demonstrated in R. v. Fenny Stratford Justices (supra) where Lord Widgery C.J. said:-

> "This case, however, does throw up for the first time the very interesting question of whether the introduction by modern science of the conception of the decibel cannot be used for the purposes of precision in cases such as the present."

At p.1107 Watkins J. accepted the value of a scientific approach as follows:-

> "I think that we should try to use the advantages that scientific development gives us rather than to reject them, and I think here there is an opportunity of using a scientific approach to what has always previously been a somewhat haphazard assessment."

Further controls on noise related problems are the general town planning constraints imposed upon the use of land. Town planning controls, in general, prevent the intermingling of incompatible uses so that, for example, industrial development or extractive industry is unlikely to be found in the midst of residential development.

In Queensland town planning matters are covered by the Local Government Act, for areas outside of Brisbane, and the City of Brisbane Town Planning Act for Brisbane. Under the relevant acts the local authorities are the relevant planning authorities within their authority area. Applications for inter alia development consents and rezonings are directed to these authorities. Appeal rights flow from a decision of the local authority to the Local Government Court which rehears the application de novo. Where a development produces noise, or a rezoning that will give rise to a development which will produce noise, albeit not excessive noise within the meaning of S.6 of the Noise Abatement Act, the question of amenity, which is a relevant town planning consideration, may be raised.

When assessing amenity and the likely effects of a proposed development on the amenity or future amenity of an area the Local Government Court has often referred to the level of amenity that is within the reasonable expectation of residents in neighbouring areas. Hence the level of noise necessary to justify the refusal of an application on amenity grounds, will vary according to those reasonable expectations.

The reasonable expectations of neighbouring residents has often been expressed to relate to the zonings of land in that neighbourhood. The result is that a person whose home is solely surrounded by Residential A zoned land will have a reasonable expectation of a quieter lifestyle than a person whose land although zoned Residential A is adjacent to land zoned for extractive industry or the like. The Local Government Court, in considering the merits of an application, takes noise production into account but what weight will be attached to that consideration will depend on the existing amenity and the reasonable expectations of the surrounding residents.

Judicial supervision of noise control measures therefore takes the form of a range of remedies, some statutory and some extra statutory which, when considered as a whole, and in addition to the statutory powers of the Noise Abatement Authority can be seen to provide significant controls of the proliferation of sources of excessive noise.

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COMMUNITY NOISE AND LITIGATION

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ABSTRACT

The details are presented of three case studies where environmental noise was a factor in a matter of litigation.

In one of the studies, the potential noise sources were vehicles and traffic and general industry sources associated with zoning for special uses (Storehouse, Goods Depot and Carriers Depot). Each side called a noise witness. The case illustrates the difference in technical approach which can be made by acoustic experts.

The second study involved a compensation claim against the Queensland Government Commissioner for Railways for decrease in pig production alleged to result from noise and vibration from ore carrying trains. This case centred on the effects of noise upon animals rather than humans and involved a somewhat different technical methodology.

The third case was an objection to a proposal by a council to grant consent for certain uses of a building. It was held that noise generated by meetings would create a nuisance in a residential area. A graphic technique was used to communicate to the court the relative levels of the potential intrusive noise and the existing background.

The studies are discussed against a background of questions which relate to standards and scientific methodology, legislation and regulation and communication.

1.0 INTRODUCTION

The last decade has seen in Australia growing technological and legislative concern over the problems which can be created by environmental noise.

On the one hand, the Standards Association of Australia has twice updated its original standard on community noise assessment. On the other hand, State Governments and Local Authorities throughout Australia have introduced and amended legislation and regulations on community noise in an attempt to enable acoustic rights (as well as other rights associated with them) to be fairly maintained within our society. Further, governmental and semi-governmental bodies have been established with at least the partial brief of assisting in this preservation of acoustic peace. Not infrequently there arise both the protagonist and antagonist in a given situation, and, in the judicial halls of appropriate courts, barristers thrust and parry armed with the trusty (or rusty) swords of "expert" evidence.

The author has served as supplier of this trusty (or rusty) sword on a number of occasions and has always enjoyed the challenges and opportunities provided for creativity. At the same time, he has never ceased to wonder at the lack of congruence between standards and legislation and at the absence of a standardised approach; nor ever failed to be entertained or amused by his own or other people's ineptitudes at court-room communication on the matter of assessing the effects produced by environmental noise.

Some of the questions that need to be addressed in the field of noise and litigation are described below:

(i) Should there be greater congruence between standards and regulations?
(ii) Is there a need for more or fewer standard procedures?
(iii) Should more relevance and practicality be introduced into legislation, regulation and administration?
(iv) Is present legal precedent sufficiently based on technical facts and scientific methodology?
(v) Is courtroom dialogue appropriate?
(vi) Is improvement needed in the communication effectiveness between noise expert, barrister, judge and juror?

In an attempt to answer some of these questions, the author presents three case studies in which he has acted as an expert witness on the subject of environmental noise.

2.0 METHOD

2.1 <u>Selection of the Case Studies</u>. Noise studies for litigation purposes are many and varied. Some relate simply to the emission of noise and whether it is within the quantitative limits imposed. Others involve the recipient of the noise as well and are concerned at the likely effects of that noise upon the recipient whether the recipient be human or animal. A common variant to this case is where the alleged deleterious effects are those produced upon humans by noise emission from animals (e.g. dogs or birds).

Quite often the noise study is one for a claim for compensation due to an intrusive element such as a freeway, railway or some other major development. The study itself involves the "before" and "after" estimates or measures of noise and the significance of their difference. The case generally involves a government department which can afford the resources to back its argument. Such studies are fairly common in an age of continuing urban and rural development. Vibration effects are increasingly included in association with noise effects in these cases.

Sometimes, however, the intrusive source is an industry or an entertainment centre and the legal debate occurs before the event, usually as an appeal against a decision by a local authority.

Whatever the origin and background to a particular case, noise studies themselves are characterised by the distinctness of three factors:

(a) the source of the noise and whether it is real or potential
(b) the nature of the recipients and the alleged effects of noise upon them
(c) the methodology used for assessment.

Each of the three case studies selected has distinctness in at least one of these factors and an element of unusualness in the other two.

2.2 Description of the Case Studies. Table 1 presents a summary of the vital aspects of the case studies presented.

TABLE 1
Comparison Between Case Studies

CASE STUDY	NOISE SOURCE	RECIPIENTS	METHODOLOGY
1	Potential intrusive sources in accordance with a possible rezoning for special uses - storehouse, goods depot and carriers depot (vehicular, industrial and traffic sources).	Residents neighbouring the property	Use of AS1055-1984 to determine: (a) real existent background level L_{Abg}, and (b) level of the potential intrusive noise L_{Amax} adj.
2	Three-and four-headed trains hauling ore.	Pigs of both sexes and all ages from birth to age at sale	Concurrent studies of (a) noise and vibration and (b) pig behaviour patterns.
3	Potential intrusive sources consistent with use of a building for place of assembly(meeting rooms) & commercial premises,administrative and clerical offices (people and vehicles).	Architect and residents in neighbourhood	Use of simulation exercise to show on chart records the relative levels of the potential intrusive noise and the real existent background noise.

3.0 RESULTS

3.1 Gunning & Ors v. Brisbane City Council and Anor; Local Government Court, Brisbane (Row D.C.J.); 27,28,29 March, 1,2,3,4 April, 22 May, 1985; (1985) Q.P.L.R., 165-175. This was an appeal by objectors against the decision by the Brisbane City Council to approve an application made by W.D. & H.O. Wills for the re-zoning of certain land at MacGregor from the Special Uses (Tobacco Processing and Cigarette Manufacturing purposes) Zone and including the land so excluded partly in the Special Uses (Storehouse, Goods Depot and Carriers' Depot) Zone and partly in the Residential "A" Zone.

Amongst other items, it was held by the Appellants that the proposed re-zoning and subsequent industrial development would adversely effect the amenity of the locality and create traffic problems. Noise was an obvious factor to be considered, and Table 1 refers to the relevant potential noise sources.

The expert witnesses in noise for the two sides based their assessments and arguments on quite different approaches. The Witness for the Appellants (Witness 1) based his approach on L_{Abg} and $L_{Amax\ adj}$ values (AS1055-1984) and used real vehicles (semi-trailer, truck, van, hoists etc.) in another environment in order to determine the levels of the potential intrusive noise. The Witness for the Respondents (Witness 2) based his approach on L_{Aeq} values and used, for the estimation of the potential intrusive noise levels, a computer model programmed for normal roadway traffic of variable flow rates and vehicle compositions.

Comparative measurements of existing noise levels by both witnesses at the same locations for week-day daytime hours are given in Table 2.

TABLE 2
Existing Noise Levels in dB(A) as Measured by Each Witness.

POSITION	RESULTS BY WITNESS 1			RESULTS BY WITNESS 2	
	L_{Aeq}	L_{A90}	L_{Abg}	L_{Aeq}	L_{A90}
(i)	43	41	40	53-55	44-45
(ii)	48-51	43-47	41-43	59	46

Comparative estimates of potential intrusive levels at the same position, position (i), by both witnesses are given in Table 3.

TABLE 3
Potential Intrusive Noise Levels in dB(A) as Estimated by Each Witness.

RESULTS BY WITNESS 1		RESULTS BY WITNESS 2	
Source	$L_{Amax\ adj}$	Source	L_{Aeq}
Real vehicles	79,86,74,77	Computer Model	58

Whereas Witness 1 used semi-trailers, vans, trucks and hoists as noise sources, Witness 2 used the Noytra program based on a flow rate of 32 cars and 37 trucks per hour.

Overall, Witness 1 concluded that at a residential boundary such as position (i), the potential intrusive noise would, during significant periods of the day, be exceedingly annoying because values for L_{Amax} adj - L_{Abg} varied from 31 dB(A) to 43 dB(A). Witness 2 on the other hand concluded that for the worst case - very near position (i) - the existing daytime L_{Aeq} value would be increased by only 3 dB(A) and that a two metre high acoustic barrier would reduce road noise level by 5 dB(A) and so eliminate the increase in L_{Aeq} value and eliminate also potential annoyance.

The District Court Judge much preferred the noise evidence of Witness 2 for the Respondents but brought down his judgment in favour of the Appellants, obviously not on the grounds of potential noise but on some other aspects of town planning.

3.2 E.N. and M. James v. The Commissioner for Railways; Queensland Land Court (Mr. Johnston); Townsville, 11-15 October, 1976; Brisbane, 10 December 1976; (1976) Q.L.C.R. (3), 396-417. This was a claim for compensation due to resumption for railway purposes of an area of land from the owners of a commercial piggery. The piggery operations included facilities for mating, farrowing, suckling, weaning and fattening of the progeny for sale as porkers. As a consequence of the resumption, part of the Greenvale to Yabulu railway line was constructed "about 75 yards" from the piggery itself and ore haulage operations commenced in late 1974, building up to a normal traffic in 1976 of ten trains each way per week - five "four headers" and five "three headers".

The case for the claimants was based on two propositions, namely -

(a) that the noise of the railway construction and the daily maintenance of the heavy equipment so disturbed the piggery that there was a sharp decrease in pig production during the construction period; and
(b) that the noise and vibration caused by the ore carrying trains drawn by three and four diesel locomotives on the completed railway had continued to cause reduced production to such a degree that the piggery was no longer a profitable undertaking.

It was not practicable to report upon the alleged noise during construction. However an investigation was carried out in September, 1976, into the noise and vibration produced by the trains on the Greenvale line at the claimants' property and into the effects, if any, developed by that noise and vibration on the pigs housed in the piggery on the property.

Concurrent studies were made by a noise assessment specialist and an animal husbandry officer. Magnetic tape recordings of noise and vibration were made during the passing of trains and further recordings of the surrounding noise and vibration experienced at the piggery were made at other times. These recordings were made by equipment installed and operated at strategic positions near or at the piggery and railway line. Observations and photographic records of pig behaviour before, during and after the passage of trains were made by the husbandry officer.

The findings of the noise specialist were that the noise and vibration levels produced little or no reaction in pig behaviour due to the passage of the trains. The conclusions of the husbandry officer were that the passage of trains produced no changes in the behavioural pattern of the pigs different from those produced by normal piggery activities. Further it appeared that the pigs which were observed were able to recognise the sound of the train and had habituated to this stimulus. No physiological measures were incorporated in the study and hence no valid comment could be made about any physiological stress which may have been experienced by the pigs.

In his judgment, the Land Court Member stated that he "was firmly of the opinion that the claimants' pigs of all ages and sexes have become accustomed to the operations of the railway with the passage of ore-laden trains and that any disturbance considered likely to affect adversely the reproductive capacity of the breeding herd and the growth rate of the growers from birth to sale would be of short duration." He found, on the evidence, "that the piggery business has not been a viable undertaking from its inception... " However, he found that the loss in production during the year of railway construction was "attritutable largely to stress caused to all pigs in the claimants' piggery by the disturbance engendered by the use of heavy motorised equipment and the accompanying servicing, maintenance and repairs."

3.3 Noel & Robyn Robinson v. The Liberal Party of Australia (Qld) Pty. Ltd. and Brisbane City Council; Local Government Court, Brisbane (Mylne D.C.J.); 24,25 February, 4,5,17 March, 8,14 April, 1976; (1976) Planner L.G.C., 68-76. In this case, the Appellants objected to the proposal of the respondent council to grant consent to an application by the first respondent, the Liberal Party of Australia (Qld) Pty. Ltd. for consent to use a building situated at the corner of Gregory Terrace and Victoria Street, Spring Hill, Brisbane for the purposes of a place of assembly (meeting rooms) and commercial premises (administrative and clerical offices.) The land was situated in a Residential "C" Zone in which the Council could give its consent for the purposes. Further, the building fronted on to Gregory Terrace which carried relatively high density traffic by night as well as by day.

Amongst other items, one of the grounds of the objection was that noise generated by meetings, functions and demonstrations would create a nuisance in a residential area.

In order to determine the likelihood of noise annoyance from meetings and functions (but not from demonstrations), it was decided to measure, and also to record with an instrumentation tape recorder, the level of the existing noise in the immediate environment. It was further decided to conduct an experiment to determine what level of sound could be transmitted from the meeting rooms to the property line of the nearest neighbour. It was decided to use, as a noise source inside the meeting rooms, something with a recognisable signature on a chart record. A cassette of music was used and the sound level inside the room, with windows open, was adjusted to be of the order of 90-95 dB(A).

Subsequent chart records of the noise recorded on the property line clearly indicated the fluctuating levels of the background noise due to the flow of traffic. It was only occasionally, however, as shown in Figure 1, that the background level would get low enough for the signature to appear of the "intrusive" noise from one of the meeting rooms, despite the fact that it was set to a level which would be intolerable inside the meeting room.

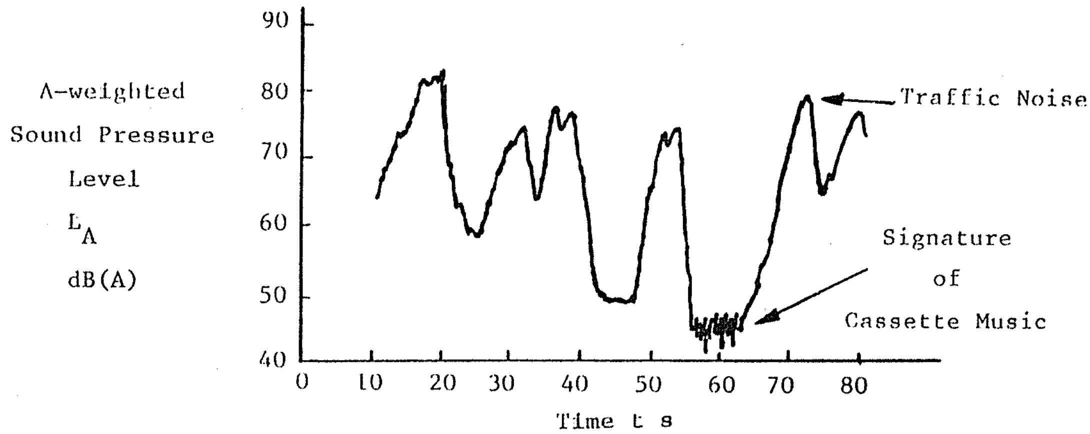

Fig. 1 Chart Record of Sound Level L_A on Property Boundary.

The District Court Judge found in favour of the Respondents and the appeal was dismissed. He instructed that there be a screen fence between the building and one of the neighbours, not as a sound barricade, but as a barricade to stop possible annoyance from car lights.

4.0 DISCUSSION

Each of the case studies is now considered in the light of (i) standards and scientific methodology, (ii) legislation and regulation and (iii) communication.

4.1 Case Study re Land Usage. In this case study, the two noise witnesses used different descriptors for the assessment of noise annoyance and different models for the prediction of potential intrusive noise levels. AS1055.3-1984 states that in predicting "the noise situation arising from proposed non-existent installations ... the predictions must be made through the use of suitable calculation methods or by scale model investigations."

In the absence of any ordinance in the council's Town Plan to control noise, it is reasonable to use any suitable scientific technique for prediction. In fact it could be argued that reference to a situation similar to that proposed is more tenable than use of a computer model for traffic flow which is not necessarily indicative of the potential noise levels.

As regards communication, the simple statement by Witness 2 regarding the worst case increase in equivalent level of 3 dB(A) was most effective whatever the validity of the background levels measured or the predicted levels computed. On the other hand, Witness 1 had difficulty in effective communication probably because of the apparent lack of support given by his own barrister.

4.2 Case Study re Loss in Pig Production. Though earlier studies (Bond J. et al and Welch B.L. and Welch A.S.) had shown that pigs habituate to noise, it was decided to acquire data as pertinent to the situation as possible. Accordingly an animal husbandry expert was called in to make visual, aural and photographic observations to assess pig behaviour patterns. Noise and vibration from the trains, as well as from other sources, was evaluated using standard instrumentation techniques.

In the absence of any specific legislation dealing with the effects of noise upon farm animals, the case was argued quite substantially upon the above observations and evaluations.

The barristers for both appellants and respondents seemed to have a singular lack of regard for scientific evidence and one barrister can be quoted as saying to his own noise witness "we are after all, on the same side."

When accused of collusion with the Department of Railways, regarding taking measurements of three-headed rather than four-headed locomotives, the noise witness was able to draw quite successfully on the facts of decibel addition to support his evidence. Predicted aspects of sound attenuation, such as 6 dB loss with doubling of distance, were also substantiated.

4.3 Case Study re Use of Building. There was no relevant council ordinance regarding the level of noise from such a building and it was therefore decided to use the simulation exercise described earlier.

Once the court had understood the nature and purpose of this experiment, it was surprising how readily it accepted the simple, graphic evidence on relative noise levels which was presented.

5.0 CONCLUSION

Instrumentation and scientific methodology are well enough advanced to provide acceptable evidence in a wide variety of cases dealing with community noise. Generally, the available standards are fairly technically based but they occasionally need to be more relevant.

Difficulties can occur when there is no ordinance or regulation dealing specifically with noise. Though noise may be included under aspects of amenity, the noise witness has to make recourse to the most relevant standard or create a suitable assessment technique. Though justice is still invariably done, it is achieved at somewhat greater expense of time and money than necessary. Production of specific legislation in congruence with relevant standards seems worthy of greater consideration.

Increasing dialogue between technical experts and legal practitioners, supported by appropriate training and education, will go a long way towards improving the effectiveness of technical evidence both in its preparation and in its courtroom presentation.

No doubt many of the problems associated with community noise and litigation would be eased if all "experts" had the wisdom as well as the sobriety of a judge.

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STREAM B

SOUND TRANSMISSION BETWEEN ROOMS THROUGH OPEN WINDOWS

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Although there have been a number of studies of sound propagation through apertures very little information exists on the transmission of sound between two large apertures separated by a semi-reverberant space. The present model study was undertaken with the aim of producing some guidelines for planners and designers concerned about the transmission of sound, through open windows, between two rooms in the same building or from one building to an adjoining building.

1.0 INTRODUCTION

Noise, from close or neighbouring properties, appears to be an important source of annoyance. This is especially so in multiple-occupancy residential buildings (Fricke, F.R.; Langdon, F.J.) where windows are a significant sound path within and between buildings (Collin, I.D.; Michelsen, N.). In tropical and sub-tropical areas sound transmission between detached dwellings can be important and even in more moderate climates where there are pressures for higher residential densities and low-rise buildings noise transmission can be a serious problem. The problem arises because of the conflict between the need for ventilation and the desire for sound isolation.

In more affluent suburbs the transmission of sound through open windows is usually of little importance as the distance between dwelling is large and windows are shut because of air conditioning. In less affluent suburbs blocks of units and individual houses are built to within one metre of the property boundaries and, where openable windows exist, sound transmission through them can be much more significant than the transmission through a single brick wall separating two adjoining units.

A number of studies of sound propagation through apertures have been carried out (Parkin, P.H.; Oldham, D.J.; Kubota, K.; Kuga, S.; Mizia, U.), but there is very limited information available on sound transmission, through large apertures, between two rooms separated by a semi-reverberant space. The work by Kuga, Parkin and Oldham is the most relevant, though the work by Parkin and Oldham is for a single opening and for distances of more than 10 metres from the openings. In the present work the transmission of sound between two rooms, through open windows separated by distances of less than 12 m, was studied using $^{1}/_{8}{}^{th}$ scale models.

2.0 EXPERIMENTS

The two rooms were modelled using boxes constructed of 12 mm plywood. The box dimensions were 510 x 380 x 280 mm. One face of each model room features a rectangular aperture the size and shape of which could be altered by replacing one wall of the model room. The experiments were carried out in an anechoic room which provided freefield conditions for frequencies above 500 Hz.

A noise source with four impinging air jets was used as the sound source. It produced a wide band frequency spectrum and was particularly rich in high frequency sound (Veneklasen, P.S.; Cann, R.G.), which was needed for the modelling work (Watters, B.G.). This source radiated sound omnidirectionally to within $\pm$ 2 dB and was located near the corner of the model and away from the aperture. For measuring the sound level in the source and the receiving room, a $^{1}/_{4}$" free field condenser microphone was used. It was located in the centre of the model room, a position which was found to have sound levels close to the average sound level in the room, for various room configurations and source positions. The experimental setup is shown in Figure 1.

The measurements were made in four octave bands, which, in full scale, simulated the frequencies of speech (250 Hz - 2 kHz). This procedure was less complicated than measurements of $^{1}/_{3}$ octave bands (van den Eijk, J.) and, although approximate, was considered to be quite appropriate for the purpose of this work where different room dimensions and acoustical characteristics, windows sizes and orientations and external conditions are being modelled generically.

The experiments were undertaken by varying the distance, angle between the apertures, aperture area and the position of reflecting surfaces. Aperture areas varied from 1 m to 4 m and distances between the apertures up to 12 m.

The attenuation of sound between the two rooms was measured in terms of dB(C) - dB(A), where C-weighting was used in the source room, and A-weighting in the receiving room. This measurement method has been used previously (Leventhall, H.G.) to reduce level fluctuations due to the emphasis of low frequencies and to make all parts of the spectrum equally significant and independent of the source spectrum (Lim, C.H.; Stephens, D.H.).

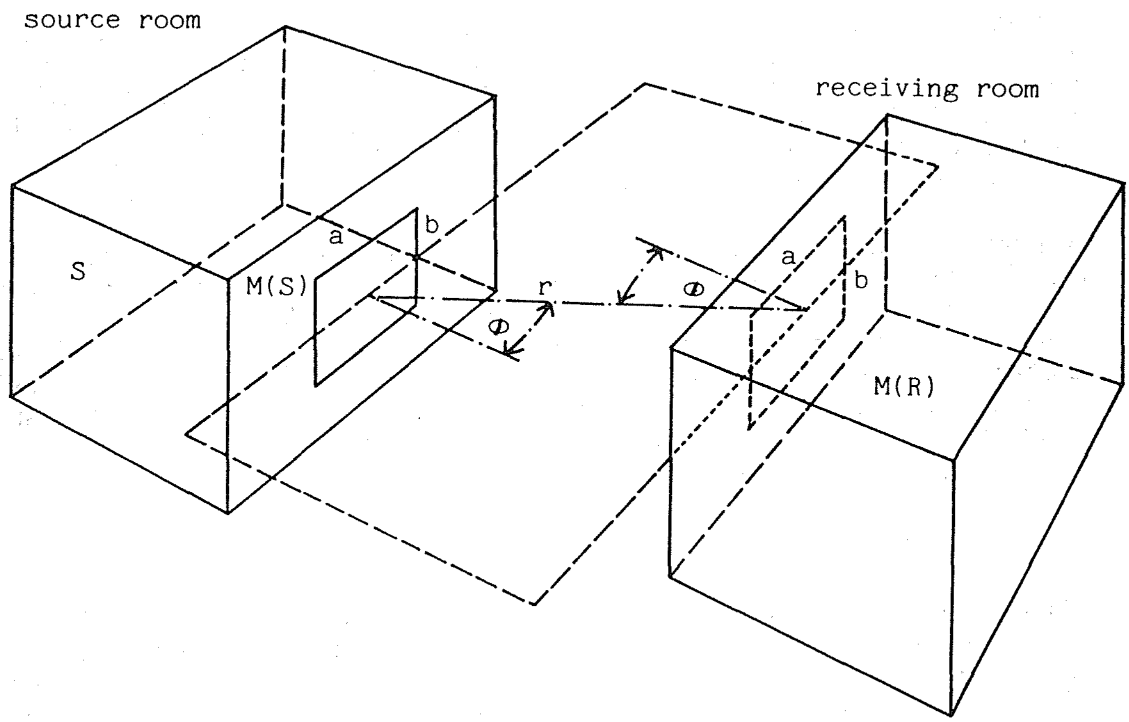

Fig. 1. Coordinate system of the experiment.
S is sound source, M(S) is microphone position in source room, M(R) is microphone position in receiving room, a is aperture width, b is aperture height, θ is angle between normal to the aperture and the line connecting the two aperture centres, r is the distance between the two aperture centres, S, M(S), M(R) and the two aperture centres are on the same horizontal plane.

3.0 EXPERIMENTAL RESULTS

From Table 1 it can be seen that horizontal apertures tend to produce the lowest noise reduction between the two rooms, as do the larger sizes of apertures. The reason for this is that horizontal windows result in the effective distance between the openings being less than the distance between the geometric centres. The same reason applies to larger openings, with the added effect that larger openings allow more energy to be radiated from them.

For $\theta = 0^o$ in Table 1 it can be seen that a doubling of the opening area decreases the attenuation by approximately 3 dB, as expected. This is because a doubling of the opening size increases the sound power transmitted by a factor of 2. The 3 dB change is not exact, probably because of ground interference effects.

A number of tests were undertaken where the distance and angle between the apertures was varied as was the geometry of nearby reflecting surfaces forming a courtyard. It was found that the presence of the reflecting surfaces nearby considerably increased the sound transmission between the two open windows. It can also be seen from Figures 2 and 3 that the noise reductions, in terms of dB(C) - dB(A), of the openings with areas of 2 m^2, were less than 30 dB for distances up to 12 m, i.e. considerably less than the attenuation (≈ 45 dB) obtained with a single brick wall which is normally considered to give satisfactory sound isolation.

With one window closed the noise reduction between two rooms opposite one another ($\theta = 0^o$), and separated by a distance of 12 m, will still be less than that obtained using a single brick wall. When the windows are beside one another ($\theta = 90^o$) and separated by 5 m, the noise reduction between the rooms is equivalent to a single brick wall only when the window opening is less than 1 m^2, one window is shut and the nearest vertical reflecting surface is greater than 12 m distant.

TABLE 1

Noise reduction, in term of dB(C) - dB(A) between two rooms, separated by a distance of 5 m, through apertures and over reflective (hard) ground.

APERTURES			dB(C) - dB(A)		
area (m2)	ratio	type	$\theta = 0^o$	$\theta = 45^o$	$\theta = 90^o$
	5 : 1	vertical	26	32	42
1	1 : 1	square	25	31	41
	1 : 5	horizontal	22	23	40
	$2^1/_2$: 1	vertical	24	28	39
2	1 : 1	square	23	25	38
	1 : $2^1/_2$	horizontal	18	19	34
	$1^1/_4$: 1	vertical	18	23	35
4	1 : 1	square	17	18	34
	1 : $1^1/_4$	horizontal	15	15	33

It is therefore not surprising that people living in detached houses in urban temperate zones often perceive more noise coming from their neighbours than people living in multiple-occupancy dwellings (Fricke, F.R.).

4.0 CONCLUSIONS AND DISCUSSION

In room arrangements with $\theta = 0^o$, the noise reduction between the rooms could be 17 dB lower than rooms with $\theta = 90^o$. Except for very small apertures, high frequencies or distances much more than 12 m, it is almost impossible for room arrangments in a courtyard form with $\theta = 0^o$ or even 90^o, to get the equivalent noise reduction of a single brick wall.

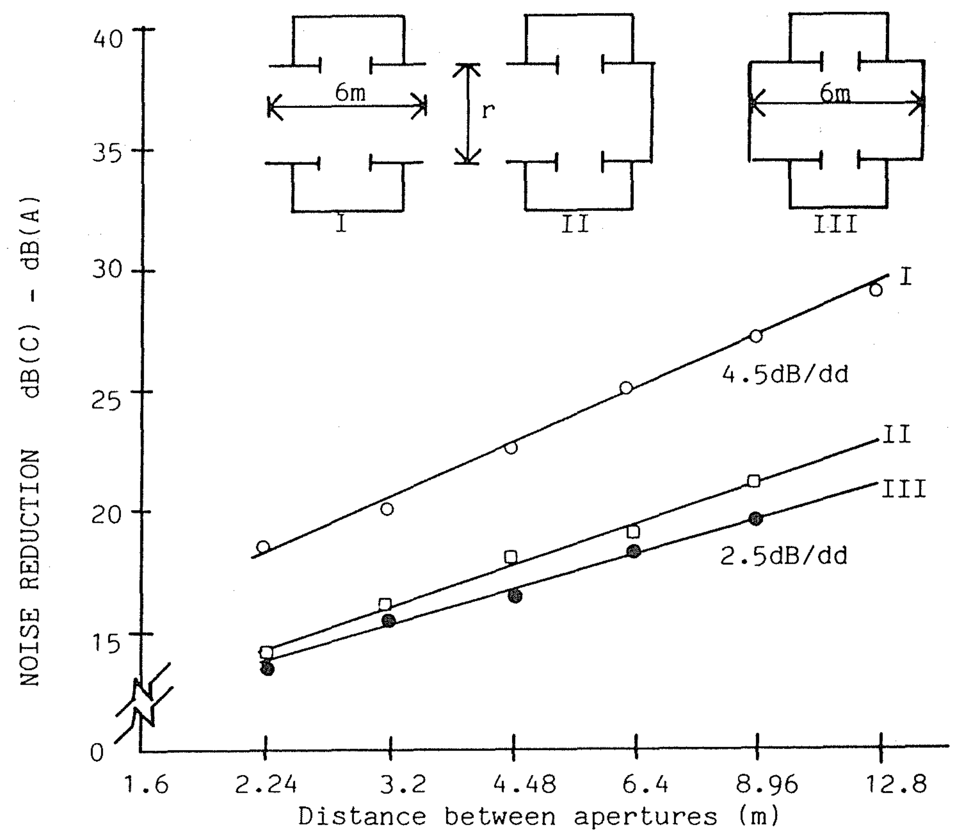

Fig. 2. Relationship between noise reduction and distance between two rooms, opposite each other, with and without end walls. Windows are square with an open area of 2 m^2.

In a courtyard type outdoor space, both in the case of $\theta = 0^o$ and $\theta = 90^o$, the noise attenuation will be reduced by 2 dB to 8 dB compared with a non-courtyard type case. Covering the courtyard with roof will decrease the noise reduction between the two rooms by up to 3.5 dB. Where distances between the openings were small the ground reflected sound component was small, though not insignificant. The height of the window above the ground is however, a second order effect.

No full-scale measurements were undertaken in the present work, but comparisons were made with Kuga's full-scale work on sound propagation between rooms with open windows. For a range of frequencies, window sizes and wing wall lengths the present model results were always within 2.5 dB of Kuga's results. Thus, despite the simplications introduced, such as wall thickness and ground conditions, it appears that the results obtained can quite accurately be applied in practice.

Finally, a comment on the present trends in housing in the light of the work presented. Obviously noise transmission is only one of many factors determining the layout of suburbs and the design of houses. However, if noise transmission, cost, ventilation, thermal insulation and the spread of fire were the main factors, it would make a lot more sense to build town houses or semi-detached houses where low rise, high density housing is required. It is perhaps time that Australians changed their attitude to detached houses and opted for something with ensures a better environment.

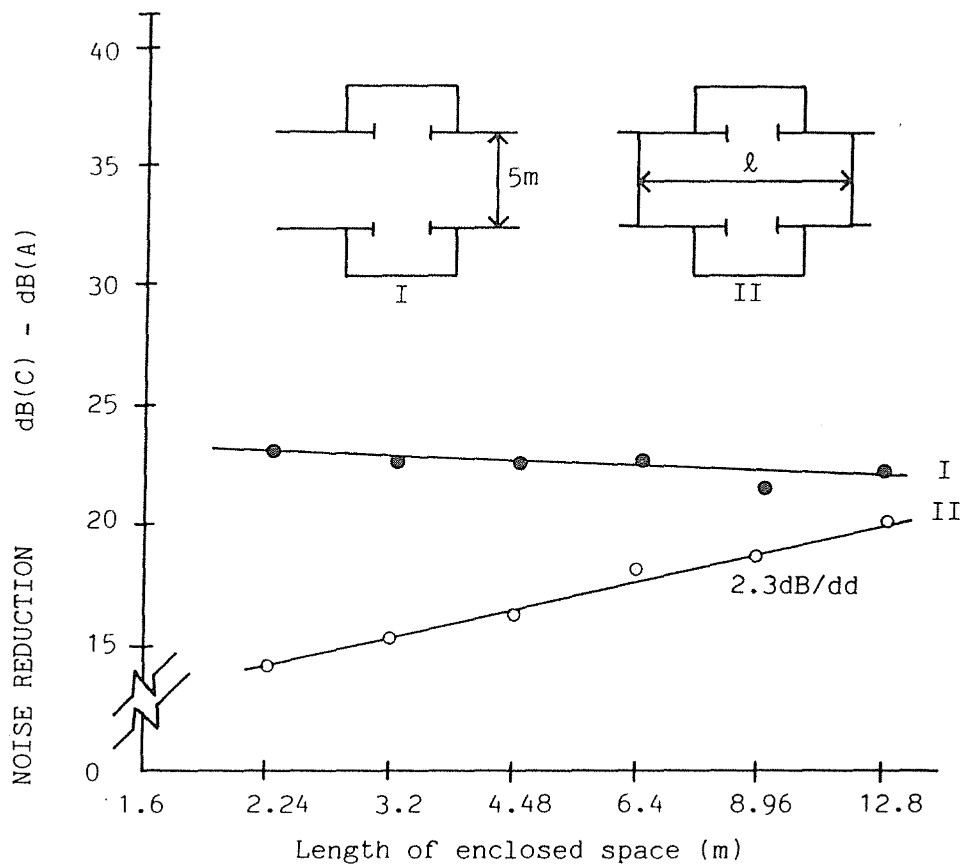

Fig. 3. Relationship between noise reduction and length of enclosure (e) for 2 rooms opposite each other and separated by 5 m. The windows are square and 2 m^2 in area.

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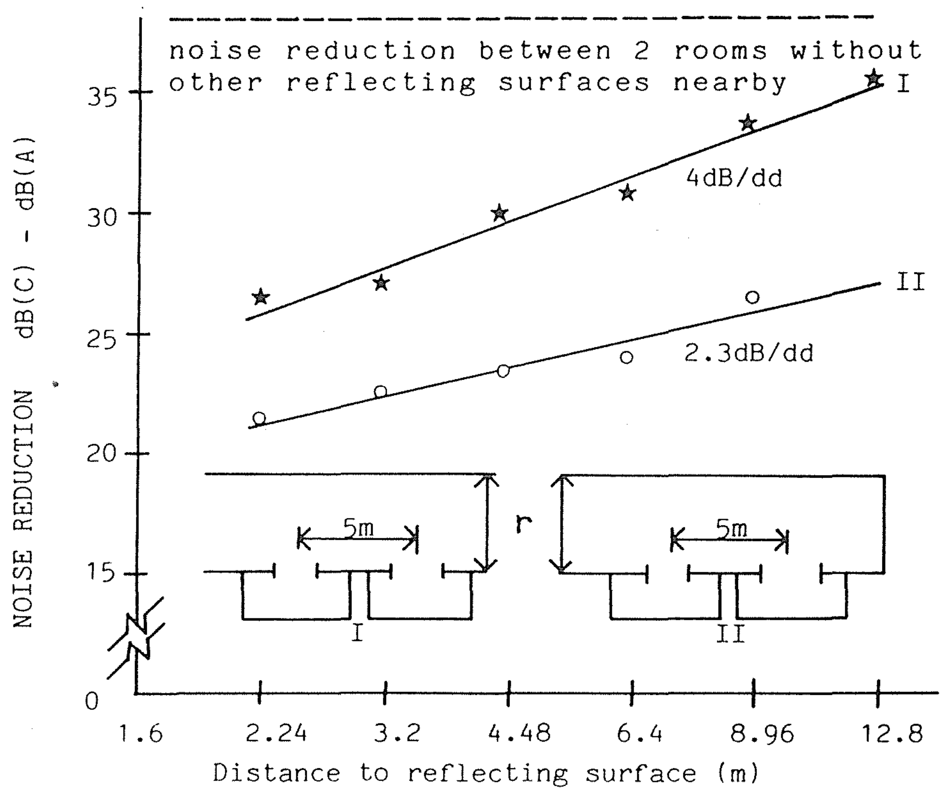

Fig. 4. Relationship between noise reduction and distance (r) in the presence of reflecting surfaces nearby. The windows are square and 2 m^2 in area.

ROCK FESTIVAL NOISE POLLUTION

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ABSTRACT

Rock Festival Noise Pollution.

Rock Festivals are one of the most visible contacts between legislative Authorities, youth sub-culture and the general public. All the ingredients are there for severe noise pollution and public disorder and while some festivals pass off peacefully, some are a disaster. The paper discusses various noise control methods and the units used to monitor them.

The legislative framework of such events is considered and proposals for simple legislative powers evaluated and the means to implement them presented. Case studies of three festivals are reviewed, showing the mistakes made by the legislating and controlling authorities.

ROCK FESTIVAL NOISE POLLUTION

This paper addresses some problems of legislating in the special area of outdoor music festivals, specifically Rock Concerts. These events are by their nature often transitory and almost by definition generate high levels of noise. Indeed that nearly always seems to be the purpose of the event. A rock concert without sufficient noise may well satisfy the unwanted recipients of the 'music' but would not please the audience.

No one has, to the authors' knowledge, produced a total solution to this problem and we are therefore suggesting some ways of legislating and controlling the 'problem' without significantly affecting the enjoyment of the patrons at the concert. Through some case studies, we show how some of these methods have worked and identify some of the difficulties. A legislative and control procedure is proposed which, if followed, should prove effective.

London, for reasons of prestige and population is a favourite site for Rock Groups. However, London is one of the world's most populous cities and uncontrolled noise cannot be permitted. London is made up of 33 independent boroughs but the central licensing authority was until April 1986 the Greater London Council (GLC).

In 1976 GLC published a Code of Practice which set standards for all aspects of such events including noise (1). As a result the Scientific Services Branch (now London Scientific Services) has monitored the noise of many such concerts and gained experience in solving many of the problems that occur.

The Code

The Code covers two elements of noise: minimising the risk of hearing damage to those attending, and preventing the noise from the concert adversely affecting those who live or work near the venue.

The enforcement of the legislation that exists lies jointly with the Environmental Health Officers (EHO) of the local Borough where the concert is held and the licensing authority. Under the Control of Pollution Act 1974, the EHO's have the power to stop the concert if, in their opinion, a noise nuisance is being caused. Similarly, under the London Government Act 1963, the licensing authority has a similar sanction. (2,3).

To minimise the risk of hearing damage, the Code specifies the noise limit that should be met at a distance of 50m from the speakers and at a nominal height of 1.75m, and describes how the equal energy principle should be used to modify the limit according to the length of the concert. The environmental effect is described by the change that occurs in the Leq (measured over 15 minute periods) at the facade of sensitive buildings during the concert (or rehearsals) compared with the Leq measured over similar 15 minute periods when no concert is in progress. The number of concerts that are held at a particular venue and the time of day will determine which one will predominate. It is to comply with these criteria that a limit within the stadium is set, but it is essential that the value given in the licence conditions is one that can be easily monitored during the event.

In practical terms, the best place to monitor the noise is at the mixer. This has the advantage of being close to the engineer who has control over the volume of the music. But unless the mixer position is 50m from the speakers further correction factors such as distance, height and the effects of audience absorption need to be included in the figure that is stipulated in the licence.

Many of the difficulties with the code stem from the fact that the main motivation of promoters and bands at these events is not control of noise pollution. Indeed, they do not consider the noise they make as pollution and when fans are prepared to pay a high price for listening to them this point of view is reasonable. The Licensing Authority must also bear in mind that if the environmental sensitivity of the neighbourhood causes the limit to be set at a very low level, then the concert will be an ineffective form of entertainment. The limit will inevitably be exceeded and great difficulties will arise. In these circumstances, the licensing authority should refuse the licence rather than permit the concert to occur with unrealistic conditions attached. Even here though, care is needed to avoid being too restrictive; for, with good control, successful concerts can be held at venues which, at first sight, seem, environmentally, to be totally unsuitable.

Of course even with an agreed level, problems arise if the level is exceeded. It is difficult to argue logically about level excedance or indeed any other matter in an ambient noise of 1ØØ+dBA. Thus problems must be resolved before the event, not during it.

A further problem occurs at large festivals like Reading Rock, an annual 3 day event. While Reading is not part of GLC responsibilty the promoters themselves attempt to keep to GLC guidelines. Here, the festival site is in a bowl about 1Økm across and the effects of an inversion layer can totally upset any transmission characteristics and make the limit meaningless. As at all concerts, to try to maintain the external level, active control must be used based on radio links between the mixer and teams of monitors outside the venue.(4)

Even without the problems imposed by weather, communication with the site is vital. The only point where the level can be controlled is at the mixing tower. At large festivals it is virtually impossible to reach the mixer because of the crowd. It should be remembered that there will be up to 1ØØ,ØØØ people at some of the bigger festivals; the population of a reasonable town.

Case Studies

1. Wembley Stadium July 1985

There were 4 days of concerts during the month. Bruce Springsteen on the 3rd, 4th and 6th followed by the well publicised Live Aid on the 13th.

For the Springsteen concerts, it had been calculated that an Leq of 96dBA should be the limit. However, allowing for the correction factors discussed earlier this was equivalent to a level of 1Ø1dBA at the microphone position that was going to be used.

Some confusion then arose regarding whether it was a measured level of 96dBA or 1Ø1dBA that would be permissible - acoustically a large difference. It was finally established that 1Ø1dBA was the correct level and a one minute Leq technique with someone in attendance at the mixer throughout was used as the control procedure (5).

A further problem arose at one of the concerts and as a result the limit level was exceeded. When the engineer refused to turn the volume down the recourse was to the promoters. In this case, in order to protect their good name and so that future licence applications would not be jeopardised, the promoter insisted that the engineer reduce the volume.

Live Aid, watched by millions around the world was most successful. The limit level was carefully calculated and agreed beforehand, the promoter and mixer engineer recognised that any failure to comply would prejudice their chances of future concerts at Wembley, and active control through attendance and monitoring resulted in the limit level being comfortably met. Although the success can be partly attributable to the favourable publicity that the concert received, lessons from the earlier concerts had been learnt by both sides.

2. Crystal Palace. Status Quo 'Farewell'

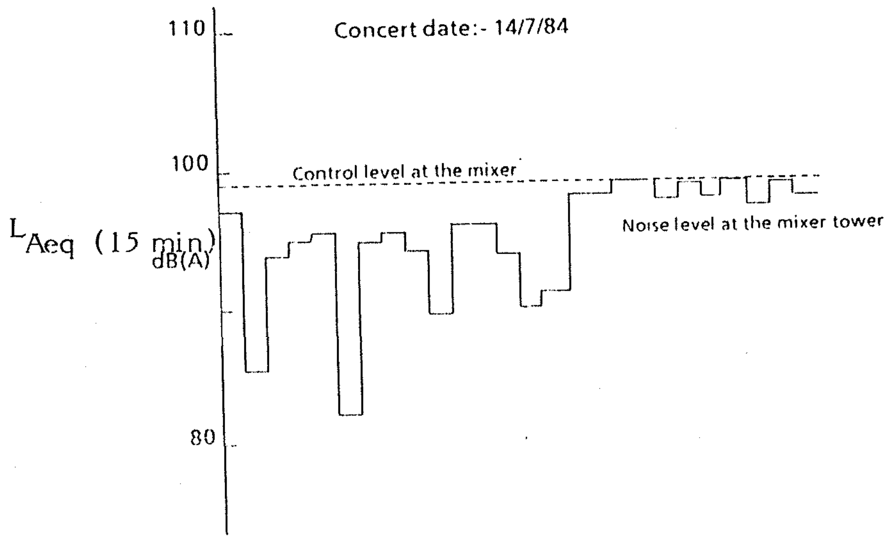
This followed an earlier concert which was not an environmental success. Thus great efforts were made by the authors, from their different view points, to ensure that the minimal noise pollution was caused. One of the important pre-conditions was adhered to in that the whole sound system was available 24 hours before the event to test for transmission loss. This was particularly important as the Football Stadium where the event was held is closely surrounded by high density housing. A good public relations exercise was undertaken and much planning was done by the sound consultant (Cirrus Research), the local authority (Croydon Borough) and the GLC.

Tests carried out the day before the concert established a limit level at the mixer which was agreed by all parties. At the height of the concert, one or two of the local borough councillors felt the noise level was too high, although the limit wasn't being exceeded. Pressure was put on the EHO to serve a notice to stop the concert, which left the EHO in an invidious position. Just handing a piece of paper to, say, the promoter or the mixer engineer wasn't going to stop the concert with 25,ØØØ fans at the peak of excitement. In this case, no serious environmental damage occurred, again, due to careful pre-planning, together with the setting of a reasonable limit and the keeping to that limit by continuous monitoring at the mixer. Diplomacy was used to placate the one or two neighbours who were concerned and the concert was acoustically very successful (6,7). Fig. 1 shows the computer trace with the level superimposed.

3. Reading Rock

This cannot, in reality, be considered a single case study as the work was spread over 1Ø years of annual concerts. Also, the conclusions of the noise control team from Cirrus Research and Reading Council have been published elsewhere.(9) However, the important lessons learnt can be summarized by the 3 words - communication, planning and public relations.

Figure 1 GRAPHICAL REPRESENTATION OF THE MEASURED AND THE MAXIMUM PERMISSIBLE NOISE LEVELS AT THE MIXER TOWER AND IN HOLMESDALE ROAD



Reading is unique in that the local council is the landlord of the festival and can therefore impose any restriction it wishes. However, all parties used the venue as a test bed for ideas and systems and because of the continuity offered by a stable promoter - landlord relationship it was possible to try out regulations imposed by the team itself.

The noise team tried to write regulations to control its own work on the principle that the best test for legislation is to test the regulation. Eventually it was concluded that co-operation was much more effective than legislation and the published work emphasises this point.

Legislative Proposals

Diligent use of licensing powers can provide adequate controls with realistic conditions being carefully laid down in the licence and detailed monitoring during the event (8). But what can be done if the limits are exceeded? During a concert in Britain there are at present no effective sanctions although, technically, there is the power to stop the concert. In reality, turning off the sound would probably cause public disorder and to use physical force to reduce the volume is not an option. The licensing authority can prevent the promoter from returning to the venue if it is dissatisfied with the running of the event, be it for the breaking of noise limits or any other aspect. This, as has been described, can be sufficient on the day to achieve a reduction in volume. But to be able to impose a real sanction upon the errant promoter, consideration may have to be given to a performance bond, backed by a financial institution, which may be forfeit if certain parameters are exceeded. These parameters must be measured in the ground, and, ideally at the mixer so that the promoter/mixer engineer can see that the limits are being met.

As in the GLC code, therefore, the licence must stipulate that the licensing authority has an official on the mixer throughout. In addition, it is clearly up to professional acousticians to ensure that promoters are aware of the restrictions they are accepting. The authors have found, not surprisingly, that there is a real lack of perception amongst promoters of what a particular Leq means.

Control Procedure

A suggested legislative and control procedure is given in the checklist below.

1. Establish criteria for the noise limits to be used (such as those in the GLC code). These must be carefully explained to the promoter.

2. Careful wording of the licence condition so that the level stipulated is realistic, accurate and can be easily measured.

3. The licence to permit an official's presence at the mixer throughout and to include a financial penalty should the limit be exceeded.

4. The licence to specify that the speaker array in the form it is to be used is available 24 hours before the event so that the transmission loss between the mixer and the nearest noise sensitive dwellings can be determined. This gives time for the speaker stack to be re-arranged to give the maximum possible attenuation.

5. The licence to make it clear that any subsequent application would be assessed on the promoter's degree of compliance with the conditions.

6. Active control on the day with radio links between the mixer and those monitoring outside. Any complainants can then be visited quickly and the results of measurements then fed back to the mixer.

7. The data gathered to be used to prepare for the next concert.

The Technical Future

The use of Leq as the active control parameter has now generally replaced the L50 which was used in the past (4). Following publication by Luquet and Komorn (10), the concept of 'Short Leq' was tried as a parallel control at the Status Quo concert in Case Study 2. This approach required the use of a real time computer to calculate not only the 15 minute Leq as specified in the GLC code but any combination of parameters required. For example an L50 based on 125ms Short Leq can be computed instantaneously with the 15 min Leq. Also a running 15 minute Leq can be plotted against time. Finally, the computer can calculate the level required - over the next few minutes - that would be needed to maintain the overall Leq at the desired level.

This approach can use several Leq meters at various sites - inside and outside the venue to compute the concert 'footprint' on a continuing basis and to give some idea of the changing environmental situation. Such ideas, still in their infancy may well lead to even better control techniques being established.

8. Acknowledgements

Messrs Griffiths and Turner have published this paper with the permission of the Head of London Scientific Services. The views expressed, however, are those of the authors.

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NOISE CONTROL IN MAJOR HIGH VOLTAGE TRANSMISSION SUBSTATIONS

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ABSTRACT

It is less costly and more convenient that noise complaints, caused by Power Transformers and Reactors of major transmission substations which are located in residential areas, be anticipated and preventative measures taken before commissioning of the substation. This paper outlines the development of a computer model used in predicting sound levels at the substation boundary, and also reviews the use of masonry block enclosures in reducing noise. Based on the results, enclosures were designed and built for a 275 kV substation then under construction. The resulting sound attenuation of the enclosures and substation boundary sound levels are tabulated.

1.0 INTRODUCTION

The ever increasing load growth of power systems brings with it the need to install large high voltage transformers and reactors. Major transmission substations are often constructed in comparatively unpopulated areas but become steadily surrounded by subsequent housing development.

Power transformers and reactors emit low frequency sound of a tonal nature at the even harmonics of the power system frequency of 50 Hz. Because of these discrete tones, the sound is usually more audible or perceptible, and if at a level appreciably above ambient, will cause annoyance to residents of the area.

2.0 BACKGROUND

A series of complaints during the commissioning of transformers at Belmont substaion in February 1971 caused an investigation by the then S.E.A.Q. which resulted in the design and construction of Transformer noise enclosures. The enclosures were constructed of concrete masonry blocks, with an outer fascia of split rib blocks. The inner wall consisted of masonry blocks on their ends with 50 mm concrete tiles between each course to obtain a closed cavity with each block. The inner side of the block was drilled to give appropriately sized holes to produce Helmholtz resonator type cavities designed to absorb noise at 100 and 200 Hz.

Installation of these enclosures eliminated noise complaints at Belmont, and similar enclosures were then constructed at the Ashgrove West substation. The projects highlighted the need for accurate predicitions of boundary sound levels for future substations in order to prevent a reoccurrance of noise complaints.

Construction of Ross substation, a 275 kV substation near Townsville, commenced in 1983. The initial development included two 275 kV power transformers and two 275 kV line reactors, to be commissioned in May 1985. The site was located in an urban residential area with future residential developments proposed.

Accurate noise predictions of the boundary noise levels for each stage of development were desirable to ensure the cost effective measures were incorporated in the design to ensure that future community noise problems were avoided.

As a consequence, Vipac Pty. Ltd. was commissioned by the then Q.E.G.B. to carry out a series of noise prediction studies for the Ross substation, using a computer model. They were also to review the effectiveness of the Q.E.G.B. design of masonry block enclosures. Because of the high cost involved in drilling holes in masonry blocks, a standard "Acousticell" block was to be considered as a possible cost effective replacement.

3.0 NOISE PREDICTION METHODOLOGY

3.1 GENERAL

Fundamental to the prediction of boundary noise levels and to the selection of optimal noise control methods were the following:

- Accurate measured data on the sound power radiation characteristics of the various sources.

- A sufficiently accurate prediction methodology to calculate the propagation of acoustic emissions from source locations to adjacent boundaries or communities.

- A reliable estimator for the prediction of community response to transformer noise.

3.2 TRANSFORMER-REACTOR SOUND POWER DATA

Source noise data was provided by Q.E.G.B. in two forms:

- As space-averaged A-weighted sound levels measured at 1 m from various transformers and reactors.

- As frequency spectra and overall levels at multiple positions around a typical transformer and a typical reactor.

Typical sound power spectra (PWL) for each source were then calculated from the space-averaged near-field sound level spectra (SPL)(1).

3.3 COMPUTER MODEL

The Vipac community a noise computer program, COMNOS, is a mathematical model of sound propagation which is based on the Concawe Report 4/81 "The Propagation of Noise from petroleum and Petrochemical Complexes to Neighbouring Communities"(2).

This model uses the source sound power spectrum and computes the contribution of each source at each received point of interest by octave band frequency. Each individual path is determined and the appropriate correction made for distance, atmospheric, meteorological, barrier source height and ground cover attenuation effects. The resultant sound level at each location is then the sum of these individual components.

Barriers formed by structures adjacent to the source and located between the source and receiver point are modelled in the computation as realistically as is feasible. Topographical barrier effects are also modelled although in this instance such effects were minimal.

3.4 BARRIER INSERTION LOSS CALCULATIONS

The path-specific attenuation values (measured in dB) were obtained by numerical integration of the contribution of point and sound sources covering all radiating areas of the transformer and on the appropriate normalisation of the results of these numerical calculations, as described by BBN (3).

3.4 BARRIER INSERTION LOSS CALCULATIONS (CONTINUED)

It was clear from the barrier insertion loss algorithms that the absorption coefficient of the enclosure lining should be maximised to achieve maximum enclosure effectiveness.

3.5 SOUND ABSORPTION CO-EFFICIENTS OF BARRIER LININGS

A common form of absorptive treatment for exposed sound-absorbing barriers consists of Helmholtz resonators formed into the cavities of concrete block wall constructions such as custom drilled Besser concrete block (single and double holed) or standard Boral "Acousticell" blocks.

Measurements of random-incidence sound absorption co-efficient for walls constructed of each product were carried out in the the 204 m^3 reverberation chamber at CSIRO, Highett, Victoria. The Besser block wall was also tested when water had been introduced to all cavities.

The testing program indicated that:

- Adjustment of Besser block hole diameters was required for optimal lining design due to the development of peak absorption in the 125 Hz one-third octave band instead of the 100 Hz one-third octave band.
- Part filling of the Besser block cavities (by rain water or mortar spillage) increased the resonance frequencies, as expected.
- Besser block sealing was critical to maintaining design resonant frequencies.
- Peak absorption for standard Boral blocks occurred in the 200 Hz one-third band.
- The custom-made Besser Blocks were more efficient sound absorbers of single transformer tones than the standard Boral "Acousticell" block (eg at 200 Hz, 1.5 metric Sabins per square metre compared to 1.14)

3.6 EFFECTS OF FIREWALLS BETWEEN TRANSFORMERS

The acoustic effects of the placement of a firewall of dimensions 11.2 m wide by 7.6 m high between the transformrs was analysed using conventional acoustical arguement (4). It was concluded that the firewall would have no measurable effect on sound levels at any community location and so it was not included in the mathematical model.

3.7 COMMUNITY NOISE ASSESSMENT

The procedures recommended in Australian Standard, AS1055-1984 (5) may be used to assess the likelihood of noise annoyance resulting from the operation of the proposed Ross Substation (6).

3.7 COMMUNITY NOISE ASSESSMENT (CONTINUED)

This standard compares the annoying noise level to the background noise level with adjustments for tonality, etc. In this case, a penalty of 5 dBA should be applied due to the tonal character of the transformer noise.

The greater the difference between the adjusted measured noise level and the background noise level, the greater the likelihood that the noise will be annoying.

An estimate of the community response for excesses greater than 5 dBA may be determined from Table 1, extracted from ISO-R1996 (7).

TABLE 1 - ESTIMATED COMMUNITY RESPONSE TO NOISE

Amount in dBA by which the rating sound level Lr. exceeds the noise criterion	Estimated Category	Community Response Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very Strong	Vigorous community action

4.0 NOISE PREDICTION

Accurate prediction of the effects of four-sided lined barrier enclosures, as used for transformer substations, is most difficult and so it was decided to test the agreement between predicted and measured noise levels for an existing substation prior to applying the methodology to the proposed substation at Townsville.

4.1 BELMONT SUBSTATION

Sound level spectra were recorded at four boundary locations around the existing Belmont substation, Brisbane. The transformer tones were clearly identifiable in the general background noise spectrum. In general, the A-weighted levels were influenced by local background sound levels (traffic, insects, corona) with transformer contributions being 3-5 dBA below the total measured levels. Noise levels were also predicted at the four boundary locations using the COMNOS computer model.

4.2 PROPOSED ROSS SUBSTATION

The COMNOS computer model was used to predict boundary noise levels for the following development phases of the project:

4.2 PROPOSED ROSS SUBSTATION (CONTINUED)

ie. i) Initial development - two transformers/four reactors
- no enclosures

ii) as above - with enclosures

iii) final development - four transformers/ten reactors
- no enclosures

iv) as above - with enclosures

Predicted boundary noise levels for case (iv) are shown in Figure 1.

The effect of increasing barrier heights was modelled and was found to decrease the contribution of transformers to boundary sound levels by 3 dBA.

Inclination of the tops of the enclosure walls was found to provide no reduction in boundary sound levels.

By comparing the predicted noise levels and the criteria of Section 3.7 it was concluded that the substation would cause valid community annoyance during favourable atmospoheric conditions with adjusted excesses above the background and levels of 7 and 10 dBA for the initial and ultimate developments. Medium community response (ie. widespread complaints could therefore be expected from residences located close to the substation boundaries.

The following noise control recommendations were provided to the Q.E.G.B. for consideration.

- Tighten specifications for construction/sealing of resonator block walls.
- Confirm manufacturer's capacity to comply with low tender specified sound power/pressure level data.
- Increase the enclosure walls height to 1.5 m above transformer and reactor tank tops.

5.0 RESULTING DESIGN AND IMPLEMENTATION

5.1 DESIGN

The following design changes were made to the previous drilled masonry block enclosure following Vipac's recommendations.

- Reduction in drilled hole size of the 100 Hz block.
- Tool all mortar joints on both sides of the drilled block wall to effectively seal the enclosed spaces of each block.
- Paint the inside face of the enclosure only, with a weatherproof sealant to reduce rain water absorption and improve sealing of the joint.
- Higher enclosure walls.

5.1 DESIGN (CONTINUED)

Table 2 shows the 100 and 200 Hz tonal noise components of a Transformer and Reactor in service at Ross substation. (Taken from manufacturers test report).

TABLE 2 TRANSFORMER AND REACTOR NOISE TONE LEVELS

Equipment	Tonal Sound Level Component, dB 100 Hz	200 Hz
275/132 kV Transformer	63.2	65.0
300 kV Reactor	73.3	61.8
(measured at 1 m)		

The ratio of 100 Hz and 200 Hz tuned blocks used for the enclosure lining is 1:1 for the transformer enclosures and 2:1 for the reactor enclosures.

5.2 CONSTRUCTION

The specification for construction of the enclosures was amended and site supervision increased, with particular attention being given to:

- The seal of all external mortar joints and the mortar joints across the block webs.
- The care taken in minimising mortar spillage into the block cavities.
- Correct hole size in the block face, with minimum break away around the inside face of the hole.
- Ensure that there is no build up of waterproof sealant around the neck of the drilled holes.

5.3 TEST RESULTS

5.3.1 Enclosures

Both overall sound levels (dBA) and frequency spectrum (dB) were measured at points around the enclosures at 1/3 and 2/3 tank height for both a transformer and reactor, and were compared with manufacturer's test reports listing overall dBA and sound spectra. The spatially averaged noise levels are shown in Table 3.

5.3 TEST RESULTS (CONTINUED)

5.3.1 Enclosures (Continued)

TABLE 3 EFFECTIVE SOUND ATTENUATION OF ENCLOSURES

Frequency	Transformer Without Encl.	Transformer With Encl.	Transformer Attenuation	Reactor Without Encl.	Reactor With Encl.	Reactor Attenuation
100 Hz	63.2 dB	49.2 dB	14.0 dB	78.3 dB	55.1 dB	23.2 dB
200 Hz	65.0 dB	46.0 dB	19.0 dB	61.8 dB	44.0 dB	17.8 dB
Overall sound level	65.9 dBA	45.3 dBA	20.6 dBA	62.8 dBA	44.3 dBA	18.5 dBA

5.3.2 Boundary Levels

Sound levels (dBA) were taken at three positions on the substation boundary as listed in Table 4. It was difficult to get accurate readings due to insect noise and corona from overhead lines. No transformer or Reactor noise was audible at these locations.

TABLE 4 MEASURED BOUNDARY NOISE LEVELS AT 7 am
(some corona still evident)

Position	Predicted (dBA)	Actual (dBA)
1	30	34
2	32	35
3	30	36

6.0 CONCLUSION

Consideraion of community noise levels at the design stage using computer modelling has enabled the substation design to be optimised with confidence and has provided a base-line from which further noise control actions have been implemented to prevent the occurrence of community noise complaints for each stage of development.

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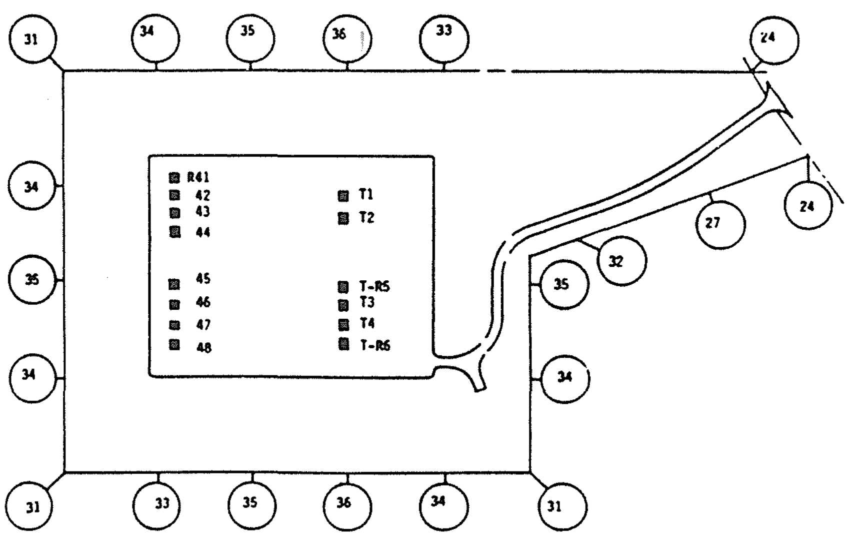

FIGURE 1 PREDICTED A-WEIGHTED SOUND LEVELS - ROSS SUBSTATION ULTIMATE DEVELOPMENT WITH ENCLOSED TRANSFORMERS AND REACTORS

THE EFFECT OF BUFFER ZONES AROUND A COAL MINE

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ABSTRACT

In anticipation of the potential for concern by residents in the neighbourhoods of proposed mines in the Hunter Valley of N.S.W. and to reduce potential for annoyance from environmental changes, Councils and statutory authorities required developers to ensure that changes in environmental quality were minimal.

When BHP Minerals commenced investigations for the development of Saxonvale Coal Mine near Singleton, it was realised that an environmental buffer zone between the mine and neighbouring residents would be an advantage. The company purchased adjacent agricultural holdings to provide a buffer zone to the north, west and south; the Department of Defence Singleton Artillery range forms the eastern border to the mine lease.

Regular environmental noise monitoring is made in the neighbourhood surrounding the mine. Seasonal meteorological conditions have the most significant effect on sound levels in the community, caused by mining activities.

The advantages and reasons for use of buffer zones around mines are discussed. Unless the areas involved are large the benefits for noise control are limited. Reduction of ground vibration is assessed to be a major determinant in planning buffer zone areas.

1.0 INTRODUCTION

The middle and upper Hunter Valley of New South Wales is an area which experienced substantial increases in coal production in the late 1970's and early 1980's. Several open cut coal mines with productions of over 3.0 million tonnes per year were planned, developed and commenced operations during this period. The development boom was a result of the "oil crisis" which precipitated an increased demand for steaming coal.

In anticipation of the potential for concern by residents in the neighbourhoods of the proposed mines and to reduce potential for annoyance from environmental changes Councils and statutory authorities required developers to ensure that changes in environmental quality were minimal. Parameters such as dust fallout, water quality, illumination, ground vibration and noise were to be reduced to appropriate levels by the time they were perceived in the surrounding community, to reduce the potential for loss of environmental amenity. The conclusions of this paper are mainly drawn from experiences encountered during the development of BHP Saxonvale Coal Mine.

2. BHP SAXONVALE COAL MINE

The Saxonvale Coal Mine is located near Singleton, 80 km west of Newcastle, in the Hunter Valley region of New South Wales. The mine was established in 1981 with coal reserves of 1 000 million tonnes or high quality energy coal distributed in 24 seams. The top nine seams are within 300 metres of the surface and are being extracted by open cut multi-bench excavations. Development is planned in four equal stages, progressively meeting export market demands up to a possible expansion of 7 million tonnes per year of raw coal. Operations are 24 hours per day for 5 days a week.

The mining method is drilling and blasting of overburden, loading by shovel into trucks for disposal in emplacement areas out of the pit and coal recovery by shovels and front-end loaders into trucks which haul the raw coal to a coal preparation plant. Cleaned coal is stockpiled for later rail transport from the mine site to an export coal loader in Newcastle. Current clean production is around 1.0 million tonnes per year.

In 1980 BHP Engineering carried out comprehensive environmental studies and prepared an Environmental Impact Statement (EIS) for the Saxonvale Mine. These provided important information for a number of parallel studies by BHP Engineering into mine planning, overburden handling and emplacement, coal treatment, engineering, economics and transportation.

The Saxonvale mine site is on undulating, poor grade pasture land with a low remnant ridge to the south separating the mine from the village of Broke.

The company purchased freehold tenure of the areas to be disturbed directly by mining activities and also some surrounding properties as an environmental buffer zone to the north, west and south. An area of 3 240 Ha (800 Ac) is held. Agricultural activities continue on land not in use for mining activities and some agricultural activities and reafforestation will be re-established on restored areas. The surrounding land use is essentially agricultural, with cattle grazing, a few vineyards and dairies and hobby farms.

Hobby farms occupy most of the area south west of the mine. Occupiers of these farms are typically "refugees from the rate race" who are able to afford the rural/agricultural lifestyle without making the land pay. They also have heightened environmental awareness and consciousness of their "rights".

2.1 Overburden Emplacement

In the initial stages of mine development as the pit is expanded to its full depth, 200 million cubic metres of overburden is being placed outside the pit.

Transportation of the overburden and interburden to the emplacement areas is by 170 and 190 tonne rear dump diesel-electric haulers. These are the major sources of noise emission from the mine. The emplacement is gradually filling into a ridge which is up to 300 m relative level. The base height and surrounding land form are around 100 m relative level while the maximum height of the emplacement will be to 160 m relative level. Thus the construction of the emplacement involves elevation of the haul trucks well above the surrounding land form which has the potential to increase sound levels at locations not protected by the intervening ridge line.

2.2 Mining Operations

Actual mining operations are confined to the pit area and as the pit has developed to deeper levels the influence of sound emissions from the pit are only nominally discernible within a few hundred metres of the pit limits.

Equipment used in the mine is diesel powered and consists of dozers, loaders, scrapers, graders and service vehicles. Shovels and drills are electric powered from trailing cables. Other sources of noise are the rail loading station, coal preparation plant and its associated breaker station and conveyors.

Blasting of overburden is by multiple detonation circuits with interval delay devices to reduce ground vibration and airblast. Times of blasting are around mid-day with normally only one shot on any day and advance warning is given on a noticeboard at the mine gate. Blast quantities vary with up to 150 tonnes of emulsion explosives being used in a shot.

The mine currently employs 330 people, most of whom live in either Cessnock, Singleton, Broke or the surrounding area.

3.0 MONITORING PROGRAMME

To ensure the effectiveness of the many pollution control measures implemented at the mine, extensive monitoring programmes for water quality, dust deposition, ground vibration and noise were instituted when construction of the mine began and has continued during the operating phase. Reports on these programmes are submitted regularly to various state and local government supervisory agencies.

An automatic recording weather station has also been established at the mine to provide meteorological information needed in the water management programme and to correlate to the dust, water and noise monitoring.

3.1 Ground Vibration

A condition of development approval was that ground vibration and air overpressure from blasting would be below limits set by the State Pollution Control Commission. Blasting practices are designed to minimise these effects, and permanent recording facilities for measuring peak particle velocity and air overpressure have been installed to monitor blast effects.

The unit chosen was a Sprengnether VS1600 automatic remote vibration and blast monitor. It is located on the southern property of the freehold buffer zone, between the mine and the village of Broke. It has also on occasion been located near residences further distant from the mine.

To date the SPCC limits have not been exceeded in recorded blasts. Some problems have arisen with the operation of the remote unit having significantly more recordings than blasts at the mine. This was found to have been caused by operations at the adjacent army artillery range causing ground vibration levels above the set threshold of the unit. The occasional F-111 dropping 500 kg bombs and heavy artillery fire cause ground vibration levels similar to those from blasting at the mine.

3.2 Noise

As a condition of the development approval, the SPCC required that a programme be set up to monitor sound levels in the community around the mine. At some mines one or two fixed units monitor sound levels continuously. It was decided that a more effective programme would be to make regular sound level surveys on a seasonal basis at many locations in the community surrounding the mine. In this way the noise environment of the neighbourhood could be better defined, daily and seasonal variation in background sound levels more easily noted and the difference between the mine in the operational and idle phases identified. Most importantly, this programme has an experienced pair of ears with a sound level meter out in the neighbourhood to identify the major sources of mine noise emissions to the community, the causes of high background sound levels at different times, the effects of weather and sound transmission and to interpret readings, and assess and evaluate where potential problems for mine operations may occur.

Sound level measurements are made at around 20 locations near residences and in the neighbourhood of the mine. The same locations are used for each survey to provide comparisons between surveys in different seasons and from year to year.

Measurements are of A-weighted sound pressure levels for the following parameters:

(i) background - the average minimum measured
(ii) average - average sound level
(iii) maximum event - maximum sound level noted from a specific source.

Statistical sound loggers are also locatd at four of the locations for the duration of the survey. These give statistical distributions of sound level, exceedence levels and L_{eq}.

The surveys take two to three days, depending on operational and meteorological conditions. Sound levels are measured during daylight hours, then early evening and finally early morning (usually midnight to 3.00 am). During these times, sound levels are measured with the mine both operational and idle, where possible. This gives information on the increase in sound level caused by the mine.

More time is devoted to measuring sound levels at night because of the higher potential for noise annoyance and the enhanced transmission of sound in the atmosphere at night. Thus, the programme attempts to measure sound when mine sound emissions have the highest potential for noise annoyance.

4.0 DISCUSSION

4.1 Buffer Zones

The intention of the buffer zones around Saxonvale Mine and other coal mines in the region is to physically separate the mines and their associated potential environmental impacts from the surrounding community. Such effects as dust fallout, water quality,illumination, ground vibration and noise are expected to be reduced to appropriate levels by distance. Most development approvals require screening of the mines by tree planting and 'environmentally harmonious' design and landscaping of buildings.

It appears that the intention of councils and government planning bodies is to allow the mines to operate behind a screen so that the surrounding community and passing travellers are not disconcerted by the activity. This, of course, leads to community harmony but, the moral question of not allowing the public to see, whilst an industry which utilises modern engineering technology and is our major export earner and local government rate payer, carries on its business next door, is difficult for the curious and technocrats amongst us. "Out of sight out of mind" does not seem appropriate.

With respect to noise and ground vibration, the buffer zone becomes essentially a trade-off in cost. The development plant for Saxonvale Mine involves the pit's gradually increasing in size (area and depth), then moving ahead in one direction at one end while in-pit dumping occurs at the other. Thus, the buffer zone includes the area eventually to be included in the mine, the overburden emplacement area and coal handling areas.

Outside the areas to be directly affected by mining operations is the 'pure' buffer zone. This is the land purchased by the company which lies between mining activities and neighbours and under current plans will never be mined.

The trade-off in cost provided by the buffer zone is that associated with noise controls at the mine in accordance with the following principle. Machinery associated with mining activities emits noise, the major sources of noise emission being haul trucks transporting overburden to elevated emplacement areas.

These haul trucks have sound levels of 90 to 95 dB(A) at 15 m. To reduce the potential for noise annoyance in the community, sound levels can be reduced either at the source by treatment of the vehicle, in the transmission path by construction of barriers, by conducting operations far enough away from residences to allow sufficient distance attenuation or a combination of all three. (Treatment of the receiver is not normally an acceptable solution). Therefore, by having a large distance between the mining activities and the receivers/residences, to act as a buffer zone, the cost of other controls is reduced.

Other agricultural land adjacent to the company land acts as an extension to the buffer zone and limits the number of potentially affected residences but control of development in these areas is not available to the company. Local government town planners therefore have responsibilities in these areas to control development and eliminate potential conflict between adjacent land uses. For example, a housing estate close to a mining operation could constitute a conflict of land use.

In determining a suitable size for a buffer zone, the area to be purchased increases by a square law as distance increases. Some mines have spent 10 to 15% of their capital budget on buffer zones. As the buffer zone is increased in size, a point is eventually reached where capital and operational costs become too high at which point the mining companies have to employ farmers and agricultural consultants. When some land-owners refuse to sell, the environmental benefits become smaller.

For the Saxonvale Mine, the increases in dust deposition rates approach background level within about 1 km of mining operations, yet the buffer zone extends much further than this, with the nearest residences to the pit currently being 2.5 to 3 km, and one residence at 1.5 km from the nearest emplacement area.

4.2 <u>Saxonvale Community Sound Levels</u>

Experience gained from the monitoring surveys has indicated that the benefit of the buffer zone for noise reduction is limited.

The noise environment of the Saxonvale Mine neighbourhood is typically agricultural, with generally low sound levels dependent upon seasonal factors and time of day. Daytime sound sources include birds, insects and small animals, which can be significant in summer and near wet areas, farming activities, aircraft, occasional artillery range noise and vehicle transportation noise. Vehicle transportation noise is the major noise source during daytime and until after 10.00 pm at night, although at night-time the traffic flow is gradually reduced, with peaks occurring around shift change times. Night-time sound sources are mainly birds, insects and small animals, which can cause background sound levels around 45 to 50 dB(A) in summer, and farming activities - pumps, sprays etc.

Daytime background sound levels are generally lower than night-time sound levels, except perhaps during winter, because of the daytime refraction of sound upwards. The influence of sound emissions from mine activities is greater at night-time. Background sound levels during daytime are usually 30 to 35 dB(A), except when close to sources of human origin, or at times of high wind speeds. Night-time background sound levels vary from around 25 dB(A) or less at some locations in winter, to 45 to 50 dB(A) in summer when insect activity is high.

Meteorological conditions in the cooler months of the year can also significantly affect sound transmission. To the south and west of the Saxonvale Mine are significant areas of mountain wilderness - Wollombi National Park. The Wollombi Brook, west of the mine, flows north towards the Hunter River. In cooler months, there is cold air drainage from the mountains, along the Wollombi Brook valley at night-time. This places a layer of cold air several metres deep along the floor of the valley and acts as an enhanced transmission path for sound. Low level atmospheric inversions are built up on most nights when the conditions are calm. Therefore at night-time in winter months, there is a combination of low background sound levels of around 30 dB(A) or less, coupled with enhanced conditions for transmission of sound from mining activities.

At some locations 6 to 7 km from overburden emplacement areas, sound emissions from vehicles at Saxonvale are discernible and occasionally measurable above the background. Generally, sound levels from mine operations are within 5 dB(A) of the background sound level at locations distant from the mine (i.e. not within the buffer zone), although they have on occasion been measured up to 40 dB(A) near residences at 7 km from the active emplacement site.

Noise emissions from other mining operations to the north of Saxonvale mine are also discernible and measurable within the monitoring area. Thus, the whole noise climate of the region is becoming influenced by noise emissions from mining activities, especially at night-time. In recognition of the change in land use and the influence of mining activities, the SPCC has requested an environmental goal of 35 dB(A) in the neighbourhood of the mine, rather than the minimum background which can at times be lower by 10 dB(A) or more.

5.0 CONCLUSION

In considering buffer zones as part of a combined approach to noise control around open cut coal mines in general, with the undulating countryside typical of the Hunter Valley mining areas, and meteorological conditions causing enhanced transmission of sound through the atmosphere, the area required to ensure sound levels caused by mining operations at the nearest residences are not above background is extremely large, perhaps with a radius of 8 to 10 km from the noise source. This is unrealistic for freehold purchase in most circumstances.

The key factors for introducing buffer zones are control of dust, noise and ground vibration and improved community relations by reducing conflict with neighbours.

The dust fallout associated with open cut coal mines approaches background levels and is not regarded as a problem within less than one kilometre of mining activities. Thus, the required buffer zone is relatively small.

For minimising the effects of ground vibration from mine blasting, the distance to the nearest houses is dependent upon the size and format of the blast. By the use of scale distances and experience at similar mines, the buffer zone required to ensure ground vibrations are less than a peak particle velocity of around 1 mm/s during most blasts, can be calculated.

For minimum potential for noise annoyance from mining (or other) activities, the increase in sound level above background should be as low as possible. In determining areas of buffer zones and distances to nearest residences, the major determinant for effective control is probably the minimisation of ground vibration from blasting. After this the effects of distance attenuation of noise can be evaluated and the costs of extra buffer zone area, if available and if required, can be evaluated against costs of noise reduction engineering to mining equipment. This may be around $20 000 per machine.

For the BHP Saxonvale Coal Mine, a regular environmental noise monitoring programme has determined operating constraints for minimal sound levels in the surrounding community. Haul trucks have been retrofitted with noise controls to reduce sound levels to around 87 dB(A) at 15 m. Night-time operations are kept as far from houses as possible and behind existing emplacement areas, also where possible. These measures have resulted in sound levels from mine operations within 5 dB(A) of the background sound level on most occasions.

ACKNOWLEDGEMENTS

This paper was prepared from work undertaken by BHP Engineering for the BHP Saxonvale Coal Mine. The assistance of the two organisations in preparation of this paper is acknowledged and appreciated.

THE APPLICATION OF COMPUTER NOISE MODELS TO QUARRY PLANNING

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ABSTRACT

Environmental noise control of quarries is an important aspect of quarry management. Quarrying noise can be highly annoying to surrounding residents and poor noise control may lead to action by the appropriate authorities. Two aspects of noise control management are discussed for i) existing quarries and ii) proposed quarries.

For existing quarries, environmental noise control includes the monitoring of existing noise levels at noise sensitive areas and the computer modelling of the operations. Input to the model requires determination of sound power levels of the major noise sources, ground levels and attenuations due to ground cover at each grid point. The model, when tuned, may then be used to predict noise levels from future quarrying configurations. If noise level criteria are exceeded at nearby residences the effect of proposed remedial action may be modelled to ensure the criteria are met.

For proposed quarries, environmental noise control includes the optimum location of the crushing and screening plant, haul roads and selection of the method and extent of quarrying. It ensures noise levels at noise sensitive areas comply with the appropriate criteria. Computer modelling is an invaluable tool to achieve this end.

1.0 INTRODUCTION

In our modern world quarries represent an essential industry, providing the basic raw materials for construction of roads and buildings. Indeed both these industries are reliant upon efficiently run quarries to provide competitively priced material. Unfortunately because of their very nature, quarry operations produce various forms of pollution, including noise, dust, vibration and visual pollution. When not properly controlled, any one or a combination of these may be introduced beyond the quarry boundaries into rural or residential areas.

The majority of residents living near quarries tend to be hostile toward their operations, since they perceive them as being detrimental to quality of lifestyle and real estate values.

Partly as a result of community expectation of certain standards of living, state governments in Australia in the last decade or so have enacted legislation limiting the allowable amount of pollution in residential areas caused by industry.

This paper concentrates on the environmental noise aspects of quarries. In particular it shows that models based on sound physical principles, together with high quality source level data, are useful and effective tools in predicting noise levels from quarry operations. Because of the large computational effort involved it has been found that the most practical way of handling the wide range of geometrical complexity characteristic of a real quarry site is by means of a sophisticated computer model. Once such a model has been developed, it may be used in the case of existing quarries to arrive at the most cost-effective methods to contain noise to statutory limits in surrounding areas. In the case of proposed quarries, it can be used effectively to achieve the optimum layout, minimizing noise levels in the surrounding areas.

2.0 MAJOR QUARRY NOISE SOURCES

There are a number of aspects of the quarrying process which are associated with noise generation. Basically, these processes can be identified as:

i) drilling into the rock with a rockdrill
ii) blasting of the rock to fragment it
iii) transferring the rock from the blasting site to the crushing and screening plant by means of a front end loader and haul truck
iv) crushing and screening the rock to various sizes and stockpiling
v) loading the road trucks, which deliver the product to the markets, by means of front end loaders.

The majority of these activities tend to produce noise on a more or less continuous basis, except for blasting operations, which usually occur only once every one or two weeks.

3.0 BASIC PHYSICAL PRINCIPLES

The starting point in any modelling exercise involves the determination of representative sound power levels for the various noise sources. Once these have been established, the sound pressure level contributions at points of interest from each noise source may be found using the following equation:

$$\Delta SPL_i = SWL_i - K_1 - K_2 - K_3 - K_4 \qquad (1)$$

where

ΔSPL_i = Sound pressure level contribution at the receptor location from source "i"
SWL_i = Sound power level of noise source "i"
K_1 = Attenuation due to hemispherical spreading
K_2 = Atmospheric attenuation
K_3 = Attenuation due to ground cover
K_4 = Barrier attenuation

Various publications are available specifying the attenuations K_1-K_4 (references 1 and 2). The sound power levels are usually specified in terms of L_{eq} (the equivalent noise level containing the same energy as the fluctuating signal). This is partly because most current criteria are written in terms of this parameter, and because L_{eq} levels are additive whereas other parameters such as L_{10} are not.

The SWL's for the sources are usually obtained from sound pressure levels measured close to the source (typically 7m to 30m) by applying the relevant distance attenuation parameter K_1, since at these distances K_2, K_3 and K_4 are for all intents and purposes zero.

For quarries, the most difficult input parameters to determine tend to be the SWL's for the crushing and screening plant, since a number of significant noise sources are close to each other (typically within 30-40 metres), none of which can be readily isolated. This necessitates a number of sound pressure measurements around each source to enable the estimate of the contribution of the other sources to the measured sound pressure. The directivity of each source is virtually impossible to obtain for a large plant with many noise sources, but can be obtained for a small plant with a dominant noise source.

Particular care also needs to be taken in defining the height of each source, since this is of importance in barrier calculations and to some extent in deriving ground attenuation effects.

For the other sources associated with quarrying, the SWL's may be obtained by testing mobile equipment such as road trucks, haul trucks, dozers and loaders according to Australian Standard 2012 - 1977, "Method for measurement of airborne noise from agricultural tractors and earthmoving machinery". This standard contains guidelines to calculate representative L_{eq}'s of mobile equipment taking account of the range of functions performed and the time spent performing each function.

When dealing with the mobile sources such as haul trucks, the L_{eq} obtained by the above method is equivalent to the noise level obtained if one were to move alongside the source at a fixed distance from it.

To extract the L_{eq} at any fixed point, the total sound power level for the route travelled needs to be determined. The route may then be divided into a number of sections, each of which is represented by a point source with the appropriate sound power level.

The other major item is the rockdrill, whose L_{eq} may be obtained by monitoring while the rockdrill is used to drill one or more holes.

It is usual these days to obtain a frequency spectrum for each of the sources in terms of octave bands. Most of the acoustic energy, in terms of dB(A), lies in the range 63 Hz - 8000 Hz. The attenuations K_2, K_3 and K_4 in equation (1) are all functions of frequency.

4.0 MODELLING QUARRY NOISE

Predictions of noise levels from quarry operations were made using a computer model called NOISY which was developed by Winders, Barlow & Morrison Pty. Ltd. (WBM) to solve equation (1). The model uses an x, y, z grid system with the ground level and the ground attenuation being defined at each grid point. An advantage of this method is that noise level contour plots can be readily obtained from the results.

WBM has been extensively involved with the Pioneer owned quarry at Ferny Grove, near Brisbane. The location of this quarry relative to surrounding residences is shown in Figure 1. Also shown are the ground level contours which indicate the presence of two hills to the north and southwest of the crushing and screening plant.

4.1 MEASUREMENT OF SOURCE NOISE LEVELS

Extensive noise monitoring was carried out at the Pioneer quarry site to obtain the sound power levels of each major noise source in the quarry. Figure 2 shows typical 'A' weighted octave band sound power levels for some of these noise sources. It is evident that the predominant acoustic energy as perceived by the ear lies in the range 250 Hz - 4 kHz for the plant and 500 Hz - 8 kHz for the rockdrill.

4.2 CALIBRATION OF MODEL

Equation (1) was initially solved for the plant noise sources and the stockpile loader working nearby. In order to calibrate the model, noise monitoring at several locations surrounding the quarry at distances between 500m and 1000m from the plant was carried out. It was found that under light wind conditions the noise levels due to these sources matched the predicted noise levels to within 2 dB(A). At one location the difference was 4 dB(A); however subsequent investigation revealed that an existing bund wall had been altered. After making allowance for this change the noise level at this location also was within the above-stated accuracy.

It should be mentioned that at distances of 500m to 1000m significant variations in noise can occur depending upon prevailing meteorological conditions as outlined in references 1, 2 and 3. For example at times when monitoring was carried out upwind of the quarry operations, the plant noise was often inaudible (i.e. it was less than the background

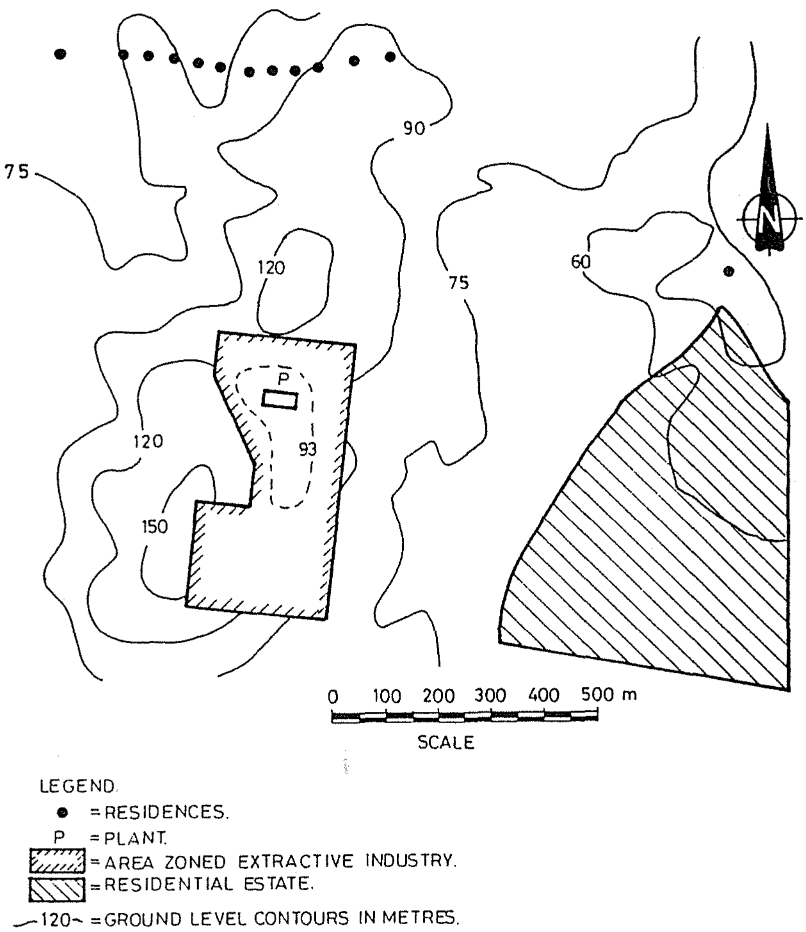


Fig. 1. AREA MAP.

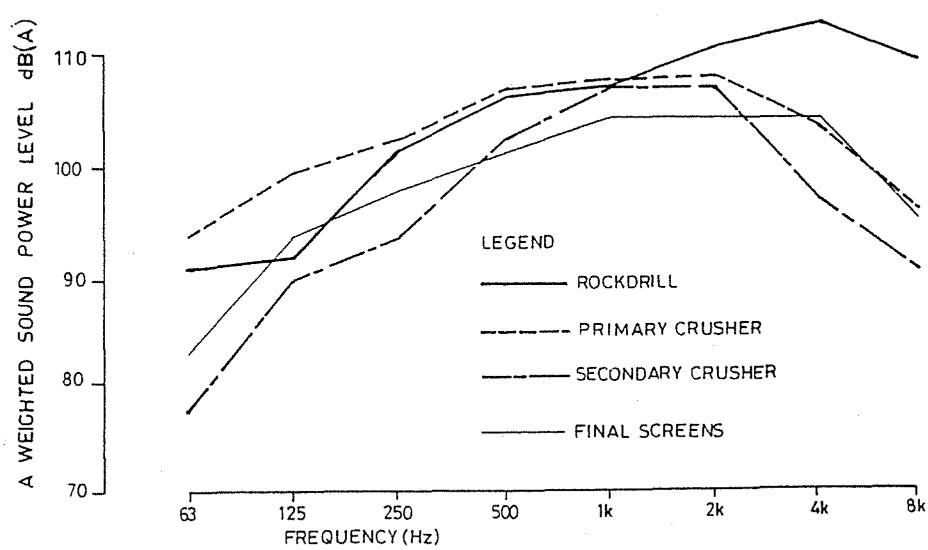


Fig. 2. FREQUENCY SPECTRA FOR ROCKDRILL, CRUSHING AND SCREENING PLANT.

noise level of around 35 dB(A)). At other times when downwind of the quarry operations for wind speeds in excess of 2-3m/sec, the noise levels were up to 3 dB(A) higher than during light wind conditions. At the same time the background levels also increased due to the presence of a substantial number of trees in the area, so that the audibility of the quarry operations was still about the same as under light wind conditions.

The incorporation of an attenuation factor K_5 in equation (1) due to meteorological conditions may well become a standard feature of predictive models in the future, particularly if a residence is downwind of operations for a significant proportion of the time during which the quarry is operating.

4.3 CASE HISTORIES

Example 1: Modelling of a bund wall

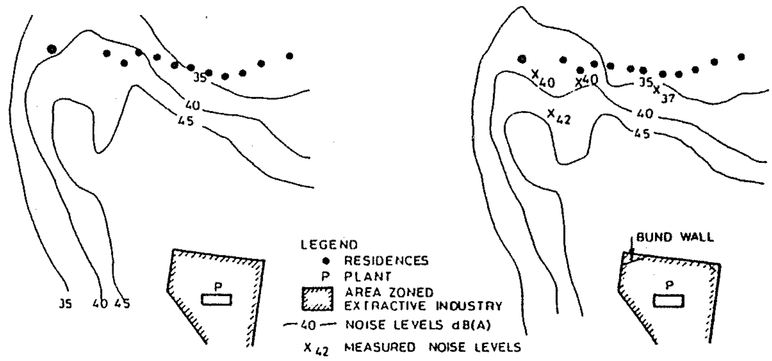
Some time ago complaints were received from neighbouring residents to the northwest regarding early morning operations of the crushing and screening plant. The L_{eq}'s at the residences were in the range of 42-44 dB(A). Figure 3a shows the existing noise levels at that time as predicted by the computer model. From Figure 1 it is evident that the noise was able to propagate to these residences relatively unhindered because of a gully between the two hills shown. It was required to reduce the noise levels to below 40 dB(A).

To solve this problem it was proposed to fill in the gully and erect a bund wall. To achieve 40 dB(A) or less at the residences, calculations indicated that the top of the wall should be at least 12m above the ground level level where the plant was located. In the event a 14m high bund wall was constructed. Figure 3b shows the bund wall location and the resulting noise levels. This figure also shows the sites where noise levels were obtained with the bund wall in place. It may be noted that the predicted noise levels are within 1-2 dB(A) of those measured.

Example 2: Quarrying method minimising noise levels outside quarry

Even though the crushing and screening plant at Pioneer's Ferny Grove quarry has the highest sound power levels, its noise propagating towards noise sensitive areas is attenuated by suitable barriers such as bund walls and permanent stockpiles. However by its very nature the quarry face (i.e. the area where rockdrilling, blasting, loading and haul trucking operations occur) continually changes. Thus at some time operations may be near the natural surface, resulting in little barrier attenuation and hence a possibility of relatively high noise levels at the surrounding residences. Therefore a particular quarrying method called the "receding tree line method" has recently gained popularity. Figure 4 shows the principle of this method. In essence quarrying operations occur behind the side of the hill, which acts as a noise and visual barrier.

Pioneer also own land immediately to the west of the present area being quarried and, since it contains deposits of suitable rock, were



(a) WITHOUT BUND WALL (b) WITH BUND WALL

Fig. 3. PREDICTED NOISE LEVELS DUE TO PLANT.

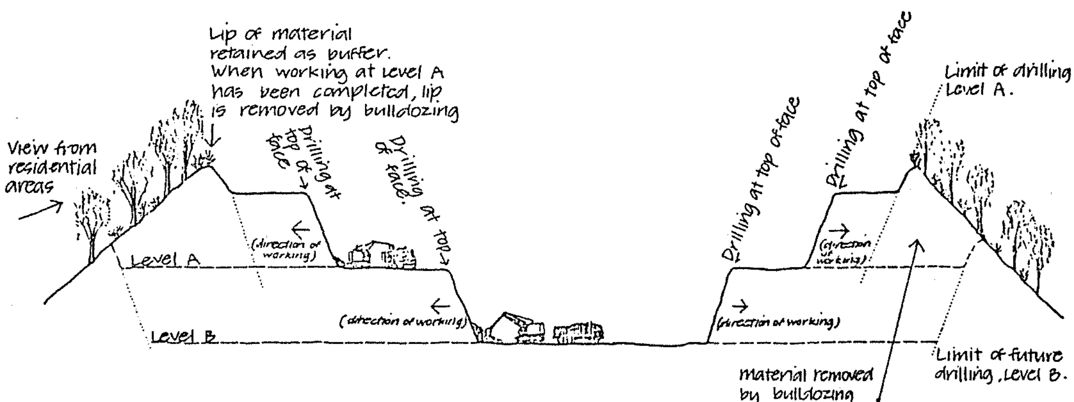


Fig. 4. RECEDING TREE LINE METHOD OF QUARRY OPERATION.

Cameron McNamara Pty Ltd (Incorporated in Queensland) (B2 2059) October 1983

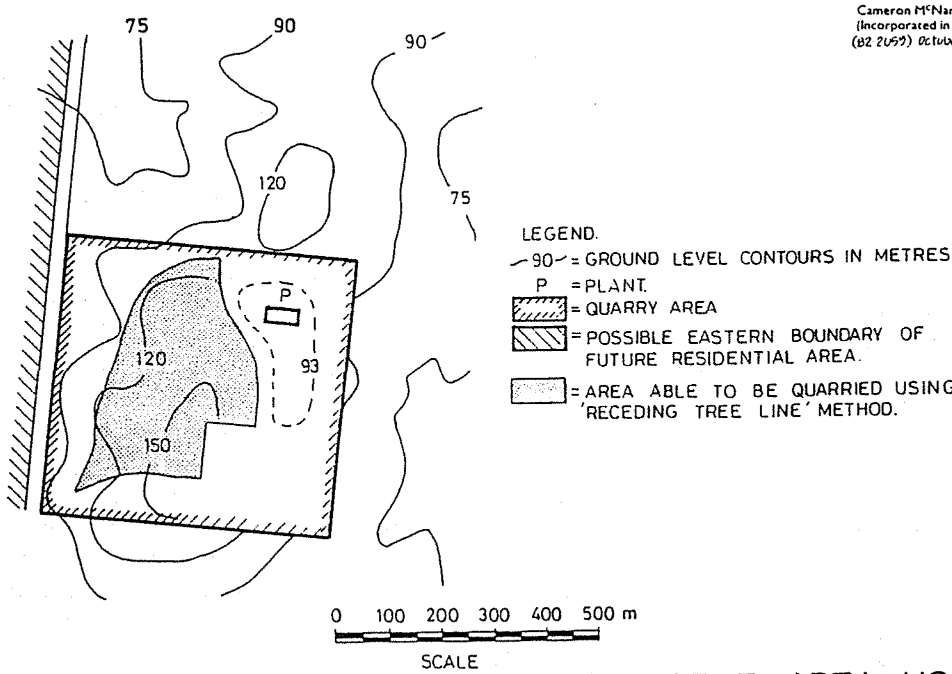


Fig. 5. PREDICTED MAXIMUM QUARRYABLE AREA USING 'RECEDING TREE LINE' METHOD SATISFYING NOISE LEVEL CRITERIA.

interested in quarrying this area. Since a future residential use is a possibility to the west of this land (see Figure 5), WBM was asked to model the receding tree line method and give advice as to the maximum area able to be quarried, without exceeding relevant noise criteria. Figure 5 shows the extent of the area able to be quarried as predicted by the model. Virtually none of the land to the west of the crest would have been able to be quarried using conventional quarrying techniques.

5.0 CONCLUSIONS

It has been shown that noise emanating from quarry operations is able to be adequately represented by a computer model when based on sound physical principles combined with accurate sound power determinations for the various sources.

Using an x, y, z grid system noise level contour plots can be readily obtained from the results.

The predicted noise levels during calibration exercises and from one case history cited were usually within 1-2 dB(A) of the measured noise levels during light wind conditions at distances of 500m-1000m from the quarry operations.

When light wind conditions do not occur, the measured noise levels at these distances can vary significantly and an atmospheric attenuation factor may need to be included in the model.

The results demonstrate that the computer model is an invaluable predictive tool for evaluating the noise reduction effects of such features as natural barriers occurring during quarrying in accordance with the "receding tree line" method and bund walls around potentially troublesome noise sources.

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ACKNOWLEDGEMENTS

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NOISE REDUCTION IN TRENCHING MACHINERY - A CASE STUDY

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ABSTRACT

Trenching machines are in common use for a variety of underground installation works. A significant proportion of this installation occurs in residential areas. As trenchers emit noise in the range 90 to 100 dB(A), they are a loud community noise source.

A textbook approach was taken in order to reduce the levels of noise produced by a new type of trenching machine. The noise produced by this 36 kW (50hp) machine was reduced by 18 dB(A) from 103 dB(A) to 85 dB(A) at the operator's position and by 10 dB(A) at the bystander's position (7m from the machine) from 83.5 dB(A) to 74 dB(A).

1.0 INTRODUCTION

Machinery used for the installation of underground community services such as gas, water, sewage and telephone have long been notorious for generating excess noise. This paper is a case study of the work taken to reduce the noise produced by one type of machine, a skid steer ride-on trenching machine. The practical aspects of implementing noise reduction in mobile machinery will be stressed. Ride-on and walk beside (pedestrian) trenching machines are widely used by Telecom Australia.

This trencher is of the type depicted in Figure 1(b) and is the result of an on going 'in house lead' project being conducted by Telecom in conjunction with local manufacturers. The machine differs significantly from the conventional design shown in Figure 1(a). The development project has sought to demonstrate that a safer, quieter and more reliable and efficient machine can be produced at a price and running costs competitive with older designs.

Noise reduction has been one successful part of the entire project.

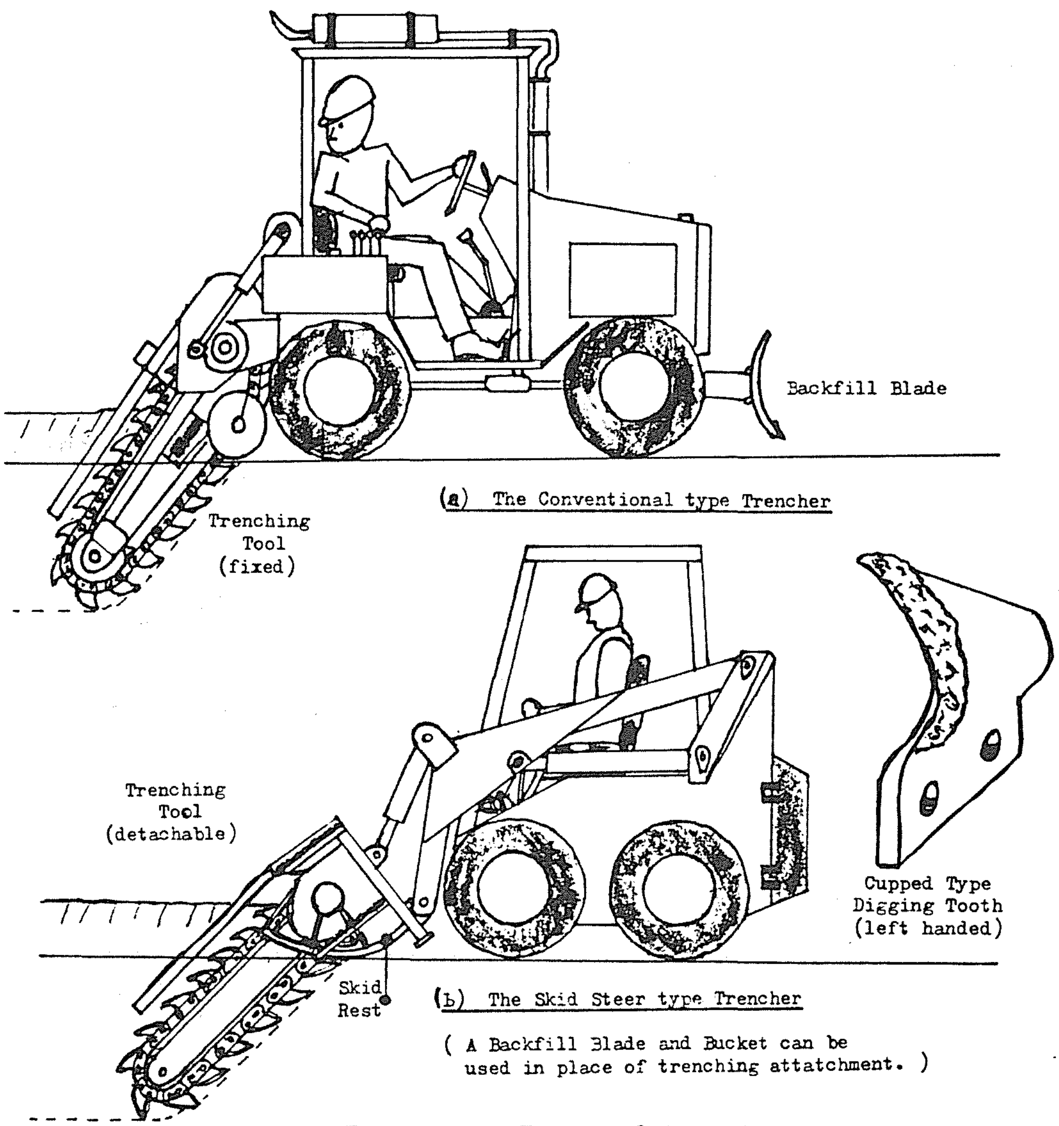

Figure 1: Types of trencher

2.0 METHOD

Noise reduction was achieved for this machine by modifying the original design. These modifications were: completely enclosing the engine and transmission; lining the engine cavity with sound absorber; vibration isolating the engine and transmission; and relocating the air intake and the exhaust systems to inside the engine acoustic enclosure.

This redesign required that some important safety and mechanical engineering criteria be met. This required some ingenuity on the part of the people involved in the trencher's construction and will be detailed in section 4.0.

At each stage of redesign the noise level emitted by this trencher was measured in accordance with AS 2012 for noise emitted by the machine at the operator's position and at the bystander's position. The noise at the bystander's position is defined as the maximum level measured at a distance of 7m from the outside perimeter of the machine and at a height of 1.2m.

3.0 RESULTS

The noise reduction realised for the trencher is indicated in Figure 2.

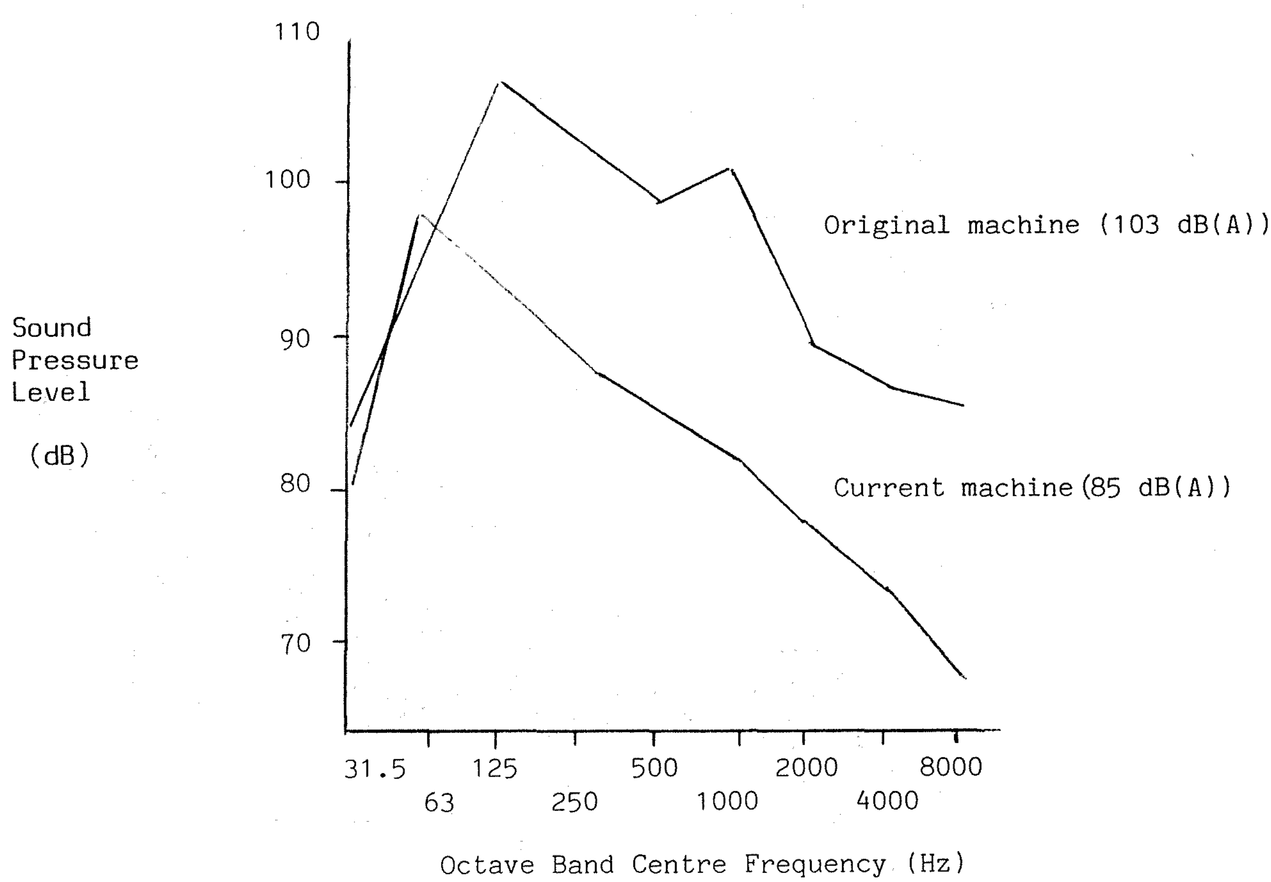

Figure 2: A comparison of the octave band noise levels for the original and current model trencher.

There has been a drop of 18 dB(A) in the noise level from the original machine to the current machine (103 dB(A) to 85 dB(A), 109 dB(C) to 98 dB(C)) at the operator's position and a drop from 83.5 dB(A) to 74 dB(A) at the bystander's position.

Unfortunately during the digging part of the trenching operation the base machine is not the only source of noise. The trencher chain produces a significant contribution to the noise. The noise level during digging for the current machine was measured at 87 dB(A).

The results shown in Figure 3 were obtained by subtracting the background noise level of the base machine from the total noise level produced when the trencher had its chain spinning. The chain noise increases with increased chain speed. At the operating speed of this trencher the chain contributes 85 dB(A) to 87 dB(A) noise level while the machine is digging.

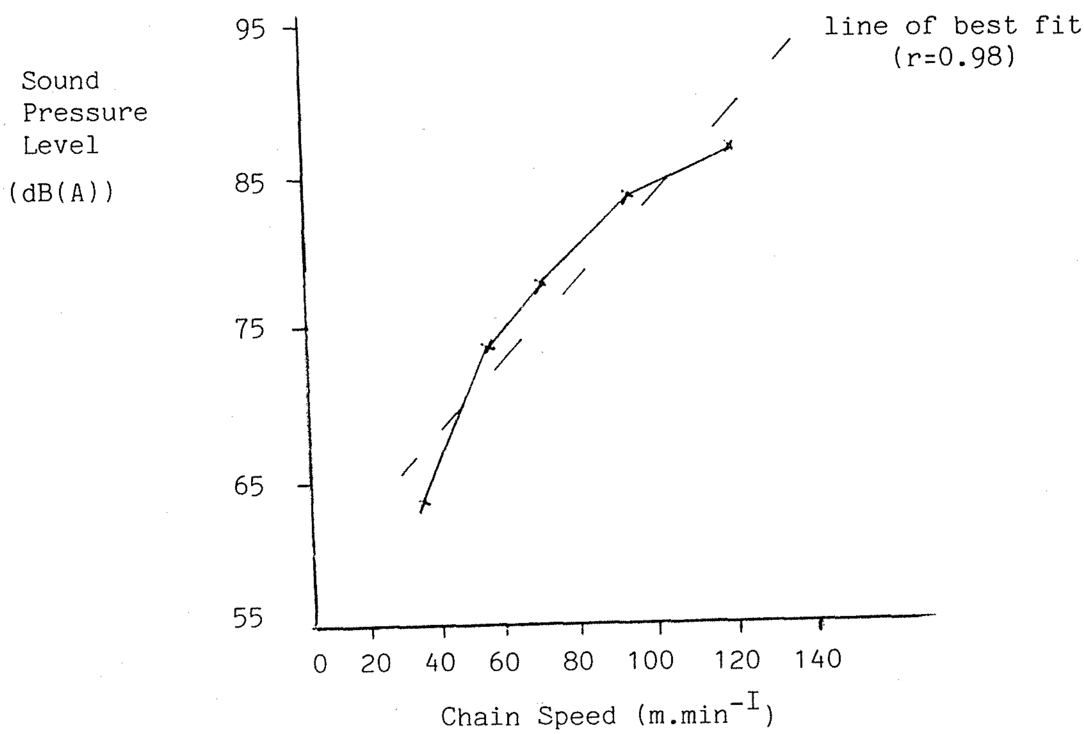

Figure 3: The variation of chain noise with chain speed.

A quieter engine is being considered for this machine and the resulting reduction in noise is strongly anticipated to give a noise level for the trencher while digging of 85 dB(A), the lower limit being set by the chain generated noise.

It should be noted that the chain speed used by this machine is considerably less than those of the conventional machines it supersedes. From the data presented in Figure 3, these conventional chain speeds of 160 to 200 $m.min^{-1}$ would be expected to set a lower limit on the noise produced by conventional trenchers in the range of 90 to 100 dB(A). The authors' work indicates that these levels are typical for existing conventional trenchers.

This lower chain speed is possible as this new trencher uses a hydraulic chain drive system that can match the digging performance of the older style high speed direct mechanical drives.

4.0 DISCUSSION

The noise reduction achieved was arrived at after a number of steps: fitting an engine cover; vibration isolation of the engine and hydraulic transmission; complete enclosure of the engine space; lining the engine enclosure with sound absorber; and internalising the air cleaner and exhaust systems. These steps and their relative effectiveness closely follow values normally quoted in textbooks. The steps as taken are outlined below including essential practical detail normally omitted by textbooks, especially when dealing with the silencing of mobile equipment.

Before outlining these steps it is important to note two features of the original machine that benefit the final result. The first is the reduced digging chain speed as mentioned in section 3.0. The second involves the detuning of the diesel engine. Engine noise increases with engine speed. If a more powerful engine than the design of machine requires is used and this engine's maximum output is limited by a governor, then this engine will be quieter than a smaller engine run at maximum output, screaming like a banshee.

A simple engine cover was fitted and gave a 2 to 3 dB(A) reduction in noise as would normally be expected.

The next step was to vibration isolate the engine from the chassis of the trencher in order to reduce the noise produced by the trencher's body panels. Usual practice in trenchers has been to mount the engine directly onto the chassis of the machine. In some makes the engine appears to be a structural component of the subframe of the machine.

In order to achieve this isolation, the main rigid hydraulic pipes had to be replaced with flexible hoses rated for pressures in excess of 20MPa. The hydraulic transmission was on the same frame as the engine and as another noise/vibration source it was useful to isolate the complete assembly as a unit.

Isolating the engine reduced the low frequency noise and eliminated a vibration bridging path allowing the enclosure of the engine to be more effective.

When enclosing an engine it is essential that an adequate airflow be maintained over the engine and radiator or the engine will overheat and seize. However, putting an intake and an outlet hole of 0.5 m^2 each in an acoustic enclosure would appear to seriously compromise the effectiveness of that enclosure. This is not necessarily so if some ingenious but simple ducting is used. Forcing the air to flow through an 'S' bend maintains airflow while eliminating any direct path for sound to escape. Lining of the duct with sound absorber reduces reflected noise.

Further lining of the engine enclosure with sound absorber increases noise reduction. It is extremely important to note that porous sound absorbing materials must NEVER be used to treat this type of enclosure. In addition to the fact that most are flammable they serve as a trap for spilt oil and fuel further increasing the fire hazard. It is also advisable not to put any sound absorber on the bottom of the enclosure for the same reason. An early prototype of this trencher burst into flames for this reason. The operator narrowly missed being incinerated with the machine.

The type of sound absorber used in this machine was a film coated foam. The film coating is a barrier preventing absorption of liquids by the foam. This works in practice only if the cut edges are folded over to conceal the bare foam from the interior of the enclosure. Care also needs to be taken to protect the protective film from solvents eg. during painting, and from heat eg. hot engine parts.

Finally, internalising the aircleaner and exhaust systems gave an additional noise reduction of 5 to 6 dB(A). The bodies and pipes of these systems emit a significant amount of sound.

5.0 CONCLUSION

Incorporating a number of passive noise reduction techniques in the design of this trencher has greatly reduced the actual noise it produces. This noise will be further reduced with the inclusion of a quieter engine in the near future. Beyond this the noise of this type of trencher is not likely to be reduced further without advances in the technology of the digging chain or tool.

Australian Standard AS2012-1977 "Method for Measurement of Airborne Noise from Agricultural Tractors and Earthmoving Machinery"

INVESTIGATION TO REDUCE NOISE EMISSIONS FROM A MINE VENTILATION FAN AND COMPRESSOR HOUSE

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ABSTRACT

Noise emissions from Tower Colliery near Wilton, N.S.W. have been the subject of detailed investigations by BHP and the N.S.W. State Pollution Control Commission (SPCC) for a number of years. Initial identification of the source was difficult until the influence of low level atmospheric temperature inversions was measured. Surface installed mine ventilation fans and air compressors were the subject of a request by the SPCC for an environmental quality objective of 53 dB(A) at 30 m from the fan-compressor house installation with all units operating. Acoustic treatment for the compressor house involved changing from natural draft ventilation to fan forced ventilation with silencer pods in all exhaust vents. This treatment was completed in November 1985. Fan silencing investigations included evaluation of passive, fibre-filled splitter silencers, a C.S.I.R.O. study of the potential for active attenuation, large lined elbow bends and tuned reactive silencers. Parameters for acceptable silencer performance included pressure loss, capital and operating costs and acoustic performance. A proprietary design of silencer with guaranteed acoustic and aerodynamic performance has been ordered and is to be installed in September/October 1986. Module tests performed in New York provide high confidence in achieving the environmental objective. Acoustic treatment to the fan inlet ductwork was also required to achieve the objective, with a design goal for ductwork cladding to achieve less than 43 dB(A) at 30 m.

The sequence of investigations, noise control measures adopted and resultant sound levels are presented.

1. INTRODUCTION

BHP's Tower Colliery commenced operation in 1976. Since 1981, detailed investigations into noise emissions have been made by BHP and the SPCC. A complaint was received from a resident about one kilometre away. Surface installed mine ventilation fans and air compressors were found to be the main source of noise emissions from the mine. Meteorological conditions were found to have a significant effect on sound levels at nearby residences.

Compressor house noise reduction has been completed. Ventilation fan treatment is to be by the addition of reactive silencers to the fan discharge, and cladding the inlet ductwork. The environmental goal requested by the SPCC is 53 dB(A) at 30m.

This paper presents the sequence of investigations, noise control measures adopted and resultant sound levels, where work has been completed.

2. TOWER COLLIERY

Tower Colliery is part of the Illawarra Collieries group of BHP Collieries and is located near Wilton, 60 km south-south west of Sydney. It is a developing colliery mining the Bulli seam with a current production budget of around 700 tonnes per day using continuous mining machines. Plans for the colliery include the introduction of Longwall mining methods in the 1990's. The colliery commenced operations in 1976.

Surface installations include two mine shafts with winding towers, one for men and materials, the other for coal; a bathhouse and office/administration building; stores and workshop; compressor house, mine ventilation fans and surface storage bins for the coal.

The product coal from the Bulli seam is high quality coking coal. It is transported by semi-trailer to the BHP Steelworks at Port Kembla for washing and ultimate use in steelmaking.

The colliery is sited in natural bushland adjacent to a rural/rural-residential type area. The nearest houses are some 500 m from the surface operations area, but the site is not completely surrounded by houses. The F-5 Freeway (Hume Highway) also passes through the area.

3. NOISE INVESTIGATIONS

Detailed investigations into sound emissions from the mine were commenced in 1981 following requests from the SPCC for a quality objective of 53dB(A) at 30 m.

Initial investigations were aimed at identifying the major source of noise causing a complaint, which was said to occur at night-time. Visits to the site were made frequently by officers of BHP Engineering and the SPCC over a number of months before the noise source could be identified and studies commenced into technical methods to reduce the sound emissions. BHP Engineering was then requested to prepare technical reports of studies into noise reduction methods available and likely costs.

Enhancement Analysis

Meteorological conditions were found to be the most significant factor influencing sound levels in the neighbourhood of the mine. For the region at the edge of the Sydney basin, low level atmospheric temperature inversions are common on more than 70% of nights during the cooler months of the year.

The entrapment of a cold layer of air near the ground surface enhances transmissions of sound through the atmosphere resulting in higher sound levels than expected at distances greater than about 1 kilometre. Thus, in winter when background sound levels at night-time are low at around 30 dB(A), and traffic on the nearby freeway reduces significantly at around 2.00 to 3.00 a.m., the inversion layer forms and sound transmission from the mine suddenly increases. Sound levels from mine emissions at some locations can be up to 18 dB(A) above the former background. The effects on sound transmission of atmospheric conditions is known from theory and found in practice. However the combination of noise source characteristics and atmospheric conditions is unusual and little practical experience exists.

Levels of enhancement occurring were determined by comparing sound attenuation occurring during non-inversion conditions (summer, early autumn) to that occurring with an atmospheric inversion.

Unfortunately a full range of measurement conditions are not available and there are several unknowns in the analysis. Only one measurement during an inversion was available but a measurement of the source at the Colliery during the same conditions was not available; it is also unknown which fan was operating. With the non-inversion sound measurements, source and receiver sound levels were obtained but they were not in 'real-time'. Despite these limitations an analysis was made to indicate in which frequencies enhancement had occurred (in third-octave bands). Significant enhancement occurs at 63 HZ and 200 Hz, and to a lesser extent at 500 Hz. At higher frequencies the difference between the background sound level at the receiving point and the source sound level from the colliery is small and do not truly indicate enhancement.

Noise Sources

Sources of sound initially identified for investigation were the mine ventilation fans and compressor house installation. These operate continuously for 24 hours a day, seven days a week whilst other sound sources at the colliery are intermittent.

The two mine ventilation fans at Tower Colliery are identical centrifugal fans 2.175 m in diameter, driven by 450 kW electric motors. Each fan is capable of delivering a maximum of 150 m^3/s (318 000 cfm) at 1.25 kPa (5" wg) pressure head. The impellor has 11 backward inclined, hollow aerofoil section blades and runs at 585 rpm. Volume flow control is by variable inlet vares with 13 blades. Fan casings and ductwork are fabricated from 6 mm steel plate.

Sound levels at 30 m distance from either fan are 68 to 70 dB(A) with both fans operating. Sound levels beside the inlet duct are around 80 dB(A) at 1 m. At 1 m from the fan discharge the sound levels are around 100 dB(A).

The compressor house is a concrete block building housing four, double acting two stage, two cylinder compressors with the cylinders in a 'V' arrangement. They have a nominal working pressure of 7.0 bar (100 psig) with a F.A.D. of 267 l/s (566 cfm) each driven by a 90 kW electric motor. The four compressors are side by side, with each intercooler ducted directly to the outside of the building. Inlet air was supplied through three wall vents adjacent to the compressors. Air exhaust from the building was through four roof ventilators, two of which were powered with axial fans. Sound levels were measured at various distances from the walls, wall vents, roof ventilator outlets and intercooler duct outlets. Sound levels at 1 metre from the wall vents were between 86 and 90 dB(A) depending on the number of compressors operating. Sound levels 1 metre from the roof ventilator duct exits were 80 dB(A) and at 1 m from the intercooler duct exits were 83 dB(A) if the compressor was loaded and 76 dB(A) if it was off load.

4. COMPRESSOR HOUSE NOISE REDUCTION

As well as considering noise emission from the compressor house, ventilation was also a prime consideration as there was insufficient cooling ventilation in hot conditions which required the large double doors on the building to be opened, further increasing noise emission.

Noise emission was mainly through the wall vents, intercooling duct ventilators and roof ventilators, as well as through the double wooden doors and single wooden main door.

The method of noise control selected was to force ventilate the room with a new fan, block up the wall vents and add acoustic absorption lining to the intercooling duct and roof ventilators with cylindrical silencing pods inserted in the exit of each ventilator. Doors were refurbished, lined with acoustic absorption faced barrier material and fitted with acoustic seals. The expected noise reduction for each "emission path" was calculated from manufacturer's data, various texts and experience. Ventilation flow was arbitrarily selected to provide a 125 Pa (1/2" w.g.) positive pressure and limit the temperature rise of air in the room to 4K (on the compressor manufacturer's recommendations).

After considering the airflow requirements for compressing air, intercooler fan flow, heat rejection radiation from compressors and electric motors, and pressure drop constraints of exhaust ventilators, the fan selected was a 1219 mm (48") diameter Axial fan designed to deliver 19 m^3/s (40 000 cfm). This type of fan was selected because it is smaller than a similar capacity centrifugal fan, variations in propellor pitch angle can be used to determine the most suitable angle for a particular volume flow, and if the fan faces a reduced pressure and delivers a higher volume, the sound emission of the fan is reduced.

Adding the new fan also brought a new noise source into the area, and noise emissions from this fan as well as noise emissions through the air inlet path were also required to be reduced. This was achieved by lining the inlet transition with acoustic absorption material, and having a duct attenuator in the air inlet path. A bag filter house with louvred doors on the air inlet also contributed to the noise reduction.

The design performance for the noise reduction was an external sound level of less than 75 dB(A) at 1 m from any surface or duct exit of the building. After issue of tender and procurement requirements, the works were completed in October 1985 by Peace Engineering. The cost for treatment was $38 000. Resultant sound levels achieved the design performance. Duct ventilators were less than 75 dB(A) at 1 m, new fan inlet 73 dB(A) at 1 m and beside the former wall vents the sound levels were 65 to 68 dB(A). The resultant positive pressure was 125 Pa, as designed.

5. MINE VENTILATION FAN NOISE REDUCTION

In 1983 a technical report by BHP Engineering considered proposals to reduce noise emission from the fans and compressor house to a sound level of less than 53 dB(A) at 30 m from either fan. Ventilation fan noise control proposals considered passive silencing using fibreglass filled splitters mounted above the fans as supplied by the fan manufacturer; an SPCC conceptual design utilising two 90° bends in a large duct; reactive silencing using tuned cavity resonator splitters designed by BHP Engineering; and active silencing using a CSIRO developed system.

The fan manufacturer's design involved an increase in pressure loss of 264 Pa (1.06" wg) and there were some doubts about the acoustic performance due to self-generated noise.

The SPCC design silencer had a lower pressure drop penalty (187 Pa) but was much larger than the fan manufacturer's design and consequently had a higher mass and cost for the silencer and support structure.

The BHP Engineering reactive silencer design was a conceptual attempt to design a silencer with good performance at low frequency (where fibre-filled splitter silencers have poor performance) and low pressure loss. Actual acoustic and pressure drop performance were unknown as the technology was recent and no similar units were in use in Australia.

Active attenuation, another new technology for noise control, had been developed by various research establishments and offers significant acoustic performance at almost no pressure drop. With this method, loudspeakers insert out of phase sound waves into the duct/evase to cancel the sound waves emitted by the fan. In Australia the CSIRO developed a system which worked in model tests.

CSIRO Studies

In 1983 the CSIRO Division of Energy Technology at Highett, Victoria, were engaged to investigate the potential for active noise control being used at Tower Colliery.

Site visits involving measurements of sound levels within the evase were made on two occasions. Substantial analysis and model tests of the Tower Fan system revealed that without improvements to the aerodynamics of the ventilation system the maximum noise reduction which could be expected was 5 dB(A), compared with the 18 to 20 dB(A) required. This was because the aerodynamics of the inlet duct system induced significant turbulence within the fan evase. Microphones used in the active attenuation system monitor pressure variations, and thus are unable to distinguish significantly between acoustic sound pressure variations and turbulent pressure variations, such that the required reduction in sound level would occur. Further work to investigate the aerodynamics of the fan system would be required to determine whether turbulence could be significantly reduced to allow use of the active system.

Passive Silencer Design

Early in 1985, the fan manufacturer was engaged to investigate noise reduction of Tower Colliery fans. They offered two alternative silencer designs - one as a single silencer which could be fitted to each individual fan, the other as one silencer to which the two fans and the proposed third fan could be attached. These involved large section ducts with fibre filled splitters and have the requirement for large structural supports. Pressure losses were given as 200 Pa for the individual silencers and 175 Pa for the single, large silencer.

SPCC Silencer Design

In July, 1985, BHP Illawarra Collieries requested a technical design and estimate for the SPCC design silencer, structural support and acoustic cladding for the inlet ductwork.

The "SPCC design" was given conceptually as two right angled bends in a square duct. The duct cross-sectional dimensions are selected to match the lowest frequencies of interest to be attenuated, and reduce flow velocities to reduce pressure loss. Detail design was done by BHP Engineering. Acoustic performance figures are available from various texts and acoustic insulation suppliers for typical air-conditioning sized ducts. These figures were used to quantify the expected performance of the SPCC duct. The resultant acoustic performance which could be quantified gave 53.6 dB(A) at 30m from one fan with one silencer or an insertion loss of 21.4 dB(A).

Reactive Silencer

At this time it was learned of proposals for installation of reactive silencers to the induced draft fans at two N.S.W. power stations (Eraring and Munmorah). As the technology of reactive silencers has developed significantly in recent years the potential for their use at Tower Colliery was investigated.

Reactive silencers have been used successfully in the U.S.A., Europe, India and South Africa since around 1970. They are particularly useful for high performance at low frequencies where conventional fibre-filled splitter silencers require bulk and high pressure losses. Their other major advantage is in contaminated flow environments where the perf-metal used in conventional silencers would quickly become clogged, significantly reducing the silencer performance. Applications have included coal-fired power stations, forced draft and induced draft fans, steel mills, breweries and mine ventilation fans.

A typical cross section of a reactive silencer includes splitter elements with "chambers". The dimensions of the splitter elements are arranged such that the chambers are tuned resonators to absorb sound in specific frequency ranges. Lining the resonant chambers with acoustical absorption material provides broad band sound absorption by presenting a surface area several times the sound absorptive surface areas of conventional silencers sized for the same application.

As the resonant chambers are larger for lower frequency sound because of their longer wavelength, a silencer designed for, say, 20 dB insertion loss at 125 Hz will be much larger than a similar insertion loss silencer for 500 Hz.

In applications where several frequency ranges are of interest, as with the Tower Colliery fans, there will be several different sizes of resonant chambers within the silencer. The overall dimensions are then basically dependent upon the insertion loss required at the lowest frequency range of interest.

After obtaining quotes from three local suppliers of reactive silencers, it was recommended to BHP Collieries that this type of silencer should be installed because of smaller dimensions than the "SPCC" design, high insertion loss performance at the low frequencies of interest, and a guaranteed acoustic and pressure drop performance. The performance objectives are to achieve a sound level of 53 dB(A) or less at 30 m in any direction from either fan with both operating; to achieve an acoustic insertion loss of 20 dB in the 63 Hz and 125 Hz octave bands and 24 dB in the 250 Hz octave band, and to limit the increase in total pressure drop on the fan system to less than 100 Pa per fan.

Duct Cladding

Sound levels adjacent to the inlet ductwork were around 80 dB(A) at 1 m, which would be expected to cause a sound level of around 60 dB(A) at 30 m. The environmental objective was set at 53 dB(A) at 30 m, and this was the performance specification for the silencers. To ensure duct sound emissions do not cause an increase above the sound level achieved by the silencers, the duct caused sound level at 30 m must be less than 43 dB(A), and this was selected as the design's objective for the duct cladding.

Measurement of performance of the cladding in-situ will not be possible because of sound emissions from the silencers and thus performance had to be assessed from previous test results on other duct systems.

After going to open tender on the cladding, most responses were for a multi-layer sandwich construction of rockwool and steel sheeting. BHP Engineering also designed a cladding system using compressed strawboard STRAMIT products to achieve the required performance which was found to have a significantly lower cost than the other systems and was recommended to BHP Collieries.

6. IMPLEMENTATION OF FAN NOISE CONTROLS

BHP Collieries accepted the recommendations of BHP Engineering in October 1985, to install reactive silencers to the fans with guaranteed performance and the in-house design of duct cladding. The costs for design, supply and installation are over $600 000.

The reactive silencers are being supplied by Pitstock, with design and module testing by IAC in New York. Installation is expected in September-October 1986.

The duct cladding is being completed in two stages, by Chadwick Industries. The fan casing and duct sections beneath the silencer support steelwork will be clad after installation of the silencers, whilst the section from the ground exit to the support area has already been completed.

7. CONCLUSION

The mine ventilation fans and compressor house installations at Tower Colliery were initially identified for investigations into methods to reduce noise emissions to the surrounding community following requests from the SPCC. The mechanism for increased sound levels in the community at night-time was believed to be associated with atmospheric temperature inversions, but this was not able to be measured for several months because of the variability of meteorological conditions. Enhancements of up to 18 dB(A) were recorded by the SPCC.

Noise reduction treatment to the compressor house was to add silencers to ventilator discharges block in air inlet vents and force ventilate the room Acoustic performance goals were achieved and overheating problems solved by this approach.

The treatment decided upon for the mine ventilation fans was to add reactive silencers of proprietary design, with guaranteed performance, to the fan discharges and to clad the inlet ductwork and fan casing. Construction of the fan silencers has commenced and installation is expected in September/October of 1986.

Other silencer designs and active attenuation were considered but not found suitable for this particular installation where high acoustic performance and minimum pressure drop were the major constraints.

The objective of the noise control engineering is to ensure sound levels from operations at the colliery will not exceed 35 dB(A) in the surrounding community. This includes atmospheric inversion conditions. On occasions, winter background sound levels are between 30 and 35 dB(A), but normally current background sound levels are 40 to 45 dB(A) caused by transportation noise from the nearby freeway and coal trucks between Picton and Wollongong. .

ACKNOWLEDGEMENTS

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The assistance of officers of the NSW State Pollution Control Commission during the testing and engineering program and their permission to publish results is sincerely appreciated. The contribution of Pitstock Pty. Ltd. and Chadwick Industries to the solution of a community noise problem is acknowledged.

NOISE LABELLING IN AUSTRALIA

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ABSTRACT

Noise labelling is a new developing means of controlling noise from products. It influences the design parameters in manufacture to encourage investment in noise control technology. Noise labelling can ensure that the cost of noise control is carried directly by those products that are used in noise sensitive locations and thus allows for the manufacture of less costly goods for use in remote locations. This new noise labelling system for Australia, including the standard label design, has been developed in association with all the environmental protection agencies. It is hoped that after a few years, the distinctive noise label will become a well known and often used means of buying quieter products.

1.0 WHAT IS NOISE LABELLING?

Information about the technical qualities of goods is always difficult to get whether you're buying a camera or a dishwasher. Have you ever tried to obtain information about the noise output of an item you intend to buy or for that matter any factual details? It's extremely difficult even if you're prepared to contact the manufacturing organisation.

Often where the noise emission from a product is a key factor in the purchase specification, it is almost impossible to obtain the information. But if you do then the next step is to do battle with the problem of comparing one manufacturers' data with another. Different test procedures are used; different indexes or measures of noise performance make the task of comparison extremely difficult.

For those who want to buy low noise products, noise labelling provides an easy source of comparison that standardises the noise test procedure for each type of product and the means of displaying information about noise.

This new system allows a buyer to inspect an item of equipment and easily find the noise emission value which means that comparisons between similar products can be made. It's as simple as that!

2.0 AUSTRALIAN NOISE LABELLING LEGISLATION

Noise labelling in Australia is less than twelve months old. Only a small selection of products are required to be noise labelled but the numbers are increasing.

Air conditioners and certain types of pneumatic equipment are required to be noise labelled in NSW. Manufacturers or any person selling new machines are required to ensure that the unit has a label with an accurate noise level stated on it in the prescribed form. The responsibility for accurate labelling rests with anyone who sells the unit as a new machine, from the manufacturer through to the retailer. The regulation requires that no one shall sell a machine that does not conform to the requirement.

Western Australia has also introduced noise labelling regulations for pavement breakers, mobile air compressors and air conditioners.

Other state and territory governments have noise labelling regulations in the processs of being drafted.

A surveillance program was introduced in NSW to ensure that units are properly labelled and that the label number accurately reflects the noise output of the machine. As information is collected, a data bank is emerging which can be used in the future to assess the effectiveness of strategies and the trends in noise control investment in products.

3.0 BENEFITS OF LABELLING

There are many benefits in noise labelling which include:

* Consumers can easily use noise information on the label at the time of purchase.

* Demand can be created within the market for products with lower noise levels.

This provides an incentive for the development and marketing of quieter products.

* Users of noise labelled equipment can easily select the most appropriate machine for the circumstances.

* Noise labelling facilitates product differentiation which helps to ensure that the cost of noise control is commensurate with the application. Some models for use in remote areas may have lower standard noise control fittings, and as a consequence be cheaper.

* Labelling increases community access to ways of controlling noise.

* Consumers, companies and control authorities can all be more influential in achieving desirable noise environments.

4.0 DEVELOPMENT AND NATURE OF NOISE LABELLING

In NSW requirements for product labelling are contained in the Regulation of the Noise Control Act. These provisions have been developed in association with industry and other representative groups.

Environmental agencies in other states and territories are involved in the development of labelling programs to ensure that the requirements are acceptable throughout Australia.

National uniformity of controls is important for industry and also it enhances the overall effectiveness of labelling as a noise control system.

Manufacturers and suppliers are required under the regulation to fulfill certain requirements. This involves measuring the noise level of each product model to assess, in a statistically valid way, the representative noise number to go on the noise label for that particular model. A standard, distinctive design for noise labelling was produced for Australian use which, as time goes by, will become recognised throughout the country by both users and purchasers.

FIGURE 1 The Noise Label Design

Because the regulation applies only to new products, it will be some years before all machines have labels on them. Although existing machines are not subject to the regulation, the Commission recommends that existing machines also be tested and labelled so that those machines can be selectively used.

4.1 Pneumatic Construction Equipment In October 1985, the first regulation requiring labelling in Australia came into effect in NSW. Other state and territory governments are moving towards the adoption of similar requirements as mentioned above. All pavement breakers and mobile air compressors are now required to carry noise levels of the type shown above. For these products, the noise test procedures used to determine the label value is Australian Standard AS2221 1979.

Brochures are available from the Commission which advise that the lower the noise number, the more appropriate the machine would be for residential or noise sensitive area use. As a guide pavement breakers produce between 99 and 111 dB(A) of noise and mobile air compressors range from 70 to 85 dB(A).

Labelling can be used by councils to set specifications for low noise machinery on construction sites where noise is a problem. For example, if a council wanted the lower noise machines used on construction sites in its area, then as a part of building consent, a condition of approval could be the following.

"ONLY PAVEMENT BREAKERS WITH LABELLED NOISE VALUES OF 100 dB(A) OR LESS AND MOBILE AIR COMPRESSORS OF LABELLED VALUES OF 70 dB(A) OR LESS SHALL BE USED"

Also, employers and those involved with hearing conservation can use the label to assess the need for safeguards for workers; an important issue these days when claims for occupational damage to hearing can be high.

4.2 Air Conditioners Another important step in noise labelling was the introduction during the year of a regulation requiring the labelling of domestic air conditioners.

The Commission, in consultation with environmental authorities in other states and territories, developed a document called - "A Technical Basis for the Regulation of Noise Labelling in Australia". The process involved extensive consultation with the many sectors of the industry. A new noise test procedure was developed for measuring the external sound power of units (a measure of the noise energy) which is the value that appears on the label. The sound power value on the label represents the noise emitted to the outside and does not necessarily indicate the noise experienced inside the house.

The scheme is primarily aimed at domestic air conditioners, the source of so many noise problems particularly during the summer months.

A number of methods can be used to determine sound power. The method used during the development of noise labelling for air conditioners uses a reverberation room. There are other less costly methods such as the Australian Standard ASD1217/5 which is recommended as an accurate and acceptable method of assessment. With this method, measurements are made outdoors, in most instances, thus avoiding the high cost of special test facilities.

The label can be used as a means of comparing similar units so that the quietest one can be selected. But the labels can also be used for assessing the noise level at a neighbour's house, using a procedure published by the Commission. It takes into account intervening walls, distance and any reflecting surfaces such as walls and obstacles.

Using this method, it is possible to predict the likely noise impact next door before any particular machine is purchased. Thus, real cost savings and a reduction of the worry felt by buyers and installers can be made. A number of possible installation positions can be examined using this method without incurring any cost. Copies of the assessment method are available from councils or the Commission.

4.3 Promotion of Labelling A selection of information materials was produced for the use of different sectors of industry and the public. Direct mailing was used to target particular groups whilst other brochures were made available through local council information centres. These first attempts to introduce the community to noise labelling and its benefits were modest. As further labelled machines become available, particularly consumer products, wider recognition and use is expected.

5.0 THE FUTURE OF LABELLING

Negotiations are continuing with industry to have other noise problem products labelled. These include chainsaws, edgecutters, lawnmowers and construction equipment. These products will be labelled using the standard label shown above and efforts will be made to ensure that measurment techniques and regulation requirements are uniform throughout Australia to ensure that the costs are kept to a minimum.

There are some products that may be more suited to voluntary labelling. This would be appropriate for items such as domestic appliances used within the house and with no external noise impact; these are less critical noise problems in terms of the responsibilities of pollution control agencies.

Under voluntary noise labelling, manufacturers could elect to label their products according to standardised test and labelling procedures. Market influences could then play a larger role in noise control related product development.

6.0 CONCLUSION

Noise labelling is a new and developing means of controlling noise from products. It influences the design parameters in manufacture to encourage investment in noise control technology. Labelling can ensure that the cost of noise control is carried directly by those products that are used in noise sensitive locations and thus allows for the manufacture of less costly goods for use in remote locations.

CONTROL OF NOISE FROM COMPETITIVE MOTOR SPORTS - PLANNING GUIDELINES

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David Moore & Associates Pty Ltd

ABSTRACT

Within Queensland there are a number of motor racing venues for which the Division of Noise Abatement has received numerous complaints alleging excessive noise. This prompted a study to facilitate improved future planning in the location of motor racing venues.

Motor racing types studied included: circuit racing (cars, bikes and road race karts); speedway (cars, bikes); drag racing (cars, bikes); sprint karts racing and motorcross motorcycle racing.

Noise levels were obtained at various racing facilities throughout the state and together with information provided by other states, reference curves established. They provide, for the types of motor racing, the anticipated range of maximum noise levels at various distances from the racing track. This information, when combined with other detailed planning criteria onto the worksheet provided, enables determination of maximum acceptable distances between motor sport facilities and incompatible classes of premises.

Although designed specifically for proposed facilities the information can also be used to aid decision-making in relation to existing racing venues.

1.0 INTRODUCTION

Why conduct a study of noise from competitive motor sports?

Nationally, there has been a significant level of complaint from communities surrounding motor racing venues alleging excessive noise, and necessitating investigations by the authorities. These complaints mainly relate to existing situations. It is at the proposed development stage for either new facilities or extensions to existing programmes that planning authorities can have the greatest input to ensure adequate controls.

This study provides, for planners and developers, guidelines for calculating acceptable distances from motor racing facilities to residential areas. It is based on a wide range of criteria, all necessary in reducing the likelihood of noise complaints.

2.0 METHOD

Noise level surveys were conducted for the following categories and types of motor racing. This study should only be applied to these racing types.

<u>Drag Racing</u>
Jet, Top Fuel (nitromethane Rails and Funny Cars), Alcohol, Gas, All other types of 'cars' and 'motorbikes'

<u>Speedway</u>
Production Saloon, Grand National, Sprintcar, Speedcar, Litre Sprintcar, Formula 500 Speedcar, 250 Speedcar, Compact Speedcar, Mini Modified, Bomber, Solo Bikes

<u>Circuit Racing - Cars</u>
Formula 1, Formula Ford, Formula Vee, Sports Sedan and Sports Car, Production Touring Car, Gemini and Mini

<u>Circuit Racing - Motorbikes</u>
from 'up to 250 cc' category to 'up to 1100 cc' category and 'unlimited sidecars up to 1100 cc'.

<u>Circuit Racing - Road Race Karts</u>
80 cc, 125 cc, 250 cc

<u>Sprint Karts</u>
100 cc Stock, International Heavy and Light, Class Australia, Ladies, Sub-Juniors and Juniors

<u>Motorcross Motorcycles</u>

A total of six motor racing venues were surveyed in Queensland. Noise levels were obtained on a number of occasions and for some of the venues simultaneously both trackside and in the nearby residential areas. Noise levels were also provided by a number of other states of Australia.

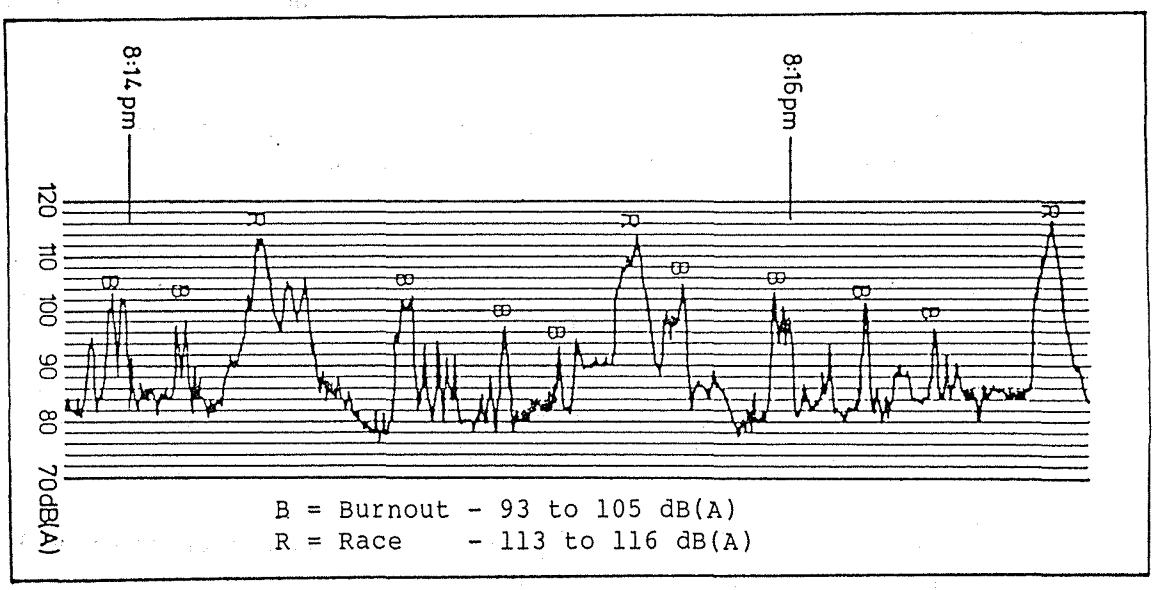
3.0 RESULTS

The noise levels were obtained using precision sound level measuring equipment set on FAST response, A weighted network and conforming with the Australian Standard AS 1259-1982 Sound Level Meters, Type 1. Measurements were conducted in accordance with the Australian Standard AS 1055.1-1984 Acoustics - Description and Measurement of Environmental Noise Part 1 - General Procedures.

Paper graphic level traces were used to obtain the highest noise levels for the various race types and vehicles and to determine the overall range of maxima and the mean of the maxima, refer Appendix 1.

By way of an example, the graphic noise level trace below (drag racing) yields the following noise level maxima (from left to right):

95, 103, 102, 97, 98, 113, 105, 106, 102, 102, 94, 94, 92, 92, 97, 93, 94, 114, 104, 103, 100, 98, 94, 101, 90, 96, 92, 90, 116



From this the following can be determined:

range:	90 to 116 dB(A)
arithmetic mean:	99 dB(A)
n:	29 samples over a 3 minute period

For the various racing categories and monitoring sites the range of maximum noise levels was then plotted against distance. For example, the results for drag racing - top fuel, alcohol and jet and speedway shown in Figure 1 clearly indicate that the 6 dB per doubling of distance rule applies.

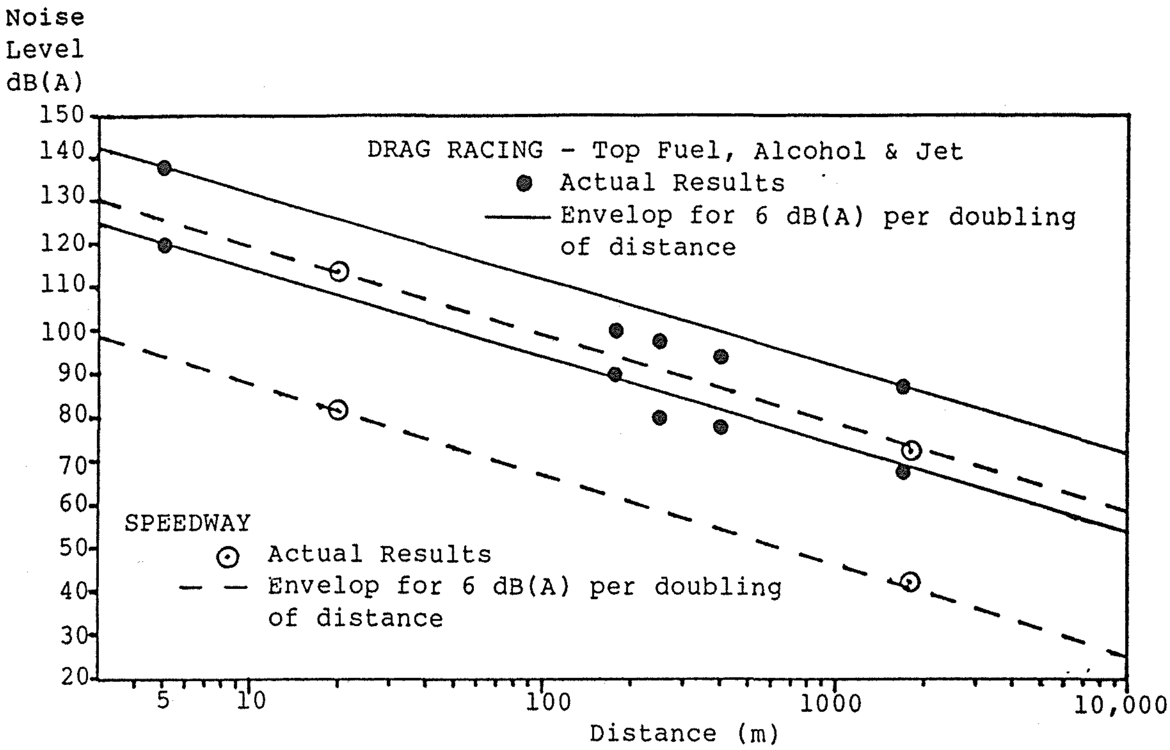


Figure 1 - Attenuation with Distance

For the range of maximum noise levels for various racing types, the highest values were plotted against distance, producing the planning curves at Figure 2.

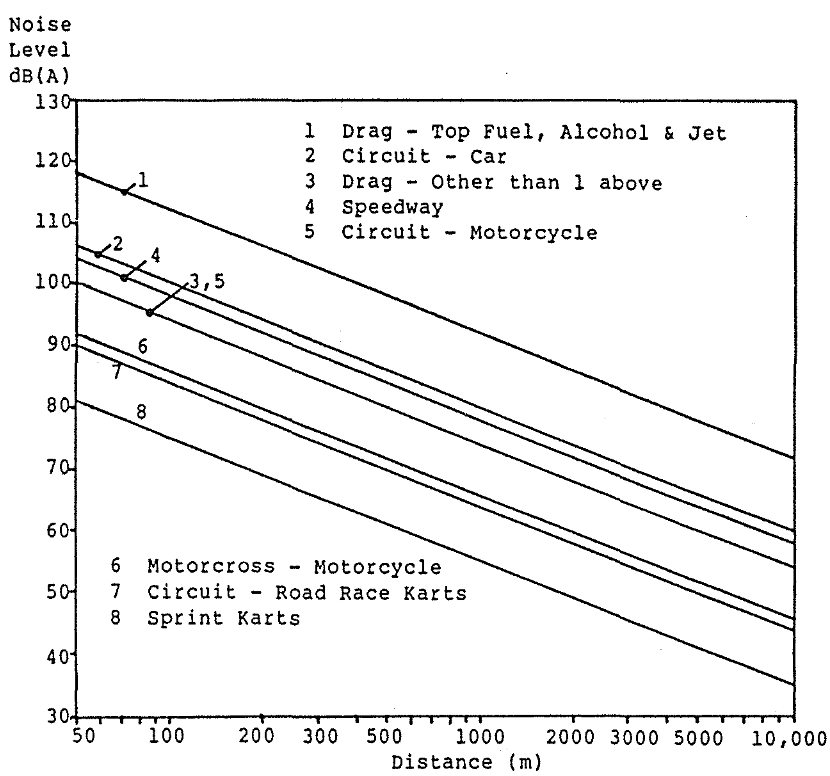


Figure 2 - Planning Curves

This forms one of the bases of the planning criteria, but it alone is insufficient. The following items must also be included for any proposed development:

- type of racing facility and range of vehicles racing
- number of races per event
- number of events per year (Table 1 refers)
- starting and finishing times for events
- time allocated for pre-event practice sessions
- description of surrounding land use, town planning zones
- background noise levels (measured or AS 1055.2-1984, preferably measured)
- any allowances for racing types (Table 1 refers)
- special allowances for noise attenuating barriers or earth mounds, vegetation, etc
- availability of car parking for spectators
- number of residences affected by noise (number of complaints).

All of the above have been taken into account in Table 1, Allowances for Competition Types and Frequency. These allowances have been empirically tested on a number of racing facilities in Queensland and found to work satisfactorily.

TABLE 1
Allowances for Competition Types and Frequency

PATTERN OF RACING	NUMBER*	L_{bg} ALLOWANCE		MAXIMUM NUMBER OF ONE DAY EVENTS PER YEAR**
		Existing	New	
Drag - Top Fuel, Alcohol, Jet	1	+50	+40	5
Drag - Other than 1	3	+40	+20	15
Speedway	4	+25	+10	52
Showground Speedway	4	+25	+ 5	20
Circuit - Car	2	+25	+10	20
Circuit - Motorcycle	5	+20	+ 5	25
Circuit - Road Race Kart	7	+20	+ 5	52
Sprint Kart (Track)	8	+20	+ 5	52
Motorcross (Motorcycles)	6	+20	+ 5	52

* Race pattern number codes correspond to those of the planning curves, refer Figure 1

** A night event should not extend beyond 10.30 pm and may be regarded as one half of a one day event.

Each background allowance is weighted according to the number of events per year. The recommended maximum is indicated in the right hand column of the table. If the number of events per year differs from the recommended maximum number, then the adjustments at Table 2 are applicable.

TABLE 2
Table of Adjustments

Race Pattern Number*	More Racing Events		Fewer Racing Events	
	Increase in Number of Events	Decrease in Background Allowance dB(A)	Decrease in Number of Events	Increase in Background Allowance dB(A)
2,3,4,5,6,7,8	2 4 6 8 10	1 2 3 4 5	2 4 6 8 10	1 2 3 4 5
1	1 2 3 4 5	5 10 15 20 25	not applicable**	

* Race Pattern number codes correspond to those of the planning curves, refer Figure 1.

** For fewer events, no decrease below the background allowance is applicable due to the high noise levels created by this form of racing.

Once all the pertinent information has been obtained, Form 1 is utilized to record the data and determine the acceptability of the proposed development. Planning decisions should be based on these findings. Refer Appendix 2 for copy of Form 1 and Appendix 3 for a worked example.

4.0 DISCUSSION

If the calculated results indicate that the proposal is acceptable then it can be concluded that there is minimal noise impact on the local community. Complaints of noise relating to the motor racing facility should not arise.

However, if the calculated results show that the proposal or part of the proposal is unacceptable, measures should be incorporated to reduce the noise to a satisfactory level or the proposed development should not proceed.

It must be remembered that this is a planning document and even though the answers it provides are finite, the possibility of noise complaints can never be totally dismissed if there are residences in the vicinity of a noise source.

5.0 CONCLUSION

The systematic approach to determining the acceptability of a proposed development in relation to noise impact has been designed to be used by those who may not be familiar with acoustics. It is hoped that the document will receive wide acceptance from developers and planners alike and be utilized at 'drawing board' stage to reduce the likelihood of community noise complaints against competitive motor sports.

APPENDIX 1
SUMMARY OF RESULTS FOR CIRCUIT RACING - CARS

Vehicle Class	Noise Level Maxima			
	n	Mean dB(A)	s dB(A)	Range dB(A)
Australian Touring Car Championships				
Formula V	81	79.1	3.1	74-86
Open Wheeler	190	80.4	3.3	66-87
Geminis	155	77.9	3.8	66-86
Minis	87	78.9	3.2	72-86
Sports Sedans (current models)	70	79.6	3.5	70-86
Production Touring Cars	317	84.7	3.0	79-94
Classes not Identified	139	80.2	2.5	74-86
Overall Results	1039	80.7	6.1	66-94
Australian Formula One and Sports Car Championships				
Formula Ford	55	74.8	2.4	70-79
Geminis	77	74.6	2.0	71-80
Sports Sedans (1960s vehicles)	45	76.7	2.1	72-81
Sports Sedans (current models)	143	78.3	3.0	68-88
Sports Cars	273	82.6	3.6	70-93
Formula One	275	83.1	3.3	72-91
Overall Results	868	80.6	4.5	68-93

APPENDIX 2

FORM 1
Competitive Motor Sports
Determination of Acceptability

Racing Facility Status:	existing	~~proposed~~
Local Premises Status:	rural	residential
	~~commercial~~	~~industrial~~
Distance Off (m):	metres - 2,800	
Access Through Area Type:	rural	~~residential~~
	~~commericial~~	~~industrial~~
Affected Area Ratings:	R_1 ~~R_2 R_3 R_4 R_5 R_6~~	(AS1055.2-1984 Appendix B)
Background Noise Level: 40dB(A)	measured	~~estimated~~

Time	L_{bg} dB(A)	
	Weekdays	Weekends/ Pub. Hols.
7 am to 6 pm	40	40
6 pm to 10 pm		
10 pm to 6 am		
6 am to 7 am		

Max. No. of Spectator Vehicles: 500
Parking Available For: 500
No. of Residences Affected: 15

Race Pattern (Number)	1	2	3	5						2
Day(s) of Operation	Sun	StSn	Sun	St/Sn						StSn
Times of Operation	8-6	8-6	8-4	8-5						8-6
Events per Year	5	10	5	15						15
Background + Allowance	40	40	40	40						40
(Tables)	+50	+25	+40	+20						+25
Frequency Allowance	-	+ 5	+ 5	+ 5						+ 5
Special Allowance	-	-	-	-						+ 3
Reference Level	90	70	85	65						73
Acceptable Distance (Graph)	1200	3400	270	2750						2400
Actual Distance	2800	2800	2800	2800						2800
Acceptability	✓	x	✓	✓						✓
Level at Actual Distance	83	72	65	65						72
Difference from Reference Level	-7	+2	-20	0						-1
Reduction in Events Required		4								
Increase in Events Allowed			to max (15)							2

Notes:
1. Race Pattern Number Codes are shown in Table 1.
2. The number codes correspond to curves on the planning graph, Figure 1.

APPENDIX 3

WORKED EXAMPLE

1. Describe the Race Pattern Number (Table 1 refers).

2. Record the day or days of operation.

3. Record the times of operation.

4. Record the number of events per year.

5. Record the background sound level [40 dB(A) in each case].

6. Determine the background allowance, from Table 1, for the various race patterns for an existing facility. Record the allowances.

7. Where more or less than the maximum number of events per year are conducted (Table 1 refers), determine the applicable allowance according to race pattern (Table 2 refers) and record alongside 'frequency allowance'.

8. Total the background level, the background allowance and the frequency allowance to obtain the Reference Level for the various race patterns.

9. By using the planning curves at Figure 2, and the reference levels, determine the acceptable distances and record them. These are the distances at which the noise levels from the various race patterns are unlikely to result in complaints.

10. Record the actual distance from motor racing venue to residential development [2800 metres].

11. If the acceptable distance equals or is less than the actual distance, record as acceptable (✓). If the acceptable distance is more than the actual distance, record as unacceptable (x).

    For the four race patterns, only Motor Car Circuit Racing was unacceptable.

12. By using the planning curves at Figure 2 and the actual distance from the motor racing venue to the residential development, determine and record the actual noise levels at the residential development. This indicates that for Motor Car Circuit Racing, the Reference Level is exceeded by 2 dB(A) [72 dB(A) - 70 dB(A)].

Because the track was existing at the time of the proposed residential development, it would seem unduly harsh to retrospectively impose conditions of operation on it. Alternatives available are:

1. It has been documented that a change in sound pressure level of 3 dB is difficult for most people to detect. Therefore 70 and 72 dB(A) would both sound much the same and one consideration would be to dismiss the difference as insignificant.

2. The planning curves depict the highest levels of the range of maximum noise levels for various race patterns. At Appendix 1, the mean of the range of maximum noise levels [80.7 dB(A)] is 12 to 13 dB(A) less than the maximum noise levels, indicating that the level of 72 dB(A) would only be reached infrequently. Because noise levels of 72 dB(A) would only be infrequent, dismiss it as insignificant.

3. To attenuate the noise level by at least 2 dB(A) at the race track, sound barriers such as stands, hoardings or earth bunds could be considered and their effect incorporated as a special allowance. As an example, the influence of a 3 dB(A) attenuation is shown in the right hand column of Form 1.

TRAFFIC NOISE - PROPOSALS FOR MEASUREMENT AND CONTROL

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ABSTRACT

Traffic Noise is the most persistent and wide spread of all urban noise pollution. No one has felt able to tackle the overall problem and so the approach has generally been towards quietening individual vehicles. From the first UK act in the late 1960's, controls have been an unsuccessful. The paper presents the different international measures taken to alleviate the problem and the different methods chosen. The Australian A.D.R. methods are discussed and the shortcomings of current instrumentation demonstrated. New proposals for Australia, the United Kingdom and France are taken together with methods used in motor cycle racing to give an effective simple and inexpensive noise control technique, capable of speedy yet accurate meausrement.

TRAFFIC NOISE - PROPOSALS FOR MEASUREMENT AND CONTROL

This paper gives a summary of vehicle noise measurements and suggests a strategy for vehicle and thus traffic noise control. This strategy is intended to achieve the stated aim of reducing the annoyance and distress caused by the small percentage of well above average noisy vehicles and deliberately ignores the legal and bureaucratic obstacles to this. These obstacles are posed in the main not by outside interference but by a few professionals who, in the past, placed exactitude before practical results.

The paper attempts to demonstrate that this passion for accuracy has in fact been the single, most important cause of vehicle noise measurement being unacceptable to many regulating authorities. Clearly there must be a known accuracy of measurement and the instruments used must be calibrated to an agreed standard, properly traced, such that contested measurements can be defended by the responsible authority. If this were not so a series of lost actions in the courts could nullify the programme.

However, if in the search for exactitude, the instrument or the method becomes unusable, the basic object of the exercise could well be lost and the measurements may never be made. The sole result of no measurements is to let the general noise level creep up year by year, decibel by decibel.

Why Vehicles?

In the UK the Wilson Committee Report on Noise in 1963 concluded that, for most people, the major source of noise pollution was traffic, but over the years no-one felt able to address the problem of traffic noise as a whole, it being too complicated for a simple solution. However, traffic is only a collection of individual vehicles and the alternative to traffic control was to control the individual vehicle noise, with a few very noise vehicles as the obvious target. The principle used was that, if the noisiest vehicles were removed, the general traffic noise would be reduced. This is true, and one reasonable estimate at the time suggested that reducing the level of the 5% of "noisy" vehicles would reduce the overall level noticeably.

History

Traffic noise is one of the earliest recorded causes of noise complaints. Ancient Romans considered that the noise of chariot wheels was excessive and no doubt there were young bloods of the time who were the ancient equivalent of the modern day kid on a motor cycle. In London similarly, iron shod, coaches and carts were a common cause of complaint by householders. So much so, that sometimes straw was put on the road to deaden the noise. In New York the traffic noise level in 1929 was estimated by modern workers as about 8ØdBA, not terribly different to todays Manhattan.

It was however, the internal combustion engine which really increased the noise level in urban and semi-urban situations. This device is really only a series of explosions which, before all the energy is used, is vented to the air as a pressure pulse. At first, with low compression ratios and very low revolutions the noise was not really a problem. However, before long the law caught up with vehicles and regulations were made to control the construction and use of the new invention. As usual, Great Britain was in the forefront of bureaucracy and the famous red flag law which stipulated that someone with a flag should walk in front of every vehicle, was the invention of a previous generation of regulators. The well known London to Brighton annual vintage and veteran run celebrates the repeal of this nonsensical law.

The first general noise law was in the vehicle construction and use regulation which specified that a silencer should be fitted to each vehicle and that it shall be "suitable and sufficient for reducing, as far as may be reasonable, the noise of the exhaust of any motor vehicle."

The most common noise offender in the early days was the motorcycle with the baffles removed from the silencer. A folk law developed of country policemen pushing sticks up silencers to check if the baffles were intact. Some 1940 motorcycles, particularly the single cylinder Ariel had very efficient silencers of a straight through construction and were therefore vulnerable to the noise test ie. the stick. Thus a 45 degree plate was welded to the front of the aperture to make the unit pass the stick test. However, the gas flow was now forced to the side of the silencer and the packing material would burn out in this area. Therefore, the motor cycle became noisy soley as a result of the 'test' imposed. Later models had the plate welded at the rear of the absorbancy area and these could be recognised by the blue area of chrome round the tail pipe where the hot gas caused unequal heating.

In 1968 the UK Construction and Use Act was amended and a noise level introduced. Also, a new standard for a special sound level meter was established, BS3539 (1962 and amended 1968). The standard was totally unnecessary. All that was required was to specify that an IEC 123 meter should be used and that a certain calibration procedure had to be followed. At least 3 major companies made special model level meters to the new standard and confidently expected large sales as it was clear that police forces would have to buy the new models. They did not buy any. Central government bought a few to 'free issue' and these were in fact left to gather dust. What was the problem? Why did the police take this attitude?

Three problems existed. The first, nothing to do with acoustics was an argument between the Home Office responsible for the police and the individual police authorities over the technique. This was resolved when a respected Chief Constable, a rally driver of repute made 'over my dead body' type comments re. the test. Others accepting his expertise followed his lead and the vehicle noise control programme died for 20 years.

The second reason was the sheer impracticability of the test. In 1968 the author was asked by a London TV Station to demonstrate the method for a science programme. It took half a day to find a suitable local site, half an hour to mark it out and then each vehicle took about 15 minutes to test. It is a small wonder that the police felt they had better things to do. The test demands an open site 100m in diameter free of obstructions and external noise. Such a site is not easy to find in cities where the bulk of noisy vehicles occur. The reason for the large site was of course to prevent the acoustic reflection. To ensure that this did not occur, the regulations specified a site that was totally impractical. This was a clear case of exactitude overcoming practical reality.

The third reason was the lack of sanctions to deal with the unco-operative driver. If the driver went too fast or too slow or passed outside a small lane, the test was invalid. How many drivers are likely to co-operate when the most the police can do is use a "catch all" offence to impose any penalty. No doubt a special penalty could be added to statute law but this was never done.

Objects and Expectations

In the pre-amble to British standard BS 3425 the standard for the Method of Vehicle Testing, it says "It is generally recognised to be of primary importance that the measurement shall relate to normal driving conditions..." The standard then proceeds to describe the method of achieving this, saying "The method is intended to meet the requirement of simplicity..." Neither of these statements is wholly correct.

There is clearly no reason why the test should reflect driving conditions. The object of the test is to weed out the really bad offenders. While strict correlation between the driveby test and other tests cannot be shown, in that there will always be a grey area, a really noisy vehicle will be picked out by any test. Also, clearly the "requirements of simplicity" were not even approached. No-one except a few professionals could understand or carry out the tests.

Rejected Proposals

In the late 60's, three important ideas were proposed in the UK. Any one of these may have made a contribution but they were all ignored. The first was what is now the half metre test. Much work was done on this but it was rejected by people who required exactitude mainly on the spurious grounds of correlation. It was however put into operation for motorcycle racing where it is proved a huge success and undoubtably contributed to the acceptance of continued motor sport in some states in the USA. The racing world didn't want absolute accuracy - it wanted results.

The second idea was to have 'Noise tickets'. The concept being that a policeman or perhaps traffic warden could give a 'noise ticket' to an alleged offender. This would require the vehicle to be presented for test within say 7 days. If it passed, no further action would be taken. If it did not, then a prosecution would follow. There were 2 major arguments against the idea. Firstly it was pushed by an unpopular pressure group and thus it was resisted by the professionals. Also, it was claimed people would simply put their vehicles in order to avoid prosecution. Why this was considered, a fault of such a proposal is difficult to see. The object of a noise law is to reduce the noise level and not to obtain prosecutions. The payment of fines or even jail sentences will, in themselves, have no effect on the creeping noise levels we are trying to halt. Clearly if severe punishment is meted out to offenders many people will be less likely to offend. However, is it not more simple to prevent the offence. This Noise Ticket approach has much to recommend it. Even in Western Australia which has one of the lowest population densities it is not a real hardship to compel a driver to report to a Noise Test Station. These stations need to be equipped with precision instrumentation, ideally computer based, to make the testing of the vehicle simple, automatic and inexpensive.

The last of the three ideas was the 'noise car wash'. An odd name but a good description of the device. It was proposed that the test should consist of an arm or gantry, which would sweep the vehicle and 'plot the overall noise level'. Sound power level was not suggested by name, but the idea clearly could lead to this. This was rejected for no documented reason I can discover. Anecdotal evidence suggests simple inertia together with its acceptance by a pressure group and lack of academic excellence.

A Manufacturers View

As producers of equipment to measure noise, it is obvious that the existance of noise laws are an aid to our continued business. However, noise laws which are not acceptable and thus not enforced or noise laws which bring into question the performance of any instrument are not desirable. This should not be taken to mean that instrumentation should not be queried. Indeed, it can and must be. However, the manufacturer should have national or international type approval for their units and such certification should be accepted by other states. Also if any state or political unit decides on regulations which require special instruments, cost, choice and perhaps performance penalties may be incurred. It is for this reason, if for no other, that manufacturers operating on a world scale must involve themselves in international and national standardisation discussions. An example of the problems facing manufacturers and which increase the cost of instrumentation and reduce the choice, is the attitude of some countries.

For example, country A will adopt, almost in its entirety, an IEC standard and or the approval procedure of a large neighbour country. Country B, next door, will then do it differently just to prove they are independent or as the cynics may say "To justify their existence." Let us look at the consequences of this. The total world industrial population is of the order of 1,2 billion people mainly in 3 groups, USA, Common market and Comencon, supporting a total sale, including research units of the order of 3ØØ million U.S.Dollars. If a new model has to be added because each country requires something different only a native manufacturer or one of the multinationals can possibly fulfill this need. Thus either units are sold which do not meet the requirements or the customer's choice is restricted. With a total market of the order of 25 cents per head of population, each million of population reflects a sale for all manufacturers together of only 25Ø,ØØØ US Dollars per annum. A sale as small as this cannot possibly justify a special model in most countries unless it is subsidised by the manufacturers general funding or one company has a monopoly and can charge higher prices. Thus attempts to "improve" the technical accuracy have a negative effect on real noise control.

It would be an impertinence for any outsider, particularly a manufacturer, to attempt to tell any body politic how it should decide on noise legislation, but it is fair and reasonable to attempt to evaluate the consequences in technical terms of a "different" approach. Further, it is often held that discussions of cost and commercial matters are no part of a professional acoustic conference which should only relate to the academic art. In the question of noise legislation this cannot be so. The cost benefit must play a part in any discussion and the advantage of following an existing standard evaluated.

Manufacturers being essentially simple engineers do not see any difference between a pair of ears on one side of the river and the other side even if the river is the Atlantic Ocean. Is there therefore any medical or acoustic argument that suggests different noise regulations?

The way forward

Early this year a new 'Noise Council' was formed in the United Kingdom. This body made up of representatives from, amongst others, the Institute of Acoustics and the Society of Environmental Health Engineers formally came into being with the publication of a booklet listing the noise legislation in various areas that had failed. Amongst the Summary of Conclusions for action on noise legislation were the following:

1. No legislation should be introduced unless the resources are available to implement it fully and uniformly.

2. Scientific pedantry is not helpful and can prevent the achievement of practicable noise control legislation and defeat the objective of controlling noise pollution, e.g. road vehicle noise measurement.

3. It is not possible to legislate to stop or even reduce all noise, particularly if people choose to ignore the law.

4. Noise control legislation cannot be changed fast enough to meet social economic changes and there will always be a tendency to lag.

The author had the honour to be on the working group which produced this document and naturally agrees with the conclusions which were based mainly on the UK experience and situation, although other countries were most certainly referred to in the discussions. It should be particularly noted that vehicle noise was singled out.

In Australia the excellent "Australia Design Rules", ADR 28A and ADR 29, could well serve as a model for others to follow especially if the levels are lowered as suggested by Stewart and Rogers (2). Work by Luquet (3) and others on computer based Leq using the method of "Short Leq" may however point the way to a system where the lead presently held by Australia in the area of stationary test procedure could be eroded.

The new method involves the measurement only of Leq. A whole series of these are taken one after the other each having no relationship to the one before and the one after. Each Leq is stored in the memory of the meter and can be retrieved later by a personal computer. In this way, not only can the existing modes of current stationary tests be reproduced but any improvement suggested can be simulated by the computer model. In addition, a permanent record of the raw data in the form of energy samples is available for legislative or other use. The time base for each Leq seems to be "standardised" on 125 mSec, the same as Fast time constant on a sound level meter, although by adding samples any time base can be simulated with a resolution of 125mSec for example, Slow response.

As the Australian Environmental Council Reappraisal (4) reported "In terms of harmonisation then Australia has few useful leads to follow from overseas - rather the converse applies in that a number of other countries are interested in our stationary controls and may well adopt them in future. The best course for Australia would thus appear to be retention of the current stationary tests with reductions in stationary limits occurring together with future reductions in drive-by limits and inclusion of these stationary controls in the Design Rules."

Conclusions

It is hard to disagree that Australia is among the leaders in real vehicle noise control, just as the UK had a significant lead over 2Ø years ago. The lead in the UK has totally vanished to the point where it is the only 1st world country to use a policeman's ear as the measuring tool for noisy vehicles. This has come about because in the search for accuracy the object of the exercise was lost and because we the professionals could not agree among ourselves what to do about it. Could not Australia look at our performance in the UK and ensure the lessons of history are well learnt and while continuing to strive for excellence accept the second best today instead of the best tomorrow - or never.

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3. "Methode Leq court" (in French) P. Luquet LNE report 7/81

4. Australian Environmental Council "A Reappraisal of Motor Vehicle Noise Control in Australia" May 1985.

EXTERIOR AND INTERIOR NOISE GENERATION FROM A VEHICLE TYRE-ROAD INTERACTION

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ABSTRACT

The total vehicle noise level is comprised of a number of separate noise sources. Engine compartment components, engine elements, power-train, aerodynamic, exhaust and tyres are sources that are important to vehicle noise. The importance of each source at any time depends on the particular operating mode of the vehicle. In the case of a motor vehicle cruising at moderate to high speeds, tyre noise is generally the predominant noise source. This paper is concerned with an experimental investigation conducted to evaluate the importance of the tyre-road induced noise transmission path in a vehicle. An instrumented vehicle was tested in the laboratory and when run on the actual road surface. The results obtained are in the form of frequency spectra and sound level meter values. The tyre variables investigated included the type of the tyre, tyre construction and its inflation pressure. The information obtained is found to be sufficient to give an indication of the maximum possible tyre-road noise which using current knowledge, would be generated by a vehicle of given speed, if both tyre and road surface parameters were optimised.

1.0 INTRODUCTION

It is essential that a tyre incorporates a tread pattern to provide grip under poor ground surface conditions such as in rain, mud and snow. For many years vehicle tyres have had their tread segments at variable pitches to break up any dominant noise frequencies. As environmental concerns about urban and rural traffic noise increase, special attention and consideration are being given to establishing tyre noise legislation. Tyre noise regulation will undoubtedly have an effect on consumers, automotive manufacturers, and their affected suppliers. Consequently it is important that any legislation adopted be realistic, beneficial to the community, and be based on a test procedure that recognizes and controls the variables important to the tyre noise level (Hillquist, R. et al and Veres, R.).

Progress in developing quiet vehicles based on quietening the power-train noise is encouraging; this is the noise from the engine inlet, exhaust, cooling systems and transmission, as far as the lay shaft. However, vehicle noise is often dominated by tyre-road noise with current tread patterns and road textures at steady speeds above 50 km/hr (Walker, J. et al, Jha, S. and Jennewein, M. et al). A reduction of lorry power-train noise by 10.0 dB(A) is thought to be within reach of our existing technology, but the benefits of such changes will not be fully realised unless at the same time rolling noise can be brought down by about 5.0 dB(A). Rolling noise includes that from aerodynamic sources, from the transmission beyond the lay shaft, body rattles, and tyre-road interface noise from tyres, road and vehicle (El-Kersh, A. M. et al, Abou-El-Seoud, S. and Abou-El-Seoud, S.). The effect of tyres and road surfaces on rolling noise indicates that the tyre-road interface noise from heavy lorries could become one of the salient features of truck noise, if the target is reached on quietening power-train noise (Nelson, P. et al).

In this paper the development and adoption of a vehicle tyre noise test procedure in laboratory by using a road surface simulator is outlined. It was necessary to determine the tyre noise contribution during testing for compliance with the various state laws governing the noise level of a vehicle in drive-by test procedure. A laboratory test procedure developed herein is to replace or supplement the drive-by test procedure. (A laboratory test procedure developed herein is to replace or supplement the driveby test procedure.) This is desirable from a roadside enforcement standpoint and the convenience such a procedure would afford an automotive manufacturer in developing a vehicle to comply with state noise levels. Inherent to the adoption of a laboratory test is the need to have a passenger vehicle tyre noise test procedure to evaluate and/or control the tyre noise contribution separately.

2.0 TYRE-ROAD NOISE GENERATION MECHANISMS

Three mechanisms for tyre-road noise generation are: 1) impacting between the tread and road; 2) micromovements of rubber on the road; and 3) air pumping by the tread pattern. Three resonances involved are those of the tyre, the air in the tyre and the tread elements. The impacting mechanism has been studied extensively in Jennewein, M. et al. Accelerometers inserted inside the tyre showed over 600.0 g change in acceleration as the tread entered and left the contact patch at a speed of 113 km/hr (70.0 mph). Carpeting the surface to soften the impact reduced the noise level of a block pattern tyre by 8.0 dB(A) at a 48 km/hr (30.0 mph) and 3.5 dB(A) at 113 km/hr. With micro-movements of the tread, their glass plate studies of a block tread, steel radial-ply tyre show up to 2.5 mm total movement of a point on the tread relative to the ground as it passes through the contact patch. It has been suggested that this is the main cause of the noise of a smooth tyre on a smooth surface.

The 1.0 kHz peak in the noise spectra which is independent of speed is close to the frequency which occurs when the tyre squeals on cornering. The squeal frequency increases as tread depth decreases (Hayden, R.E.). This is the tread element resonance previously referred to. In the investigation to find any dominant frequency peaks, the averaged output is used from three tracking filters fed from three microphones. This is done by locking the tracking filters to a particular harmonic of wheel rotation and by varying the tyre speed on the drum between 80.0 and 15.0 km/hr (50.0 and 9.0 mph). In order to determine to what extent there exist frequency peaks in the straight-ahead rolling noise, corresponding to the estimated concerning squeal frequency as 0.0 deg. slip angle is approached, the following test results were outlined with 8.0 mm and 1.0 mm tread depth tyres with serrated ribs and microslots. The increase in cornering squeal frequency is accompanied by a reduction in slip angle. As the speed falls, the particular harmonic passes through resonant frequencies and the level of the harmonic rises. Similar behaviour by several harmonics confirms the existence of the resonances. There is only a slight peak for both the 8.0 mm tread depth tyre at 1.0 kHz and for the 1.0 mm tread depth tyre around 1.9 kHz. This implies that the stroking mechanism setting up relaxation oscillations is not a dominant mechanism in the tyre noise.

The third mechanism of air pumping was discussed in Leasure, W. et al and the theory was further developed to predict directivity patterns. However, as regards the noise from cavity pockets in the road, the impacting noise mechanism was dominant. Of the other resonances, tyre vibrations have been observed, and truck cross-ply tyre resonances below 25.0 Hz show the acoustic radiation to be emanating from a region within a quarter wavelength of the tyre footprint. It is therefore necessary to investigate the nature of tyre-road noise. The approach to this is in four main parts: (1) measure and analyse vehicle coasting noise on the road; (2) measure and analyse tyre-surface noise on a drum in the laboratory; (3) construct a mathematical model in the computer in order to predict results; and (4) obtain as close a correspondence as possible between the different parts of the work, and apply the knowledge gained to produce quieter tyre-road interfaces. The present work is concerned with items (1) and (2).

3.0 TEST PROCEDURE, EQUIPMENT AND DATA ANALYSIS

The investigation of tyre noise was conducted in the Faculty of Engineering and Technology, Minia University, Egypt. The procedure developed was to establish tyre noise (exterior and interior) characteristics data based on laboratory testing. A Mazda 929L vehicle was selected. The road test measurements were done for the interior noise only at the driver's head position. This was to confirm those measured in the laboratory by using a road surface simulator with a smooth drum surface. The tests were conducted by mounting four identical tyres on the test vehicle, and the interior tyre noise was recorded at different driving conditions. The vehicle was driven on a smooth asphalt road surface texture. The frontal wind (air), inertia and rolling resistances of the road surface texture were found to be equal to 600.0 N (tractive force) on the road simulator. To separate the tyre noise either interior or exterior from the total vehicle noise recorded in the road test or on the road simulator in the laboratory, the vehicle was suspended over the laboratory floor and driven at the same driving conditions. The measurements which were recorded represent the noise of other sources. The difference between the total vehicle noise and those measured when the vehicle was suspended represents the noise generated from the tyre-road interaction only.

A set of the three tyreswith different constructions were used:
1) a normal steel-belt radial construction with a normal rubber ("normal tyre") made in Japan.
2) a reinforced steel-belt construction (2 plies) with a very soft rubber ("soft tyre"), made in France.
3) a flexible nylon construction (6 plies rating) with a very hard rubber ("hard tyre"), made in Egypt.
Figure 1 shows a photograph of these tyres. All of these tyres are of 175 x SR 14 size, and were used with inflation pressure varying from 1.5 to 2.5 bar. Prior to testing, the tyre was driven for a 20 minute warmup period. The ambient sound level (including wind effects) coming from sources other than the vehicle being tested was found to be 10 dB(A) less than the level from the vehicle. The test site consisted of a flat open space free from any reflecting surface within a 30 m radius.

Figure 2 shows the layout of the equipment used in this investigation. The road simulator gives the possibility to simulate to a very large extent all actual road surface conditions, so that adjustment and checking for the whole vehicle can be done. More detailed description can be found in Abou-El-Seoud, S. With respect to the exterior tyre noise, themicrophone/preamplifier is located near the tyre of a test vehicle approximately 0.6 m behind the centre of the offside rear tyre (opposite side of exhaust) and 0.2 m above the perpendicular to the road aimulator roller (drum). This microphone is a pressure sensitive $\frac{1}{2}$ in. Type B & K 4166. The signal from the microphone and its preamplifier was fed into sound level meter Type B & K 2209 to enable the signal to be recorded on 4-channel portable tape recorder Type B & K 7007 in the form of weighted scale (dB(A)). A real time analyser Type B & K 2033 and X-Y recorder Type 2308 were used to analyse and record the signal in real time in the form of frequency-domai, which was in turn recorded on a digital cassette recorder Type B & K 7400 in its digital form for further analysis (1/3 octave and broadband averages).

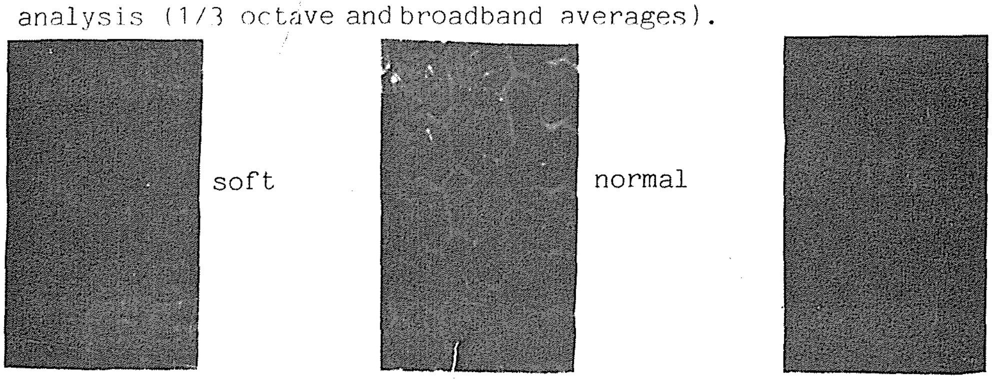

Fig. 1 Tyre construction type used in the tests

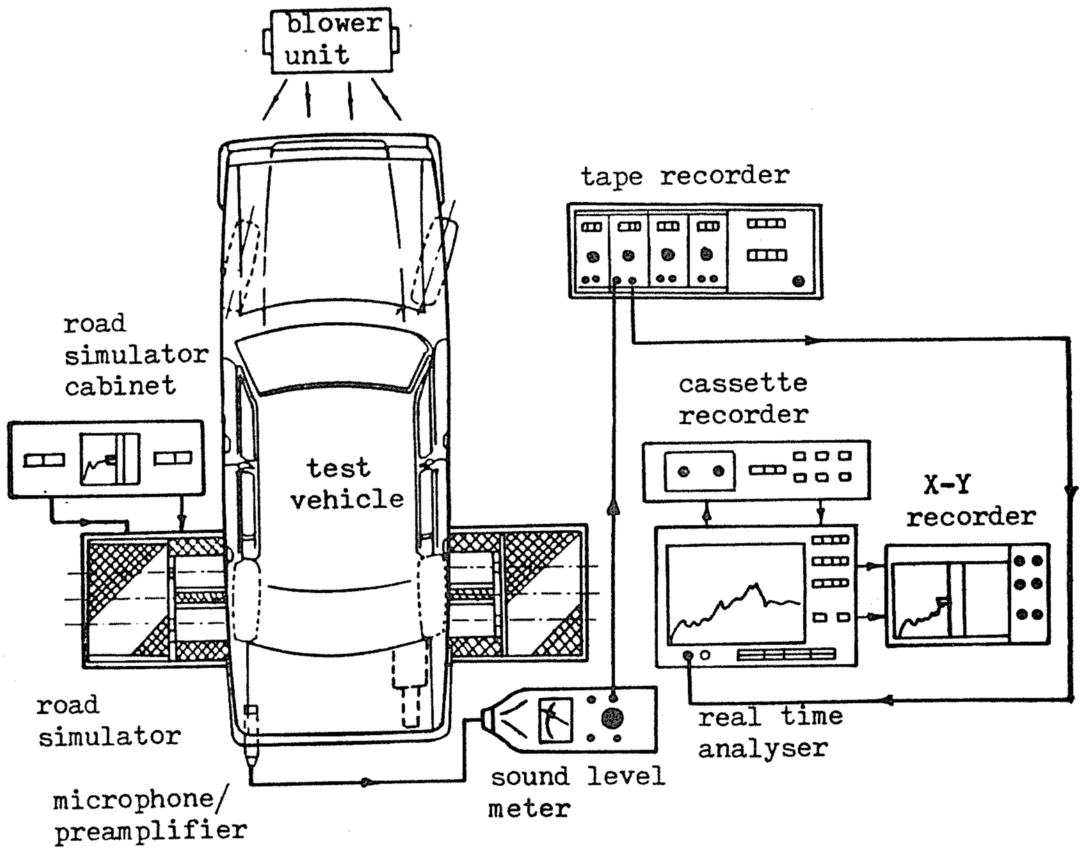

Fig. 2 The layout of the test vehicle and equipments used

4.0 RESULTS AND DISCUSSION

The total exterior and interior narrow band sound pressure level (SPL) spectra when the vehicle is driven on the road simulator and when it is suspended on the laboratory floor were measured at different driving conditions. Examples of these measurements are presented in Figs. 3 and 4. These show the exterior and interior SPL spectra respectively. The exterior SPL spectra are presented in the frequency range up to 5.0 kHz, while the interior SPL spectra are presented in frequency range up to 200 Hz. The vehicle is being driven at 60 km/hr in 4th gear. The tyre construction is "normal" type, and its inflation pressure is 2.0 bar.

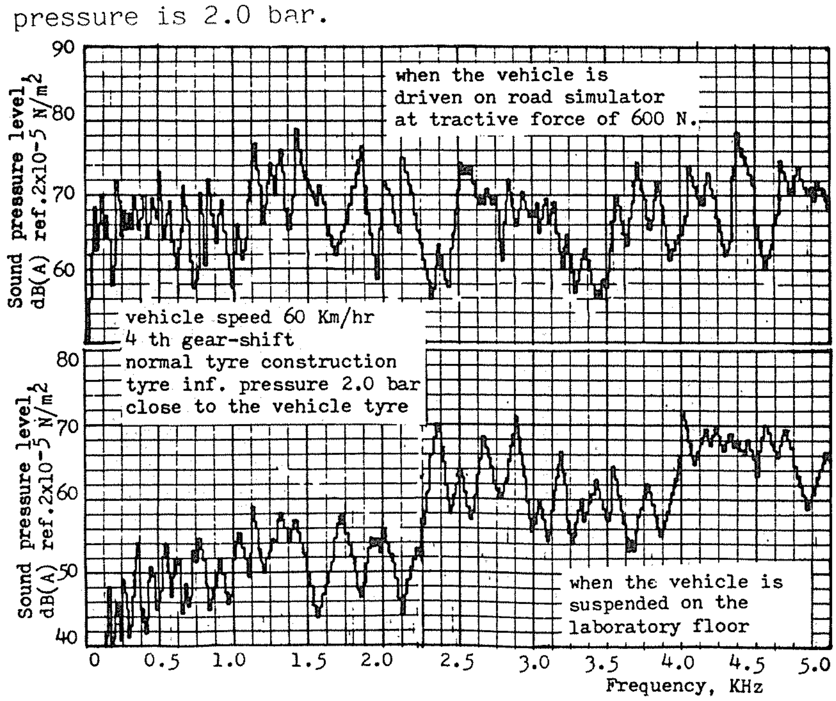

Fig. 3 Narrow band spectra for exterior sound pressure level (SPL)

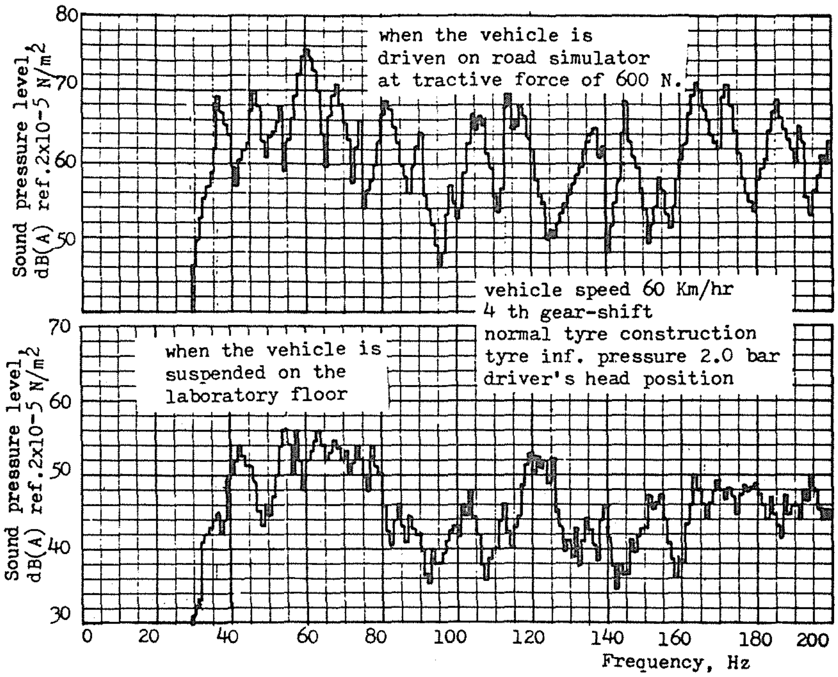

Fig. 4 Narrow band spectra for interior sound pressure level (SPL)

Figure 5 shows the narrow band interior SPL spectrum measured at driver's head position when the vehicle was driven on a smooth asphalt road surface at the same driving conditions. The results in this figure show a similar trend to that shown in Fig. 4, but slight differences occur in the sound levels.

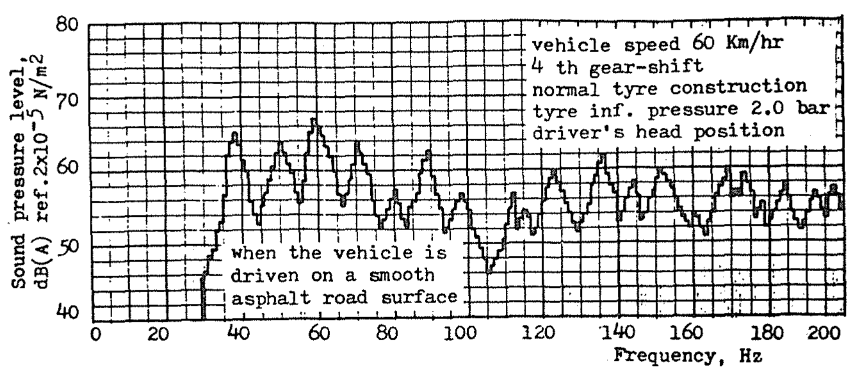

Fig. 5 Narrow band spectra for interior sound pressure level (SPL)

Figure 6 shows a comparison between the 1/3 octave and broadband average interior SPL generated by the tyre-road interaction only, when the vehicle was driven on the actual road surface (smooth asphalt), and when driven on the road simulator in the laboratory. A good accuracy is obtained in terms of broadband averages, while some discrepancies occur in 1/3 octave bands particularly in bands of 100, 125, 160 Hz. It is evident that these discrepancies are within the bounds of experimental error. In view of this accuracy, the experimental results taken in the laboratory could be used for studying not only the characteristics of interior tyre-road SPL but also the characteristics of exterior tyre-road SPL.

Figure 7 shows a comparison between the exterior SPL generated by the tyre-road interaction at the nearside and offside of the vehicle when the vehicle was driven on the road simulator. In terms of broadband averages, it is found that differences between the nearside and offside of vehicle existed. The difference may be attributed to "tyre slap" at expansion joints, or to the side tyre velocity variations, or due to the vehicle exhaust effect. Therefore, all the exterior SPL results presented later were taken at offside of the vehicle.

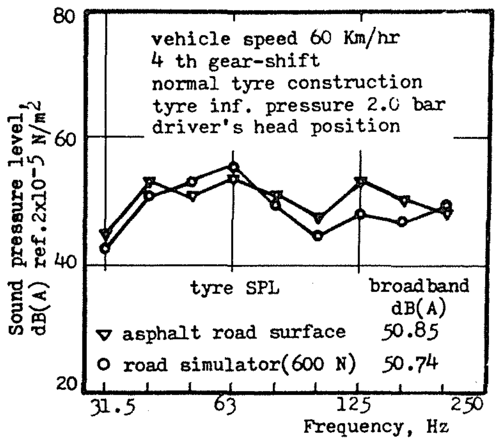

Fig. 6 ⅓-octave and broadband averages interior SPL

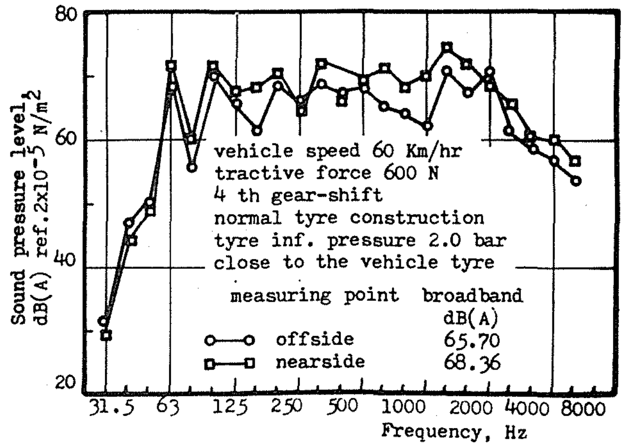

Fig. 7 ⅓-octave and broadband averages exterior SPL

In Figs. 8 and 9, the 1/3 octave and broadband exterior and interior SPL averages are shown respectively. The soft tyre with the soft tread rubber generally has lowest SPL (exterior and interior). This is true because the impact of the tread elements on the road simulator surface is softened due to this special rubber mixture, but also the air resonances in the tread grooves are decreased.

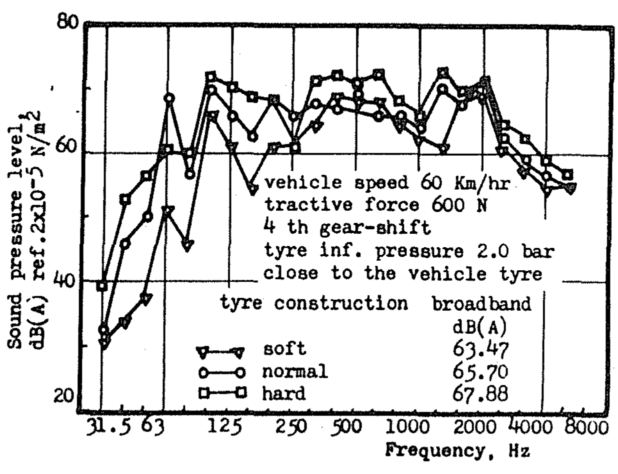

Fig. 8 ⅓-octave and broadband averages exterior SPL

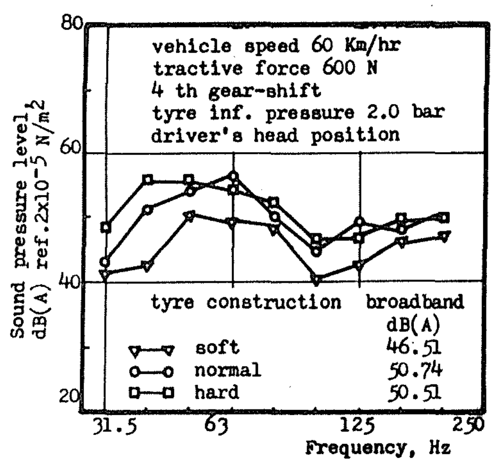

Fig.9 ⅓-octave and broadband averages interior SPL

One can find the main resonances in the exterior SPL spectra in the 1/3 octave bands of 63, 100, 2 000 Hz (Fig. 8). This could be found in interior SPL spectra also in the 1/3 octave bands of 50 and 80 Hz (Fig. 9). It has been found that the generated SPL of the soft tyre has a broadband average level lower than the normal tyre of 2.30 dB(A) (exterior) and by 3.23 dB(A) (interior) at these test conditions. It is even a little less noisy than the hard tyre construction, particularly for the tyre interior SPL. Moreover, the soft tyre reduces the impact loading at the tyre leading edge when compared with either normal or hard tyre construction. This in turn reduces the tread vibration and consequently reduces the noise generation.

Figures 10 and 11 show the influences of vehicle speed on the tyre exterior and interior SPLs respectively. In terms of broadband averages, it is found that the SPLs are highly correlated with the vehicle speed, the SPL increasing by 2 dB(A) (exterior) and 2.0 dB(A) (interior) as the vehicle speed is changed from 60 km/hr to 80 km/hr. This is also dependent on the tractive force applied.

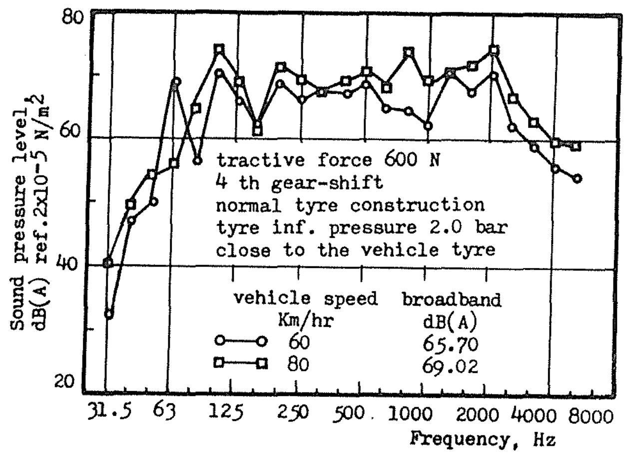

Fig. 10 $\frac{1}{3}$-octave and broadband averages exterior SPL

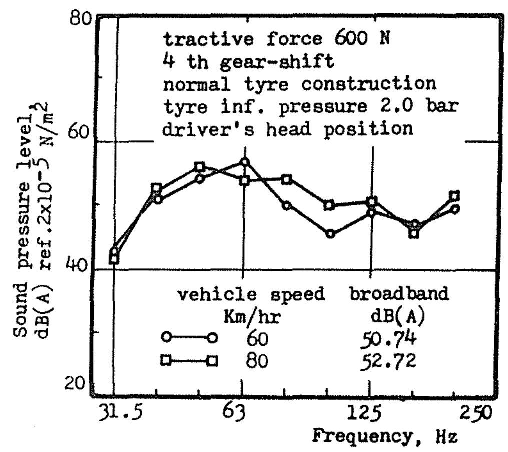

Fig. 11 $\frac{1}{3}$-octave and broadband averages interior SPL

Figures 12 and 13 show the influences of tractive force on tyre exterior and interior SPL spectra respectively. It is evident that the tractive force changes from one road surface texture to another. However, any road surface texture can be represented by some amount of tractive force applied on the road simulator. Further increasing or decreasing the texture or pattern on a road surface will increase or decrease the tractive force representation, and tends to reduce or increase the adhesion component of the surface friction yet increases the hysteresis component and the associated deformation of the tyre tread. Consequently, by decreasing the road surface tractive force, smaller slip velocities are induced. This in turn affected both exterior or interior SPLs. When the tractive force decreased from 600 N to 400 N, the broadband exterior SPL decreased from 65.7 dB(A) to 61.2 dB(A), and the broadband interior SPL decreased from 50.74 dB(A) to 47.5 dB(A).

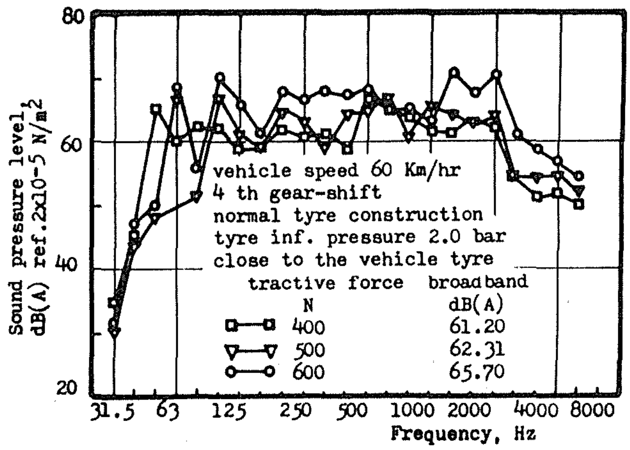

Fig. 12 $\frac{1}{3}$-octave and broadband averages exterior SPL

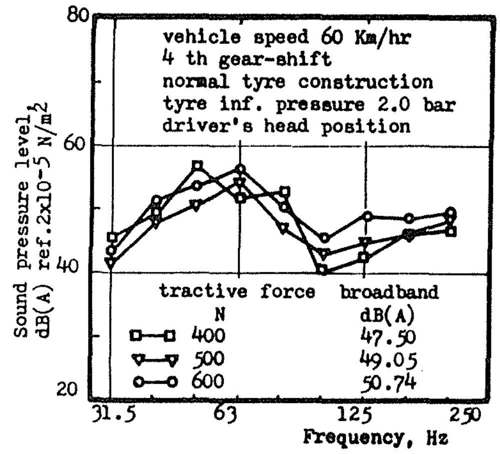

Fig. 13 $\frac{1}{3}$-octave and broadband averages interior SPL

The influences of the tyre inflation pressure on the tyre exterior and interior SPL are shown in Figs. 14 and 15. The tyre inflation pressure plays an important role in the tyre-road surface noise generation.

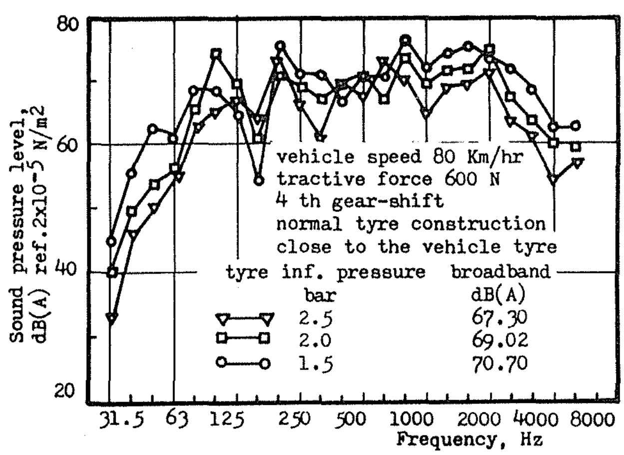

Fig. 14 $\frac{1}{3}$-octave and broadband averages exterior SPL

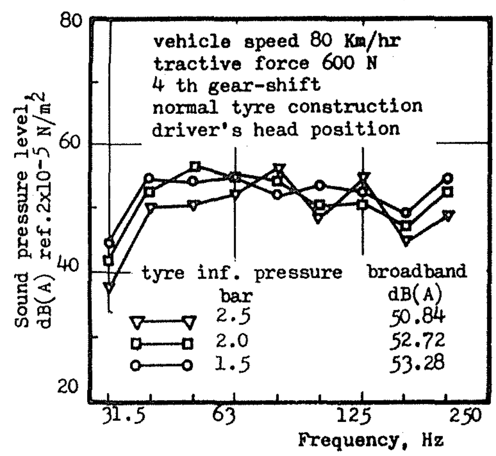

Fig. 15 $\frac{1}{3}$-octave and broadband averages interior SPL

If the tyre inflation pressure increases, the deformation of the tyre incontact region is decreased, and, therefore slip decreases. Consequently this will affect the tyre noise generation. When the tyre inflation pressure is increased from 1.5 to 2.5 bar, the broadband exterior SPL decreased from 70.70 dB(A) to 67.3 dB(A), and the broadband interior SPL also decreased from 53.28 dB(A) to 50.84 dB(A). However, the tyre inflation pressure should be maximised consistent with safety considerations.

5.0 CONCLUSIONS

1. The type of measuring technique used in this investigation is of interest for three reasons. First, it is of interest in the development of an indoor type noise test. This involves investigation of tyre mechanisms and duplication or simulation of these mechanisms indoors, where nearfield measurements are made. Second, aside from a development

and research standpoint, it may have the advantage of being more accurate and repeatable than for field (coast-by test). Third, factors like geometry of the test site, environmental effects on the propagation of sound over long distances, and wind effects become less important when the microphone is located in close proximity to the noise source.

2. It is found that the exterior and interior tyre-road SPLs are affected mainly by vehicle speed, road surface tractive force, and other operating conditions.

3. Based on the measuring technique used and the results obtained, a reduction of the exterior and interior tyre-road interaction SPL can be made by using a radial soft tyre construction with steel belts This will reduce the amount of slip in the contact area to maximise damping in the tyre structure. Furthermore, its inflation pressure should be maximised consistent with safety considerations, as this will minimise the deformation of the tyre in the contact region, and, therefore, minimise slip.

4. It is suggested that tyre vibration might be controlled by the degree of slip of the tread elements in the contact region during rolling which, in turn, is controlled by frictional adhesion between the tyre and road surface and the deformation of the tyre tread in the contact region.

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VEHICLE NOISE LEVELS 1976-1986

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ABSTRACT

Noise levels of a large number of individual vehicles in normal use have been collected, in 1976 and 1986, by roadside measurement. Various conditions of road gradient, vehicle type, speed and (for trucks) mass were also observed. Multiple regression analysis has been applied to develop phenomenological expressions for noise level in terms of vehicle speed and mass.

The 1986 data provide current information which can be applied in planning either in relation to single vehicles or in traffic noise prediction calculations.

The two sets of results also provide a basis on which to assess the effect of a decade of application of the Australian Design Rules for motor vehicle noise. There appears to be a slight reduction in noise level for cars and trucks when travelling on level roads, but the change is so small that its significance is in doubt. For both cars and trucks climbing a 6% grade, there is little difference between the 1976 and 1986 levels.

It can be concluded that there has not been any significant increase in vehicle noise levels. Increases might have occured if the design rules had not been introduced.

1.0 INTRODUCTION

The prime approach for controlling the intrusion of traffic noise into the community is the specification of compliance rules for new vehicles. In Australia , the first control of this nature was the introduction in 1973-75 of Australian Design Rule 28 (Aust. Govt., 1972). The Rule was made more stringent (for cars, trucks and buses) in 1980-81.

During 1976 an investigation of individual vehicle noise levels was carried out in order to characterize vehicle noise (in one Australian city) and to provide data for traffic noise predictions (Hooker et al, 1978). In the early years after implementation of a compliance rule, little influence on noise levels can be expected since only new vehicles are affected. The 1976 results would therefore be relatively unaffected by the Design Rule.

In 1985-86, a further study was carried out along similar lines - in part at the same measurement locations as in 1976. As well as providing recent data, the later investigation allows comparison with the 1976 data and thus enables an assessment of the influence of a decade of application of the Design Rules.

2.0 DETAILS OF THE INVESTIGATION

By roadside measurement, noise levels were observed for individual vehicles over a range of conditions - vehicle type (cars and trucks), vehicle speed, and road gradient. The measurements were taken for normal traffic on roads in ordinary use, in Brisbane, Australia. The test set-up was unobtrusive and drivers were not aware of the operation. Periods of medium traffic density were chosen so that a reasonable number and proportion of vehicles could be included.

Some locations were on highways leading to or from weighbridge checking stations. Hence, by recording registration numbers and reference to weighbridge manifests, it was possible to associate noise levels with gross vehicle mass for about half of the heavy vehicles measured.

The microphone position was 7.5 m from the centre of the nearest lane and 1.5 m above ground. Microphone placements were in open, flat regions with no reflecting surfaces nearby. All results in this paper apply to a smooth road surface - asphaltic concrete (hot mix) type. Vehicle speed was measured by radar "gun". Tests were conducted on roads of gradient zero and 6% (vehicles travelling up). Peak dB(A) values on fast response were recorded on magnetic tape for later analysis, with regular meter observations at site for cross-checking.

3.0 TRENDS OF VEHICLE NOISE LEVELS

Representation of the noise behaviour of individual vehicles has been considered by several investigators, for example, Lewis (1973), Nelson and Piner (1977), Jones and Hothersall (1980), Lamure (1981) and Lawrence (1985). There seems to be general agreement that for cars at speeds between 60 and 100 km h^{-1} the noise is due principally to the tyres, and can be described phenomenologically by the relation

$$L = B_o + B_1 \log_{10} S \quad (1)$$

where L = sound level, dB(A)
S = vehicle speed, km h^{-1}
B_o, B_1 = constants

For trucks at present in use it is commonly claimed that the principal noise is that radiated from the engine. Engine noise studies relate radiated sound with engine speed and dimensions. Engine speed is related to road speed, and engine dimensions can be related (in a "population average" sense) to vehicle load capacity. Thus a relation can be developed (Bell, 1976) in the form

$$L = B_o + B_1 \log_{10} S + B_2 \log_{10} M \quad (2)$$

where M = gross vehicle mass, tonne

B_2 = constant

Regression analysis was applied to determine best fit lines - in the form of equation (1) for cars and for trucks, and in the form of equation (2) for those trucks whose mass was known.

4.0 RESULTS

The measurement locations and some details of them are listed in Table I. Results were taken in 1986 at location 1, but had to be abandoned due to installation of traffic signals nearby since 1976. Omission of location 4 arises because road surface conditions there in 1976 were no longer applicable in 1986. The number of individual noise levels measured was approximately 500 in 1976 and 1000 in 1986.

TABLE I. MEASUREMENT LOCATION DETAILS

Location No.	Gradient %	Speed Zone km h^{-1}	Weighbridge	Year 1976	1986
1	0	80	√	√	-
2	0	100	√	√	-
3	0	60	-	√	√
5	6	100	√	√	√
6	0	100	√	-	√
7	0	80	-	-	√

Collected results for cars (including panel vans and light trucks up to 1.5 tonne) are set out in Table II. The statistically determined coefficients B_o and B_1 for the representation of equation (1) are given with the standard deviations (SD) also. The value L_{PR} is the level as predicted by the fitted equation for a speed of 80 km h^{-1}.

The nature and scatter of the results is indicated by Figure 1.

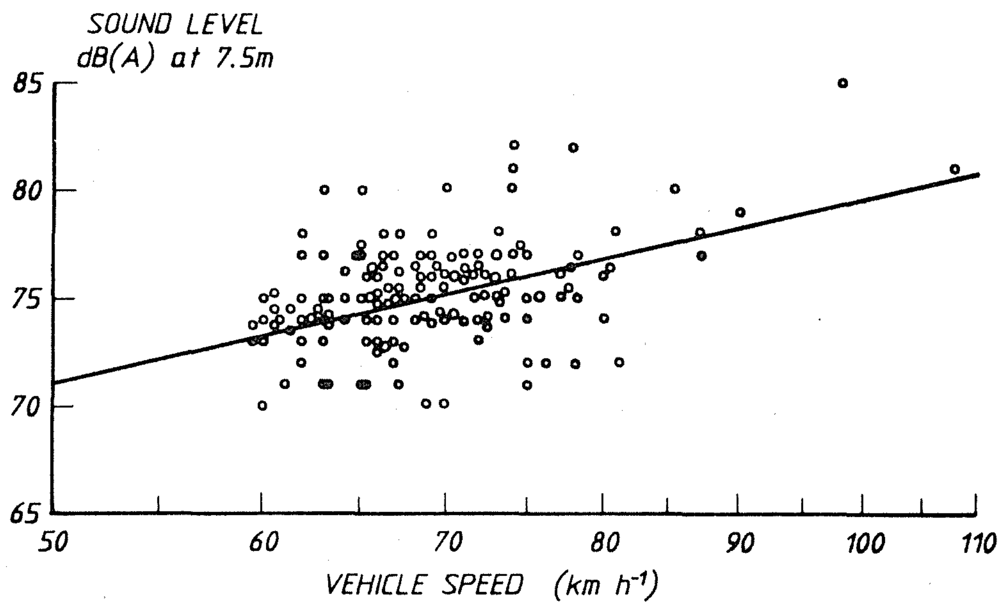

Figure 1. Individual results, cars, zero gradient

TABLE II. NOISE OF INDIVIDUAL CARS

Levels L are in dB(A) at 7.5 m
Speeds S are in km h^{-1}

Year	Grade	No. of	Range		Mean		Line Fit			
	% up	Measts	S	L	S	L	B_0	B_1	SD	L_{PR}
1976	0	136	36-111	70-87	81	79	25.3	28.1	1.8	78.8
1986	0	149	60-109	70-85	69	76	24.7	27.5	2.4	77.0
1976	6	35	64-114	71-83	83	77	34.2	22.4	2.2	76.8
1986	6	60	63-113	72-83	90	78	56.5	11.2	2.5	77.8

The car results for zero gradient are similar, with a slight reduction from 1976 to 1986, but for the higher speeds in this comparison the measurements were taken at different locations, and hence the difference can only be considered as marginal.

A surprising result for the 6% gradient is that although the ranges and means for 1976 and 1986 are similar, the fitted equations differ markedly. These two sets of results were taken at the same location. A question of sample size must be raised, although it appears that the 1986 result, with the larger sample, is the more doubtful.

For trucks, without taking into account the mass, results are shown in Table III. The L_{PR} value is again the level predicted by the fitted equation for speed 80 km h^{-1}. Although the range, mean and predicted values show a reasonable consistency, the coefficients B_o and B_1 vary markedly. Apart from one case, the sample size is reasonable.

TABLE III. NOISE OF INDIVIDUAL TRUCKS

Levels in dB(A) at 7.5 m
Speeds S in km h^{-1}

Year	Grade % up	No. of Measts	Range S	Range L	Mean S	Mean L	Line Fit B_o	Line Fit B_1	Line Fit SD	Line Fit L_{PR}
1976	0	120	37- 95	80- 96	73	89	49.1	21.2	3.6	89.4
1986	0	360	72-108	80- 96	85	87	77.1	5.1	3.4	86.8
1976	6	40	37-102	77- 94	74	86	58.3	14.9	4.3	86.7
1986	6	360	61-103	81-100	86	90	8.5	42.0	2.9	88.4

An extended regression analysis was applied for those truck cases in which vehicle mass was known. From sound level, speed and mass M, best fits in the form of equation (2) were calculated. The results are presented in Table IV. Predicted value L_{PR} is for 20 tonne and 80 km h^{-1}.

TABLE IV. NOISE OF TRUCKS - MASS EFFECT INCLUDED

Levels in dB(A) at 7.5 m
Speed S, km h^{-1}. Mass M, tonne

Year	Grade % up	No. of meausts	Range S	Range M	Range L	Mean S	Mean M	Mean L	Line Fit B_0	Line Fit B_1	Line Fit B_2	Line Fit SD	Line Fit L_{PR}
1976	0	53	37- 89	7-49	81- 96	70	21	89	39.7	20.8	8.6	3.0	90.5
1986	0	153	72-108	5-39	80- 96	84	21	88	12.0	33.7	8.1	4.1	86.7
1976	6	20	37- 86	4-36	79- 93	69	20	86	48.2	15.3	8.2	3.1	88.0
1986	6	157	69-100	8-48	84-100	83	30	90	58.4	13.3	3.9	2.4	88.8

Again it can be seen that the ranges and means, and the predicted levels, are consistent but that variations occur in the line fit coefficients. The B_2 values are close except for one case. The B_1 values for 6% gradient agree, these values being noticeably less than the zero gradient cases.

The fitted lines as defined by the coefficients in Tables II and IV are plotted in Figure 2. Since the speed range of interest is small (in a ratio sense, i.e. 0.6:1.0 for 60 to 100 km h^{-1}), the variations in speed coefficient B_1 are less significant than the numerical values might suggest. The speed coefficient is consistently lower for grade climbing than for level travel.

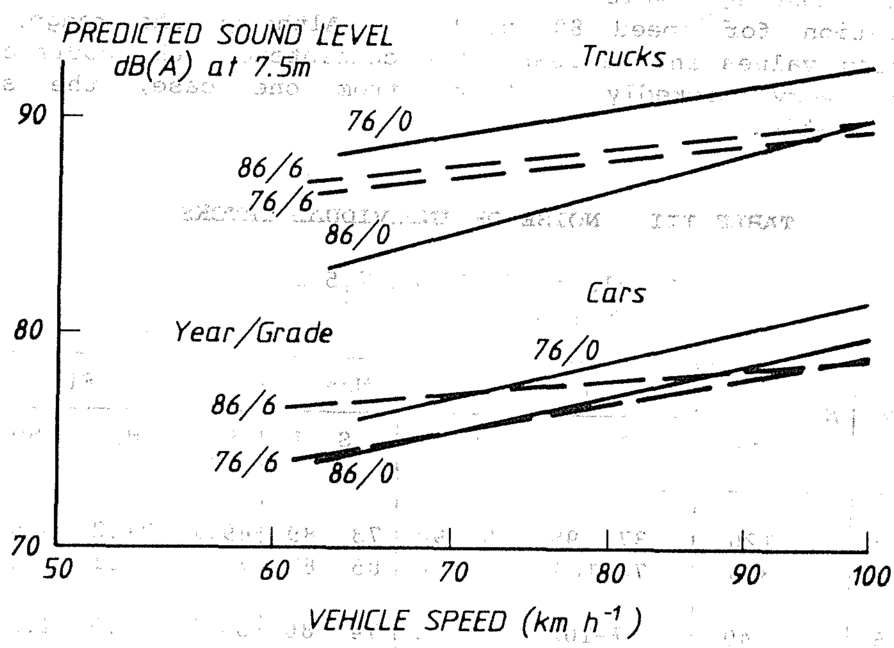

Figure 2. Regression Lines

There is a noticeable difference between the 1976 and 1986 levels for zero gradient - a reduction of about 4 dB(A). However, comparison with other data (Jones and Hothersall, 1980, Nelson and Piner, 1970) suggests that the 1976 data may be somewhat high, and hence the apparent gain over the decade may be illusory.

In all Tables, the calculated coefficients for 1976, 6% gradient, seem to be somewhat inconsistent with other results. No unusual condition of road conditions or traffic movement was noted. It has been suggested (Lewis, 1973) that older and poorly maintained vehicles generate more noise and might affect regression coefficients. If this applied to the heavier vehicles, travelling more slowly, then the effects are more likely to affect the 6% gradient data and could lead to the low values for B_1 in Table III and B_2 in Table IV.

5.0 IMPROVED REPRESENTATION

The discussion related to Figure 2 on the significance of variations leads to consideration of the basic representations expressed as equations (1) and (2). The principal difficulty lies with the misleading nature of the "intercept" term B_o, which represents the sound level for a speed of 1 km h^{-1} and mass of 1 tonne. There is also a lack of mathematical elegance in taking the log of a physical quantity.

Better representations would be

$$L = A + B_1 \log (S/Sref) \quad (3)$$

and $$L = A + B_1 \log (S/Sref) + B_2 \log (M/Mref) \quad (4)$$

Such a formulation should be readily acceptable to those with a background in acoustics. The coefficients B_1 and B_2 are unchanged. If mid-range values are chosen for S_{ref} and M_{ref}, then A gives the mid-range predicted sound level.

If S_{ref} is chosen as 80 km h^{-1} and M_{ref} as 20 tonne, then the A terms are equal to the L_{PR} values in all Tables.

6.0 CONCLUSION

Repetition in 1986 of vehicle noise level investigations conducted in 1976 shown a reasonable degree of consistency of results, although discrepancies occur due to possible changes in road, traffic and vehicle conditions.

The results indicate that after a decade of operation of Australian Design Rule 28 there appears to be a reduction of about 2 dB(A) in peak pass-by level for individual cars travelling on level road. However, a change of 2 dB(A) could well be produced by changes in measurement conditions and so no firm conclusion can be drawn. No reduction is apparent for cars travelling up a 6% gradient.

For trucks on level road, a reduction of 4 dB(A) was observed, but it must be noted that the 1976 results for this case tended to be slightly higher than some other published data. No reduction, indeed a slight increase, was noted for trucks when climbing.

For both cars and trucks, the effect of speed is less for travel up grade.

Although there is not strong evidence of any reduction in vehicle noise levels, it can be concluded that there has not been any increase. Increases might have occurred in the absence of design rules.

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ROAD TRAFFIC NOISE REDUCTION OF FACADES - MEASUREMENT PROCEDURES AND PROBLEMS

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ABSTRACT

An extensive series of measurements of the noise reduction of a variety of facades using an Experimental Building provided an opportunity to investigate aspects of the measurement procedures. If loudspeaker radiated sound is used as the source, as in laboratory measurements, it has the advantages of being constant and controllable, but it has quite different characteristics to those of road traffic noise. Comparison measurements of the same facade show that the results obtained using loudspeaker noise are consistently higher than the results obtained using road traffic noise. When this latter noise is used as the source great care must be taken to ensure that the results are not limited by the dynamic range of the measuring and analysing equipment. The sound power of road traffic noise decreases in the higher frequencies and this is the range in which the noise reduction of the facade is usually greater. Unless all these aspects are carefully considered during the measurements the usefulness of the results and their application to other situations will be severly limited.

1.0 INTRODUCTION

Noise is acknowledged to be a problem in most communities. While attempts are being made to reduce the noise levels, it is obvious that an acceptable environmental noise level for all will not be achieved in the forseeable future. Therefore many people will continue to live and work in areas where they rely on the noise reducing properties of a building enclosure to provide a satisfactory internal acoustic environment.

There is a large amount of data available for the noise reduction values (or sound transmission loss) of partitions which are used inside buildings. In contrast, there is little data available for the noise reducing properties of facade constructions, with the exception of windows (for which most of the data has been obtained for fixed, unopenable sashes). It is necessary to have information on the sound transmission loss of facades to be able to recommend the most suitable constructions for various environments, and to determine what modifications need to be made to existing buildings to improve the internal acoustic environment.

The measurement of the noise reduction, or sound transmission loss, of the facade of a building is beset by numerous problems and difficulties. These difficulties are increased if the problem is that of road traffic noise. An extensive series of measurements of the noise reduction of a variety of facades, using an Experimental Building adjacent to a major road, provided an opportunity to investigate aspects of the recommended measurement procedures and highlighted some of the problems. These aspects of the measurements are discussed in this paper, while a companion paper provides some of the results (1).

2.0 FIELD vs LABORATORY MEASUREMENTS

There are two different traditional methods for determining the sound reducing properties of building elements. One is the laboratory method where the element to be tested is placed in a special framework dividing two large rooms. Noise from a loudspeaker is produced in one room and the average sound levels in the reverberant source and receiving rooms are measured. A correction is applied to allow for the absorption of sound in the receiving room and the sound transmission loss is then determined. The procedure is specified in Australian Standard AS1191 (2) and International Standard ISO 140/III, (3). Most of the tests on elements of facades, such as doors, windows etc. have been undertaken using the laboratory procedure.

The second method is called a "field measurement". The sound insulation of the facade of a building complete with doors, windows, ventilation openings etc, is determined either with a loudspeaker noise source or with the noise from the existing road traffic. There is no Australian Standard for field measurement of facades at this time so the procedures specified in ISO 140/V (4) should be followed. In a similar manner to the laboratory method, the sound levels on the source side and receiving side of the facade are measured, corrected for absorption in the receiving room, and the sound transmission loss determined. The standard recommends the use of traffic noise as the sound source but also gives the procedure for loudspeaker noise.

Comparisons between the results of laboratory and field measurements are difficult to make because of the possibilities of additional flanking paths, which are not present in the controlled laboratory environment. However it has been found that field tests carried out in accordance with the Standard procedures using loudspeaker noise give systematically lower results than those achieved in laboratory tests (5).

3.0 DISCUSSION

3.1 Sound Source. Loudspeaker radiated sound as a source has the advantage of precise specification and control and it is also suitable for direct measurement of sound transmission, but it has some serious disadvantages when the results obtained are to be applied to road traffic noise situations. Firstly it is likely that facade attenuation will need to be measured at sites where traffic noise levels are high; thus, in order to ensure that the loudspeaker noise is the dominant source (i.e. 10 dB above the peak traffic noise levels at the facade) the overall generated noise level must be very high. This requires large loudspeaker(s) and a powerful amplifier, which will not be readily transportable. The test noise may also cause community noise annoyance in the immediate neighbourhood as the measurements may take some hours to complete.

Another disadvantage of loudspeaker noise is the limited range of angles of incidence of the sound onto the facade, compared to those from real traffic. It was found during the measurements at the Experimental Building that the results for facade attenuation using the loudspeaker source were consistently higher than those determined using real traffic, see Figure 1. Since it is well known that the sound attenuation properties of many materials vary with the angle of incidence of the sound, tending to be lower as the angle approaches grazing incidence, it is evident that the use of a loudspeaker radiated sound source will overestimate the attenuation provided by the facade.

Real traffic noise also presents some difficulties as the sound source for facade attenuation measurements; the traffic flow and composition and thus the sound source vary considerably, even over quite short time periods. This means that it is essential to make simultaneous, not sequential, measurements of the sound outside and inside the facade under test, and this, in turn, suggests the use of some sort of recording device, although "black boxes" could also be used in some circumstances. A decision also has to be made regarding the descriptor to be used for the traffic noise. Although $L_{Aeq,T}$ is increasingly being used to describe all types of community noise including traffic, $L_{A10,T}$, which is normally about 3 dB(A) higher, has a better signal/background noise ratio (where $L_{A95,T}$ is used to define background sound level). The sample duration to make a reliable estimate of $L_{A10,T}$ depends on the traffic flow rate, and can be determined from AS 2702-1984 (6).

In some situations quite low traffic volumes can still lead to great annoyance. In these cases the descriptors $L_{A10,T}$ and $L_{Aeq,T}$ do not give satisfactory indications of the annoyance caused by the occasional noisy vehicle, and the sample duration time becomes excessively long because of the small traffic volume. In these cases some assessment of the noise and of the attenuation of the facade may need to be based on data from individual vehicles. This is an area which requires further investigation.

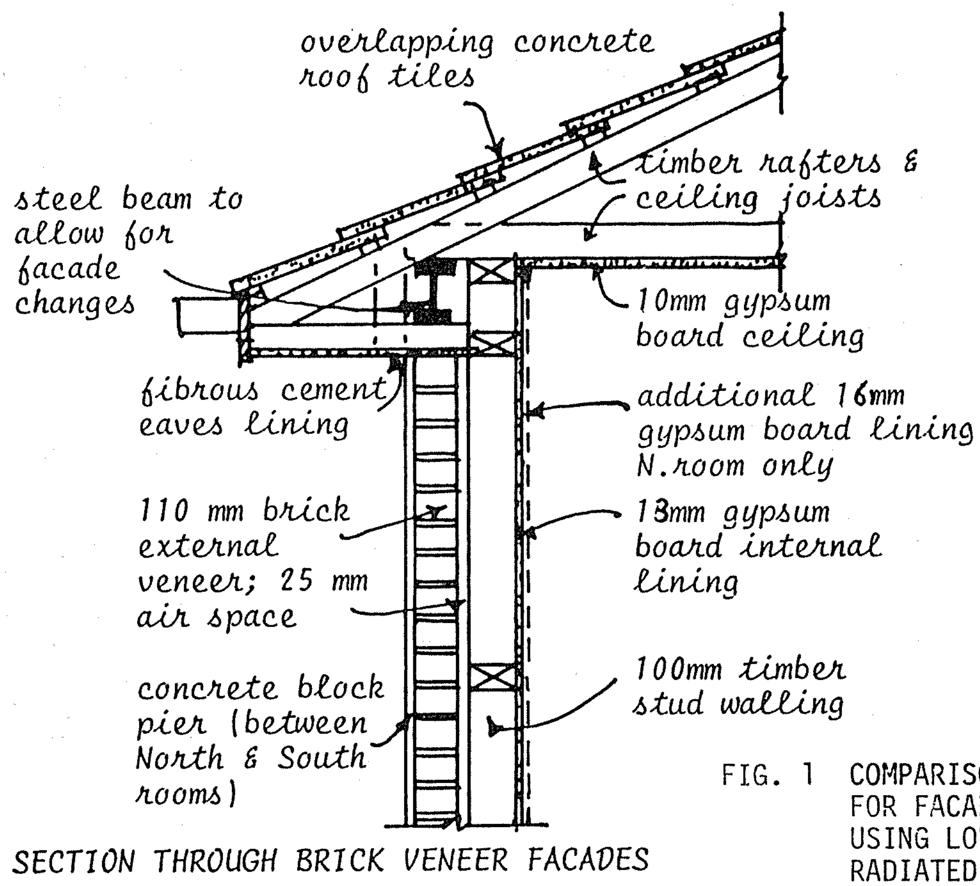
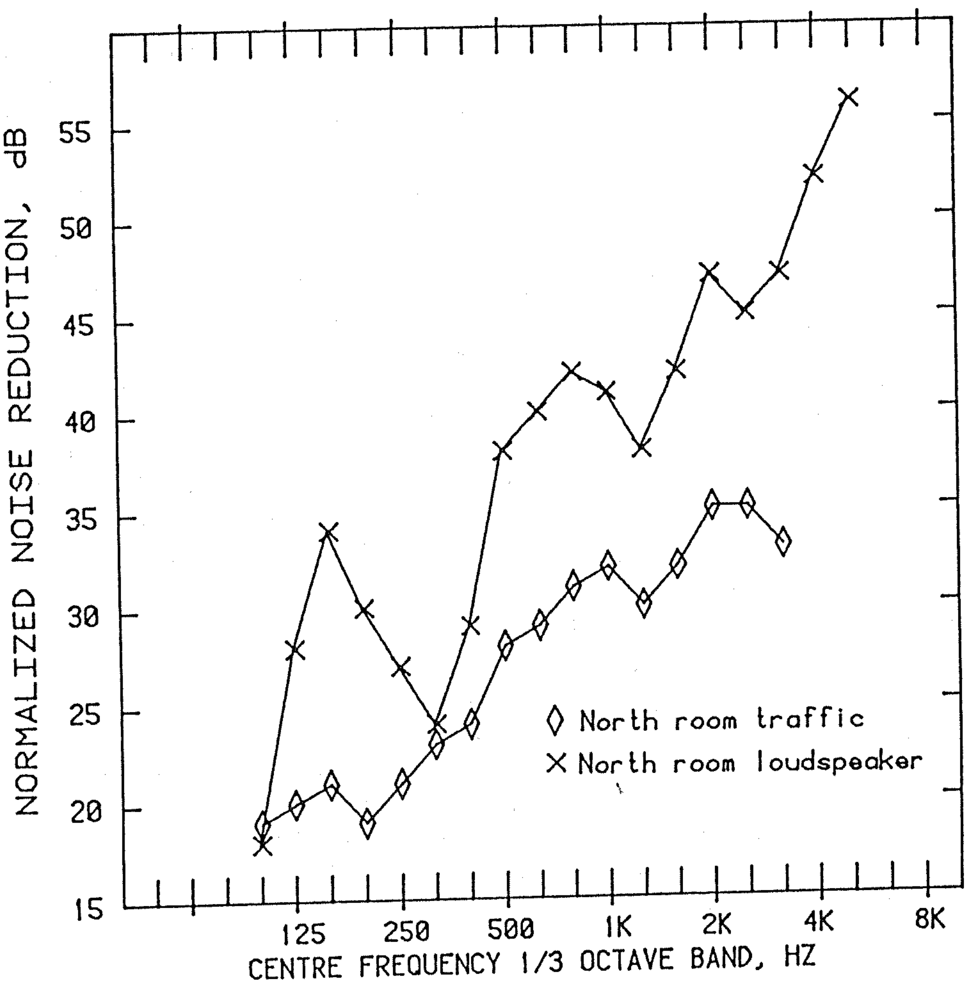


FIG. 1 COMPARISON OF RESULTS FOR FACADE ATTENUATION USING LOUDSPEAKER RADIATED NOISE AND ROAD TRAFFIC NOISE AS SOURCE.



3.2 Microphone Location. The Standard ISO140/V specifies that the microphone should be placed either 2m from the facade or as close as possible to it (less than 20mm). For most road traffic noise measurements the microphone is normally placed 1m from the facade - this is the specified distance from a facade in the Australian Standard on the measurement of road traffic noise, AS2702 (6). In the UK, compensation for those exposed to high levels of road traffic noise is based on measurements, or predictions, of the noise level at 1m from the facade (7).

While measurements of sound insulation of a facade are not made for the same purpose as measurements of traffic noise levels outside a building, it does seem sensible to make these two measurements compatible. Placement of a microphone at a distance of 2m from a facade often provides a very inconvenient location, particularly for urban and suburban houses with shrubs in the front garden. For multi-storey buildings a distance of 2m from the facade requires a major structural support while a position 1m from the facade can be supported by a simple triangulated framework.

Placement of the microphone on the facade itself is only really feasable for glass where a temporary fixing can be made with suction caps and tape. For other surfaces, in particular masonry, such a temporary fixing is not satisfactory. A more permanent fixing will cause damage to the surface.

3.3 Data Reduction. In some situations it is only necessary to determine the noise reduction in terms of dB(A) for a specific facade. However this value cannot be readily applied to other facades facing different traffic because of variations in the frequency spectrum of the source. In order to allow for general application of the data obtained using the Experimental Building it was necessary to determine the noise reduction for each 1/3 octave band and to normalise the results to allow for the absorption in the receiving room. This was a very time consuming task until software was developed which allowed the percentile values (and $L_{Aeq,T}$) to be determined for each 1/3 octave band simultaneously. It then became possible to determine the Normalised Noise Reduction (NNR) for each band, as follows:-

$$NNR_{(f)} = L_{1(f)} - L_{2(f)} + 10 \log S/A_{(f)}$$

Where $L_{1(f)}$ is the $L_{10,T}$ level measured outside for the 1/3 octave band centred on f (T=5 or 10 minutes)
$L_{2(f)}$ is the $L_{10,T}$ level measured inside simultaneously
S if the surface are of the room facade, m²
$A_{(f)}$ is the total absorption in the room determined by measuring the reverberation time.

In order that the different facade systems could be compared directly, an average A-weighted traffic noise spectrum was calculated from over 100 samples of $L_{10,T}$ for each 1/3 octave band measured at 1m from the facade. This spectrum is shown in Fig. 2. The overall level of this spectrum was set at 70 dB(A) and the indoor levels were computed from the measured $NNR_{(f)}$ values. The overall A-weighted indoor level was then computed, and this was deducted from the outdoor level of 70 dB(A) to give the overall NNR of the particular facade system in dB(A).

NNR's were determined in a similar way for each band for the loudspeaker source, and these values were used to predict indoor levels resulting from the average traffic noise spectrum and thence the overall NNR for the loudspeaker source, in dB(A).

3.4 Measuring and Analysing Equipment. For the series of measurements at the Experimental Building, high quality acoustical instrumentation was used. Even with this equipment significant problems were found with the dynamic range of the instrumentation when road traffic was used as the source.

As shown in Fig. 2 the average A-weighted one-third octave band spectrum level of traffic noise, as measured 1m from the facade of the Experimental Building, has most energy in the 1 and 1.25kHz frequency bands, and it is some 10 dB lower at the extremes of the measurement range (100 and 5000Hz). However, the measuring amplifiers were usually set on "Lin" rather than on "A"-weighting during this project, and the average traffic noise spectrum level then falls fairly constantly over the measurement range, with the level at 5000Hz some 20 dB below that at 100Hz. This of course causes no problems for the signal from the external microphone.

The signal inside the room having a facade with a reasonably good performance, however, will have a much larger level difference between low and high frequency components since such facades attenuate sound much more at high frequencies than at lower ones. Thus there may be 40 dB or more difference between the levels in low and high frequency bands and a dynamic range of 60 decibels is necessary in the instrumentation if noise is not to affect the results. In other words, because the attenuators (for a wide-band recording) must be set to avoid overload from the low frequency components, there will be inadequate signal/noise ratio at the high frequency end. Fig. 3 illustrates this problem.

If good quality digital instrumentation is available, the 60 dB or so dynamic range required should not present any problems. However, using analog equipment, including professional quality (Nagra and Racal tape recorders), it became evident, with the better facades, that instrumentation noise was affecting the results in the higher frequency bands. For the last series of measurements, therefore, additional recordings were made of the inside microphone signals using 1-octave band filters for the centre frequencies of 1kHz and above, and this overcame the problem. The improvement in S/N ratio at the higher frequencies when recordings were filtered was considerable. For example, for wide-band recording inside the attenuator was set on 70 dB, and the lowest L_{10} value at 5kHz was about 20 dB. However, for the recording filtered through the 4kHz octave band, the attenuator could be set at 40 dB and the L_{10} level at 5kHz was found to be only 4 dB - corresponding to an "improvement" of 16 dB in the facade attenuation at this frequency. It should be noted that none of the facades tested had an overall Normalised Noise Reduction greater then 34 dB(A) for traffic noise because of the flanking transmission path through the roof, etc. If facades with potential attenuations of 40 dB(A) or more were to be tested it is likely that A-weighted NNR's would be affected if either direct measurements or wide-band recordings were to be made. This has implications which must be considered if "simplified" methods of facade attenuation measurement are to be used.

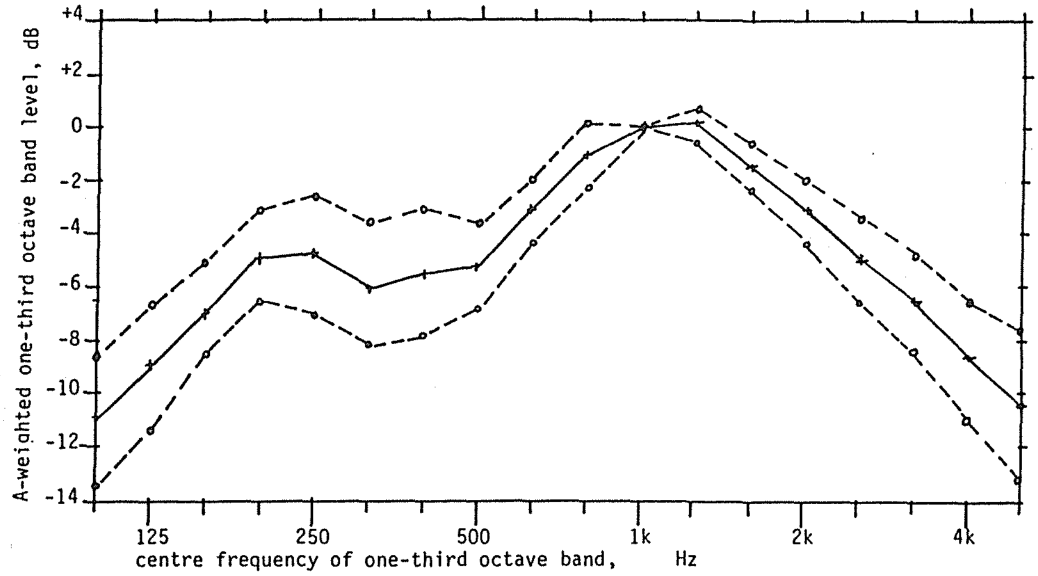


FIG. 2 AVERAGE A-WEIGHTED ONE-THIRD OCTAVE BAND TRAFFIC NOISE SPECTRUM L10 VALUES MEASURED 1m FROM FACADE OF EXPERIMENTAL BUILDING, NORMALISED TO 1 kHZ: MEAN ± 1 STANDARD DEVIATION.

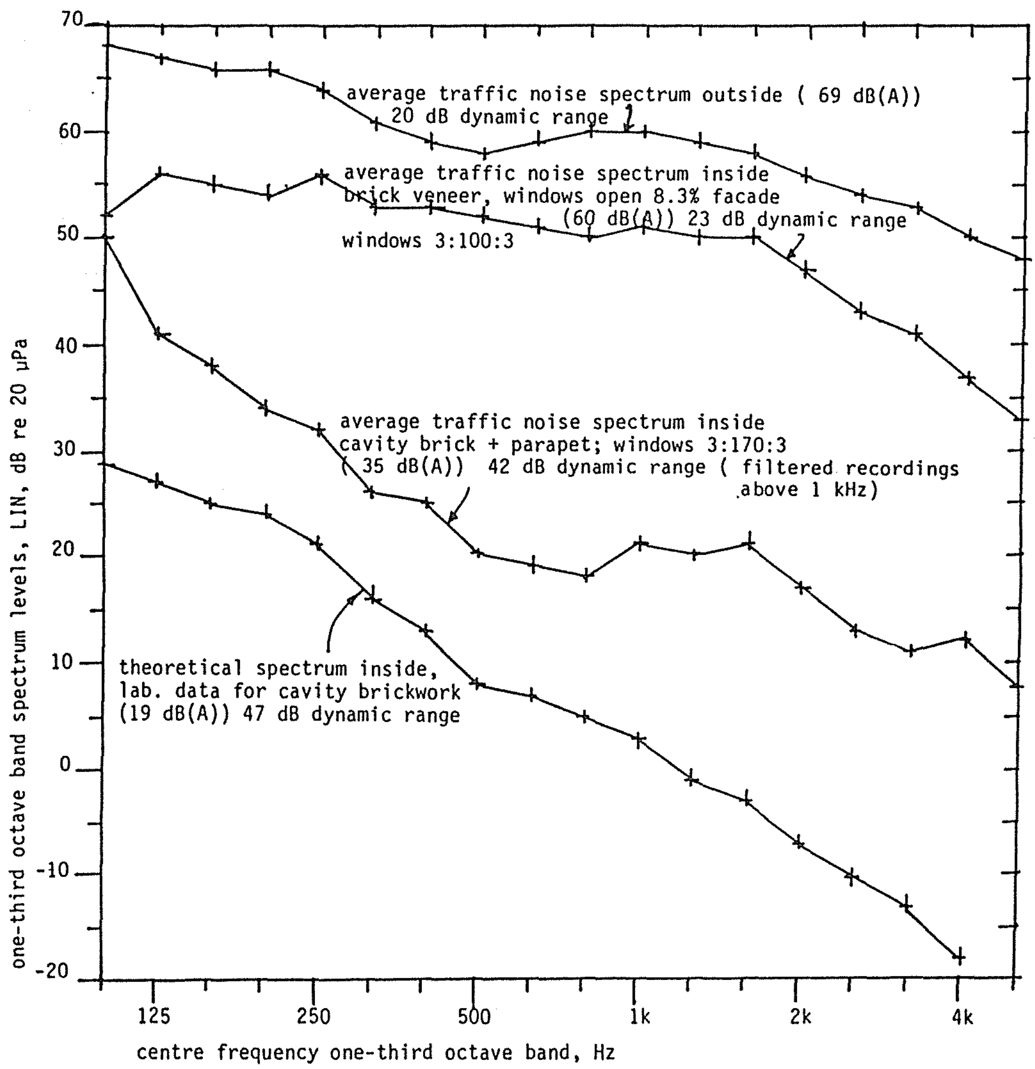


FIG. 3 EFFECT OF FACADE ATTENUATION ON DYNAMIC RANGE OF ONE-THIRD OCTAVE BAND SPECTRUM LEVELS INSIDE FOR AVERAGE TRAFFIC NOISE SPECTRUM

4.0 CONCLUSION

It is apparent that there is a general lack of information on the noise reducing properties of facades. This information is needed to assist in the selection of appropriate constructions so that a satisfactory internal environment can be achieved. The measurement of sound insulation of facades requires much more complex procedures than those followed for the sound insulation of internal partitions.

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6.0 ACKNOWLEDGEMENTS

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A SIMPLE METHOD FOR PREDICTING KERBSIDE L_{10} LEVEL FROM A FREE MULTI-TYPE VEHICULAR FLOW

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ABSTRACT

The aim of this paper is to offer a simple method to predict the kerbside L_{10} level from a free traffic flow consisting of multi-type vehicles. It is suitable to the cases where traffic volume on each lane is small and the average velocity of cars is slow.

DERIVATION OF PREDICTION FORMULA

We classify all vehicles into 4 classes (see Table 1). Because noise level L_{10} implies the sound level that is exceeded x% of the measure time, if the vehicle volume of some class plus that of higher classes has increased to a certain amount, the probability with which these vehicles appear in a given interval where the sound level meter is located in would equal to x%, thus, L_{10} should be equal to the sound level generated by a travelling vehicle of the lowest class in the end of the interval at some speed.
Provided that the traffic flows consisting of the vehicles of some classes on each lane obey the Poisson distribution, the composite of simplest streams on n lanes may also be regarded as a Poisson stream with a mean value $\sum_{i=1}^{n}\lambda_i$, where $\lambda_i=v_i t/3600$ and v_i is the vehicular volume of these classes on ith lane. Assuming that $\lambda_1=\lambda_2=\cdots=\lambda_i=\cdots=\lambda_n=Qt/3600=\lambda$, the probability that K vehicles arrive at observer is given by

$$P\{\xi=K\}=(n\lambda)^K \exp(-n\lambda)/K! \qquad (K=0,1,2,\cdots) \tag{1}$$

and

$$n\lambda=Qt/3600 \tag{2}$$

where Q is the total volume of some class and higher classes (veh/h). Furthermore, because

$$l = st \tag{3}$$

where s is the average speed of vehicles in m/s, the probability that vehicles arrive at the observer during t s is

Table 1. Classified Vehicles and Their Average Sound Pressure Levels (D_E=10m)

Classes	Types	L_p (dBA)
I	Truck with trailer, Tractor	80-82
II	Motorcycle, Truck	76-78
III	Bus	72-74
IV	Car, Wagon, Jeep	66-68

equivalent to that they appear in an interval of 1 m with a center that is just the observer. Let

$$1-P\{\xi=0\} = 1-(n\lambda)^0 \exp(-n\lambda)/0! = x\% \tag{4}$$

we can derive a formula

$$Q = -3600 X \ln(1-x\%)/t \tag{5}$$

where x is the subscript of L_x , Q is the required minimal volume of vehicles involving the vehicles deciding L_x and those noisier than them.

ATTENUATION AND SUPERPOSITION OF SOUND LEVELS

It is assumed that the composite traffic flow is set on an equivalent lane. If the speed of vehicles is taken as s=8 m/s, for t=1 s, l=8 m. When vehicles appear in the middle interval of 8 m, the mean L_p values of each class are shown in Table 1. Inserting 10 into x in Equation (5), we can calculate the corresponding Q values for each t, for example, for t=1 s, Q=380 veh/h. Then, we calculate the corresponding intervals for each sound levels successively attenuated by 2 dB. Provided that the mean vehicle's length is 8 m and the sound source is set at the middle point of vehicle. For a reference distance of 10 m, we have

$$\Delta L_p = L_W - 20\lg 10 - 8 - L_W + 20\lg D + 8 = 20\lg D - 20 \tag{6}$$

where D denotes the source-observer distances. From Equation (6), we can firstly calculate the corresponding interval lengths l for every sound levels successively reduced by 2 dB, then calculate t from Equation (3) and Q from Equation (5). For example, for ΔL_p=2 dB, D=12.6 m, l=24 m, t=3 s, so, Q=125 veh/h. Now, we know that if the vehicle volume of first class reached 380 veh/h, L_{10}=80-82dBA; if it is less than 380 veh/h, but it plus the volume of second class reached 380 veh/h, L_{10} =76-78 dBA and so forth. If the volume of first class reached 125 veh/h, L_{10} will be reduced by 2 dB, that is, L_{10} =78-80 dBA.

We also can consider the effect of the superposition of sound levels. Let's divide the road into small intervals of 8 m each. According to the independent increment characteristic of Poission process, the arrivals in each interval is

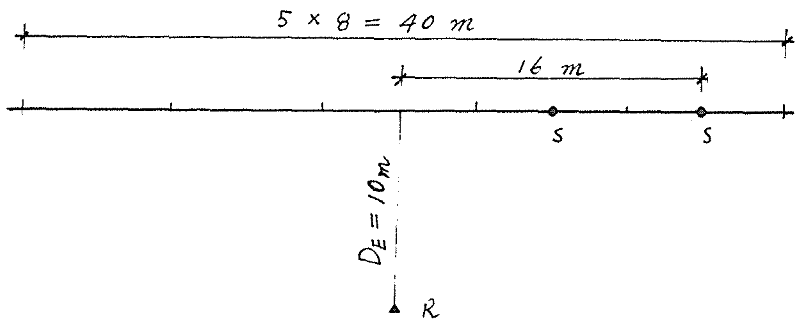

Fig.1 Calculation for sound level superposition

an independent random variable obeying the same distribution. If missing those correction values less than 1 dB, we may only consider the middle 5 intervals with a total length of 40 m (see Fig.1). In this case the maximal distance from source to point O is 16 m, the reduction of sound level is 6 dB, so, the correction due to superposition is 1 dB. When one car appears in the middle interval of 8 m, in the other 4 intervals appears another car of the same type at the same time with a probability of $C^1_{5-1}x^2$. Let $C^1_{5-1}x^2 = 0.1$,then, x= 0.16. Inserting x=16 and t=1 in Equation (5), we obtain Q= 630 veh/h. This means that if vehicular volume reached 630 veh/h, the predicted L_{10} value must plus 1 dB due to superposition correction.Moreover, we can consider the effect due to another car which appears in the two intervals near to the middle interval of 8 m meanwhile one car arrives in it. Besides, let the probability that at least two cars of same type appear in some interval equals to 0.1, that is

$$1-\exp(-n\lambda)-n\lambda\exp(-n\lambda)= 0.1 \qquad (7)$$

we can find out λ and Q from the accumulative probability chart of Poission distribution. Seting C=1, P=0.9, we find out $n\lambda=0.53$, for t=1, Q=1900 veh/h.So, if the total volume of some vehicle class and higher classes reached 1900 veh/h, the predicted L_{10} level must plus 3 dB.
As the same method we can work out the prediction tables for L_{10} level at other speeds.

PREDICTION TABLE FOR L_{10} AND COMPARISON WITH MEASUREMENTS

The prediction table for kerbside L_{10} levels at s=30 and 40 km/h are work out through calculation (see Table 2). Comparison between predicted data from Table 2 and field measurement data taken from 12 roads of Beijing has shown that the errors fall only within 3 dBA. This proved that this simple prediction method is feasible.
When using Table 2, if some cases in different columns of the table are suitable to the situation to be predicted, one must select the maximun.

Table 2. Prediction Table for L_{10} (D_E =10m)

Vehicle classes	s=30 km/h		s=40 km/h	
	Volumes(veh/h)	L_{10} (dBA)	Volumes(veh/h)	L_{10} (dBA)
I	45-55	70-72	60-80	72
	55-70	72-74	80-100	74
	70-90	74-76	100-130	76
	90-125	76-78	130-175	78
	125-380	78-80	175-520	80
	380-630	80-82	520-860	82
	630-895	81-83	860-1225	83
	895-1900	82-84	1225-2615	84
	> 1900	83-85	> 2615	85
I+II	45-55	66-68	60-80	67-70
	55-70	68-70	80-100	69-72
	70-90	70-72	100-130	71-74
	90-125	72-74	130-175	73-76
	125-380	74-76	175-520	75-78
	380-630	76-78	520-860	77-80
	630-895	77-79	860-1225	78-81
	895-1900	78-80	1225-2615	79-82
	> 1900	79-81	> 2615	80-83
I+II+III	45-55	62-64	60-80	64-66
	55-70	64-66	80-100	66-68
	70-90	66-68	100-130	68-70
	90-125	68-70	130-175	70-72
	125-380	70-72	175-520	72-74
	380-630	72-74	520-860	74-76
	630-895	73-75	860-1225	75-77
	895-1900	74-76	1225-2615	76-78
	> 1900	75-77	> 2615	77-79
Total	45-55	56-58	60-80	57-60
	55-70	58-60	80-100	59-62
	70-90	60-62	100-130	61-64
	90-125	62-64	130-175	63-66
	125-380	64-66	175-520	65-68
	380-630	66-68	520-860	67-70
	630-895	67-69	860-1225	68-71
	895-1900	68-70	1225-2615	69-72
	> 1900	69-71	> 2615	70-73

TRAFFIC NOISE BARRIERS : A CASE STUDY ON THE INSTALLATION OF BARRIERS ON THE WESTERN ARTERIAL, BRISBANE

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ABSTRACT

The Moggill Road - Jerrang Street Section of the Western Arterial in Brisbane has been constructed through a residential area. Traffic noise barriers were included as an integral part of the design of this road facility in order to reduce the impact of traffic noise on the surrounding suburban community. The noise studies, impact assessment and design of the barriers are discussed together with the Main Roads Queensland's approach to traffic noise investigations. The assessment of the impact of the barrier is evaluated in the following manner:-

(i) the accuracy of the prediction model
(ii) the effectiveness of the barrier in reducing noise levels
(iii) the total acoustic effect of the road with barrier on the acoustic environment of the adjacent residences
(iv) the effectiveness of the barrier from the adjacent residents' point of view

The following conclusions have been drawn:-

(i) the assessment procedures are adequate for practical application
(ii) the barrier designs have been successful in that a major noise generator has been introduced into a residential area with minimal adverse noise effects
(iii) the design of the barrier appears to have been an adequate compromise between acoustic requirements and aesthetics.

1.0 INTRODUCTION

This paper describes the planning, design and construction and an evaluation of the effectiveness of a particular traffic noise barrier constructed recently. It has been provided as an integral part of the construction of a section of the Western Arterial through a residential area. Some 1500 metres of barrier were erected specifically to reduce the effect of road traffic noise on adjacent dwellings.

The objective of this paper is to provide another point on the graph of Australian road traffic noise experience.

2.0 MRD APPROACH TO TRAFFIC NOISE INVESTIGATIONS

Investigations are not carried out on every new or improved road facility. They are mainly carried out in urban areas as follows:

(a) For major facilities to determine noise level changes and to predict community responses;

(b) Where property resumptions are required, and traffic noise may be a factor taken into account in assessing compensation for injurious affection.

The L10 (18 hr) index is used to determine the degree of annoyance experienced by the residents. The DoE or CORTN method (Department of Environment, 1975) is used to predict this index and where measurements are undertaken, they are carried out in accordance with the requirements set out in Australian Standard 2702-1984.

It has been known for some time that noise impact extends below the 68 dB(A) L10 (18 hr) level commonly used as a guide for undertaking corrective action. Moreover the extent of impact at levels below 68 dB(A) has been quantified (Lassiere, 1976 and Harland, 1977). A single cut-off level ignores the very important fact of the variation in noise sensitivity of people throughout the community. It is preferred to use estimations of percentages of people "not bothered", "bothered" and "seriously bothered".

Basically the method determines by prediction, the number of residences in the surrounding suburban community exposed to traffic noise levels within given cell widths for the range of noise levels 54 dB(A) and upwards. Multiplication by the relevant noise reaction probabilities allows the determination of the most likely number of residents who will react in terms of the responses mentioned above. Summation of these numbers over all cell widths then allows the total impact to be estimated. To accomplish this analysis, it is necessary to extrapolate the predicted noise levels out beyond the first line of houses, until the predicted noise level is equal to either the existing L10 (18 hr) level or 54 dB(A), whichever is the greater. The existing or "before" levels are obtained by measurement.

For this case study, the number of residences exposed to traffic noise levels within each 5 dB(A) cell width were considered using the response data (Harland, 1977) available at the time. Response data (Lassiere, 1976) with respect to 2 dB(A) cells widths have been used more recently.

As to whether or not ameliorative measures e.g. barriers etc. should be used, MRD prefers not to be constrained by the rigidities of a fixed policy. After careful examination of the results of impact studies, a decision is taken as to whether or not ameliorative measures in the form of traffic noise barriers are to be implemented. Currently, these measures are only considered for a new road facility through a residential area and not to an improved existing facility as it is considered that the adjacent residences are already affected to some degree by traffic noise. In addition it is often difficult to physically place the barriers for best effect.

3.0 WESTERN ARTERIAL PROJECT

The Western Arterial in Brisbane is a north-south arterial located to the west of the central business area. The detailed section, from Moggill Road to Jerrang Street, is new construction on a deviation and has been built to 4 lane, divided, grade-separated, arterial standard. A typical cross-section is shown in Figure 1.

This particular link had been planned since the early 1970's. In 1978 MRD issued a brochure showing the proposed route. This issue resulted in a public meeting later that year at which local residents voiced a number of concerns, including traffic noise impacts. At that meeting an undertaking was given that the matter would be investigated and steps taken to install noise barriers if appropriate.

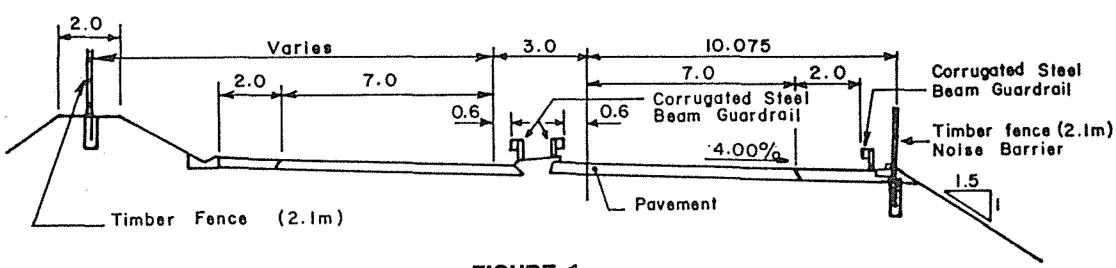


FIGURE 1

4.0 NOISE IMPACT ASSESSMENT

4.1 <u>"Before" Noise Study</u>. Eighteen hour (0600 - 2400 hours) noise level measurements were made at various locations in the study area adjacent to where the new arterial was to be constructed, in order to determine the noise climate resulting from traffic on existing streets. The defined study area extended approximately 150 metres away from the proposed construction and included some 155 dwellings. In all, 24 measurement sites were required to adequately cover the study area.

From these measurements the "before" noise levels were interpolated for each dwelling in the study area.

4.2 "After" Noise Study. "After" noise levels, both with and without barriers, were predicted at various locations (55) in the area of interest. From these both post construction/pre-barrier, and post-construction/post-barrier predicted levels were interpolated for each of the 155 dwellings.

The "before" and predicted "after" noise levels at the 155 dwellings in the study area are summarised in Table I. The results are presented in the 5 dB intervals used in the impact assessment.

TABLE I

NUMBERS OF DWELLINGS IN THE STUDY AREA EXPOSED TO EACH NOISE INTERVAL (N = 155)

Noise Interval dB(A)	"Before" Measurements	"After" Predictions	
		Without Barrier	With Barrier
50 - 54	33 (22%)	0 (0%)	10 (6%)
55 - 59	63 (41%)	26 (17%)	76 (49%)
60 - 64	54 (35%)	54 (35%)	52 (34%)
65 - 69	5 (3%)	57 (37%)	17 (11%)
70 - 74	0 (0%)	18 (12%)	0 (0%)

It can be noted that without the barrier, the predictions indicated that the noise exposures would have been increased considerably.

4.3 Impact Assessment. An assessment of the impact of the roadway was made using these measured and predicted levels. The percentages of dwellings in which residents were expected to have "seriously bothered", "bothered" and "not bothered" responses to the new source of noise are indicated below:-

(a) Without a barrier, the impact was estimated as:-

17% Seriously Bothered;
45% Bothered; and
38% Not Bothered.

(b) With a barrier design, the impact was estimated as:-

10% Seriously Bothered;
42% Bothered; and
48% Not Bothered.

In addition to this estimate of community response, it can be seen from Table I that the percentage of dwellings in the 65 - 69 and 70 - 74 dB(A) noise intervals reduced from 49% without the barrier, to only 11% with the barrier. The improvement was considered to be adequate justification for detailed design to be undertaken.

5.0 NOISE BARRIER DESIGN

Following the impact assessment, the final locations and heights of barriers were refined with the design objective being to maintain the post-construction/post-barrier acoustic conditions in the adjacent community as close as possible to the pre-construction noise climate.

The visual impact of the barrier on the adjoining suburban community and the road user was considered, leading to a choice of a timber fence, and timber fence/earth mound combination. The timber fence consisted of hardwood weather boards placed vertically. It was considered that the maximum height of a timber barrier should be 2.1 m to retain a reasonable appearance.

The total cost of the barriers was about $250,000. This consisted of 1500 m of timber fencing at a cost of $125,000 and additional earthworks for mounds at a cost of $125,000.

6.0 EVALUATION OF THE EFFECTIVENESS OF THE BARRIER

6.1 Method. The barrier, and part of the procedure used to assess the potential impact of the barrier, were evaluated in several ways:-

(a) The accuracy of the noise prediction procedure was evaluated by comparing the predicted post-construction/post-barrier noise levels with the noise levels measured in the "after" measurement program.

(b) The effectiveness of the barrier in reducing noise levels was estimated by comparing predicted noise levels to which dwellings would have been exposed if the barrier had not been built with the noise levels measured in the "after" measurement program.

(c) The total acoustic effect of the new roadway with barrier on the acoustic environment of the study area was evaluated by comparing the "before" and "after" noise level measurements.

(d) The effectiveness and other characteristics of the barrier from the point of view of nearby residents were evaluated by a resident survey.

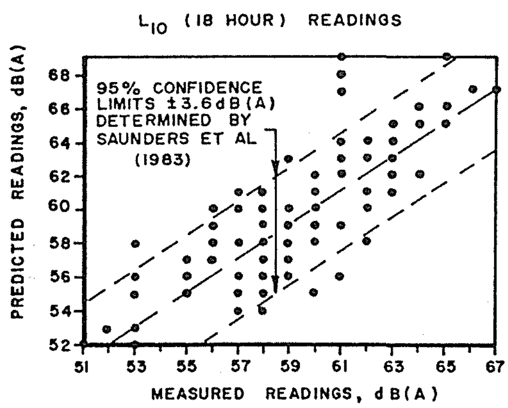
6.2 Accuracy of the Prediction Model. Figure 2 is a scatter diagram plotted for each of the 155 dwellings as follows:-

(a) Predicted. Post-construction/post-barrier predictions interpolated to each dwelling.

(b) Measured. Post-construction/post-barrier measurements interpolated to each dwelling.

Simple regression analyses were conducted on these data. The results of the analysis are tabled in a recently presented paper (Golding et al, 1986).

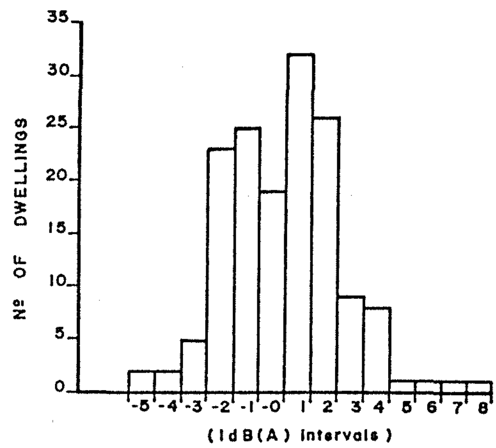
Figure 3 is a frequency distribution of the differences between the post-construction/post-barrier measurements and the predictions at each household. This distribution has a mean of 0.4 dB(A) and and a standard deviation of 2.19 dB(A). These results are similar to those of previous work (Saunders et al, 1983) i.e. the DoE model tends to overpredict marginally. The essential difference in the data in this work and that of previous work (Saunders et al, 1983), is that in this work the noise values for each location were interpolated from a small number of actual sites, while the previous work (Saunders et al, 1983) represents actual sites. Interpolation is the practical method in impact studies of this sort, and it is reassuring to see the replication of the results. As such, no confidence has been lost in the prediction methods adopted in this work.



POST CONSTR / POST BARRIER PREDICTED NOISE LEVELS PLOTTED AGAINST MEASURED LEVELS

LEVELS SHOWN ARE INTERPOLATED FOR 155 LOCATIONS IN STUDY AREA.

FIGURE 2



DIFFERENCES BETWEEN

POST CONSTR/ POST BARRIER PREDICTIONS

AND

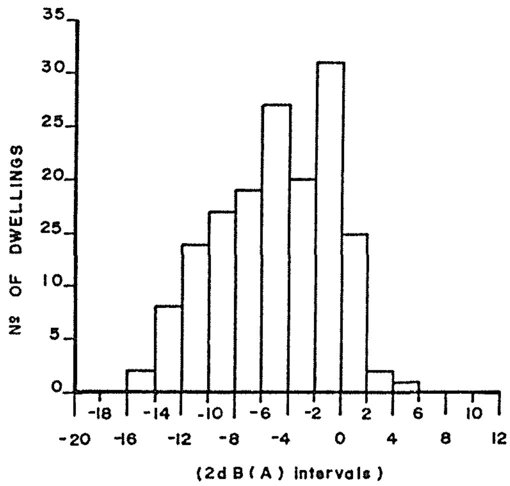
POST CONSTR./POST BARRIER MEASUREMENTS

(PREDICTION ACCURACIES)

FIGURE 3

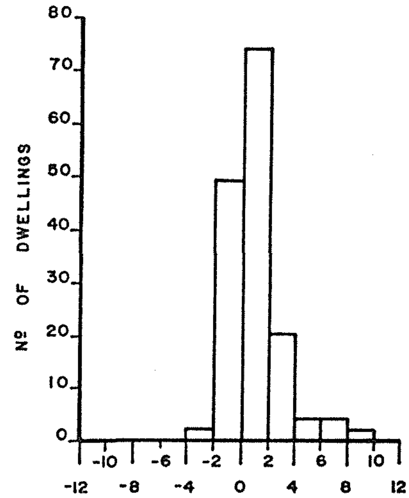
6.3 Effectiveness of Barrier. Figure 4 is a frequency distribution of the differences between post-construction/pre-barrier predictions interpolated to each dwelling, and post-construction/post-barrier measurements interpolated to each dwelling. Given the conclusion in the preceding paragraph, Figure 4 represents a substantial improvement given a barrier compared with no barrier. In making this statement, recognition needs to be given to the fact that the predictions have 95% confidence limits of ± 4.4 dB(A).

6.4 Study Area Acoustic Environment. Figure 5 is a frequency distribution of the differences between pre-construction measurements interpolated to each dwelling, and post-construction/post-barrier measurements interpolated to each dwelling. This analysis indicates that on balance, about 30 houses are worse off due to the presence of the road with barriers. The great majority, about 123, appeared to have suffered no significant change. The mean of this distribution is 0.9 dB(A) and the standard deviation is 2.0 dB(A).



DIFFERENCES BETWEEN
POST CONSTR/ PRE-BARRIER PREDICTIONS
AND
POST CONSTR/ POST BARRIER MEASUREMENTS
(BARRIER EFFECTS)
[PREDICTIONS HAVE 95% CONFIDENCE LIMITS OF ± 4.4dB(A)]

FIGURE 4



DIFFERENCES BETWEEN
PRE-CONSTR. MEASUREMENTS
AND
POST CONSTR./POST BARRIER MEASUREMENTS
(ACOUSTIC ENVIRONMENT)

FIGURE 5

6.5 Opinions of Residents. It was considered useful that the opinions of residents living in the vicinity of the facility be obtained to see if perceptions were consistent with the results of the physical studies. A survey was conducted in late 1985 and is reported in full in a recent publication (Brown, 1985). Only the main findings of this survey are reported here. The study ascertained the opinions of residents concerning the effectiveness and appearance of the noise barrier.

The study area was the same as that area for the noise measurements. The format of the study was household interview using a structured questionnaire.

The results from this resident survey can be summarised as follows:-

(a) There was widespread knowledge amongst residents (74%) that the fence had been constructed specifically to reduce noise.

(b) Majority opinion was that the fence was effective in reducing levels of road traffic noise from the Western Arterial. 62% of respondents thought that it reduced noise, 5% that it increased noise, 20% that it had no effect and 13% had no opinion or no knowledge of its effectiveness. Residents who would have been most exposed to freeway noise thought the fence effective.

(c) Resident opinion on the appearance of the fence (from the dwellings) was mixed, with half (52%) indicating that it was reasonably attractive and over one third (37%) indicating that it was reasonably unattractive.

7.0 CONCLUSIONS

This paper has outlined a practical approach to the question of noise barrier installation. Initial measurements and assessments were primarily aimed at the installation question, and not at a research undertaking. However, the results of comparative measures and the residents' survey are encouraging. The following conclusions have been drawn:-

(a) The assessment procedures are adequate for practical application;

(b) The barrier designs have been successful in that a major noise generator has been introduced into a residential area with minimal adverse noise effects;

(c) The design of the barriers appears to have been an adequate compromise between acoustic requirements and aesthetics.

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ROAD TRAFFIC NOISE REDUCTION OF DOMESTIC FACADES

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ABSTRACT

An Experimental Building was designed to facilitate the measurement of road traffic noise attenuation of different facades under field conditions. Facades tested ranged from timber stud framing with lightweight claddings through brick veneer to cavity brickwork; in addition the attenuation of the same facades containing single and double glazed windows, either closed or partially open was measured. The poor performance of brick veneer and cavity brick facades confirmed the presence of significant flanking transmission through the eaves/roof/ceiling and the final modification made was to remove the eaves and to construct a brick parapet to provide some shielding to the roof. The main conclusion reached is that the road traffic noise attenuation of typical Australian dwellings is poor and that installation of double glazing is unlikely to provide substantial improvements in attenuation because of transmission through flanking paths such as the roof/ceiling.

1.0 INTRODUCTION

Many thousands of people are adversely affected by road traffic noise when at home. Although the introduction of vehicle noise limits may eventually lead to lower road traffic noise levels, this is an extremely slow process (1). Traffic management schemes and barriers can also be helpful, but in many cases improving the attenuation of affected building facades is the only possible solution.

Since openable windows are often considered to be the main path for traffic noise transmission, an obvious method of improving attenuation is to seal the windows and to install a second window spaced some distance away to form a double window. Some other means of ventilation, such as a mechanical ventilation system or an alternative, shielded opening must then be provided. This becomes a very expensive exercise, rarely undertaken by an individual unless in receipt of assistance in the form of compensation. Unfortunately, not only are double windows expensive, but frequently the expected benefits from them are not realised.

This paper reports a major study of traffic noise attenuation by domestic-type facades and the reason for the inadequacies of typical remedial treatment is postulated. The Experimental Building used for the measurements has been previously described (2).

2.0 MEASUREMENT RESULTS

The measurement procedures are described in a companion paper (3). Although some preliminary results have been reported previously, an improved analysis system was developed as the project progressed and it was decided to re-analyse all previous measurements so that variations caused by different traffic flow rates and vehicle mixes could be eliminated. The effective traffic noise attenuation of each facade system, for an averaged traffic noise spectrum is described in terms of an A-weighted Normalised Noise Reduction (NNR). This is related to L_{10} traffic noise levels with a correction factor which allows for the sound absorption in the receiving room and the area of the facade. In other words, if the traffic noise level, $L_{10,T}$ is 70 dB(A) at 1 metre from the facade and a level, $L_{10,T}$ of 30 dB(A) is required inside a room, it would be necessary to select a facade having an NNR of 40 dB(A). Measured NNR values are shown in Table I for facades without windows and in Table II for the same facades but with different (closed) windows installed.

The first facades tested consisted of lightweight timber-framed construction, with and without single or double windows (Fig. 1); the rather low attenuation values measured were consistent with expectations. However, when the facade was changed into brick-veneer construction (Fig. 2), the expected large improvement did not occur. Since there is little or no data available regarding the sound transmission loss of brick-veneer construction, few conclusions could be drawn at this stage.

Finally, the timber frame skin was removed and a second brick skin constructed, forming a traditional cavity brickwork facade (Fig. 3). This also failed to provide a significant improvement in attenuation and it became apparent that there must be some important flanking transmission paths. In order to test this hypothesis a second layer of eaves lining was fixed, 50mm glass fibre was laid between the ceiling joists of both rooms and, in one room only (the North room) a second sheet of plasterboard was fixed to the top of the ceiling

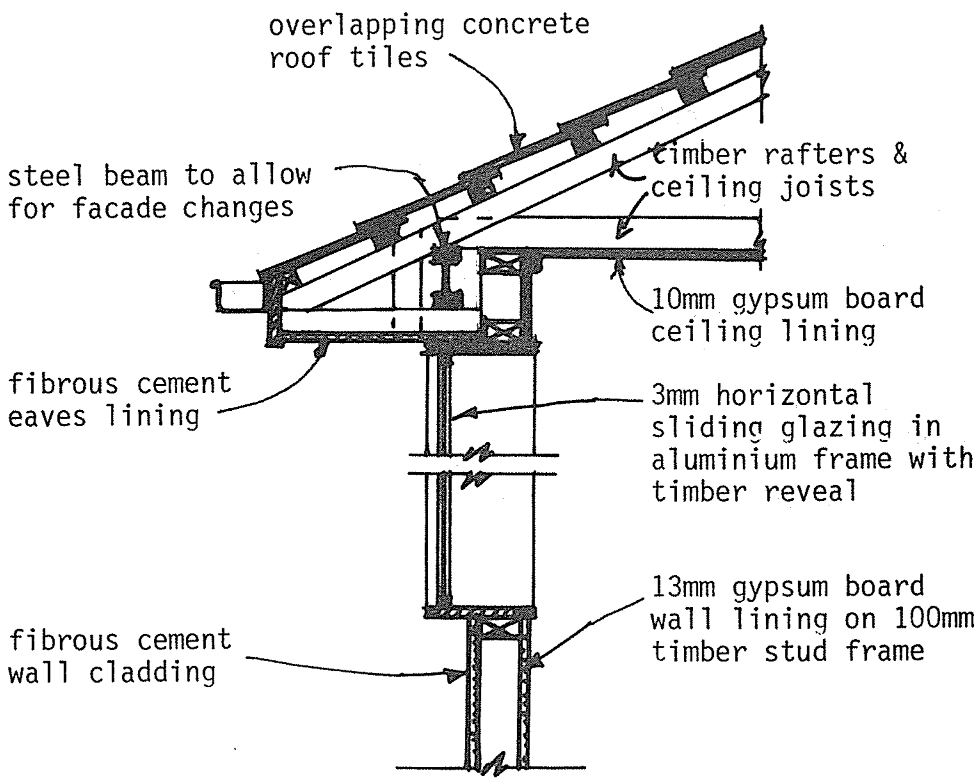

FIG.1. SINGLE GLAZED WINDOWS IN TIMBER STUD FRAME FACADE

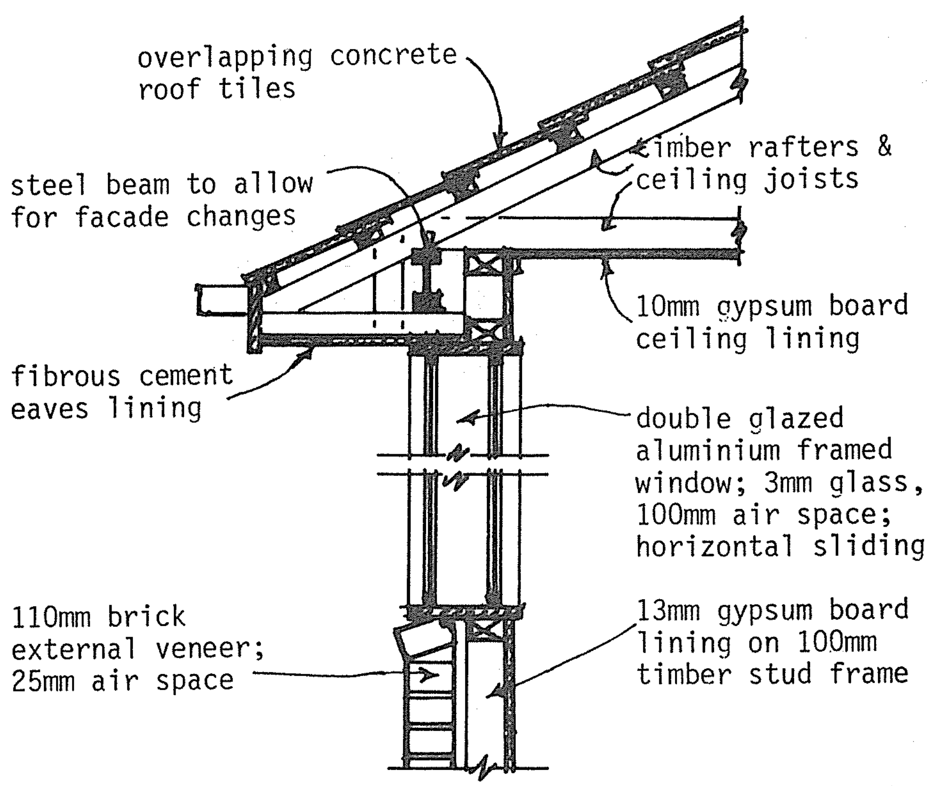

FIG.2. DOUBLE GLAZED WINDOWS IN BRICK VENEER FACADE

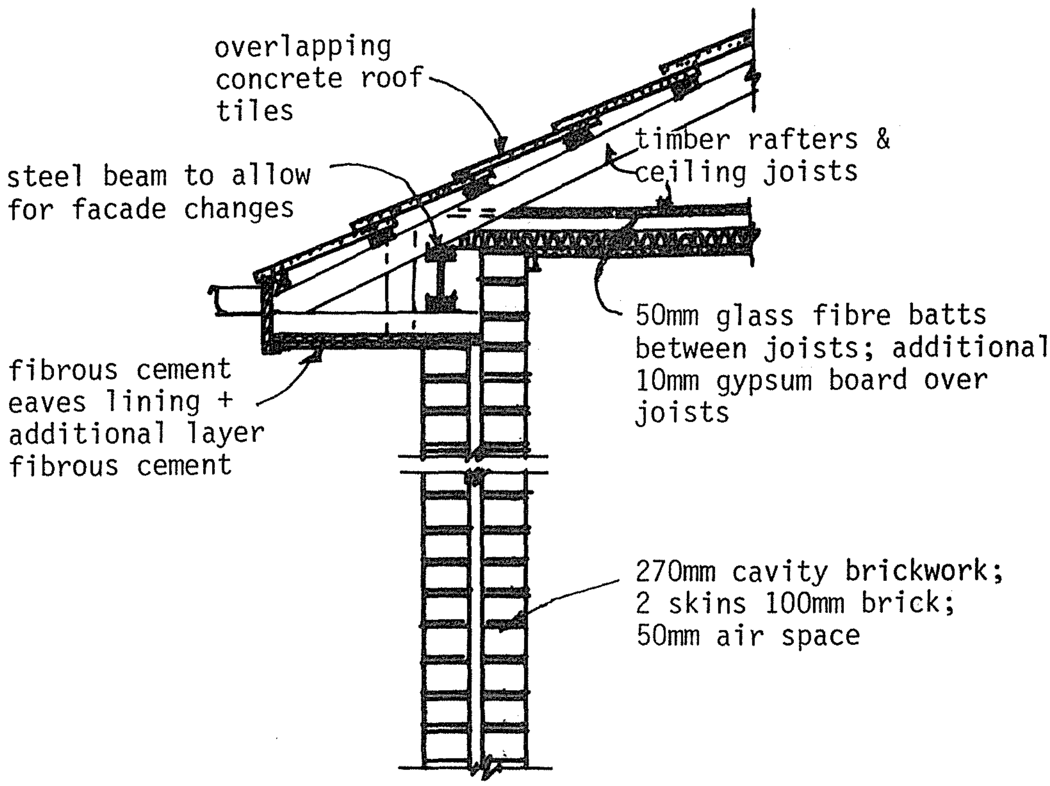

FIG.3. CAVITY BRICK FACADE WITH IMPROVED EAVES/CEILING

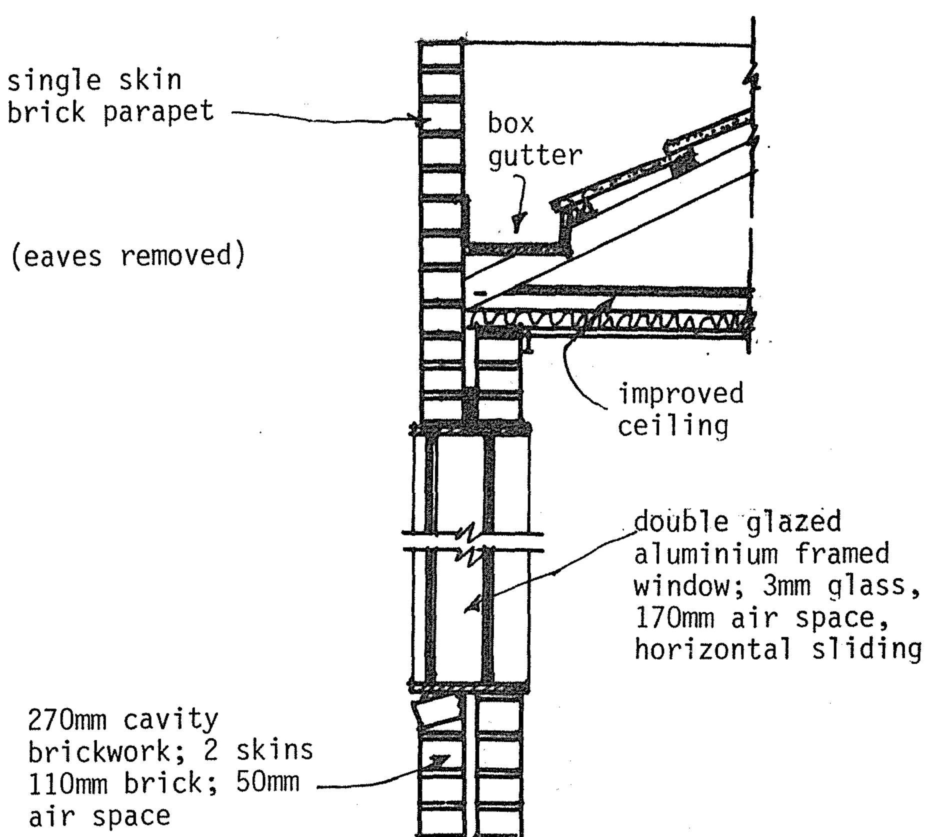

FIG.4. DOUBLE GLAZED WINDOW IN BRICK FACADE WITH PARAPET

joists. This resulted in an improvement of about 6 dB(A), to NNR 32, still much lower than would be expected from a cavity brick wall (about NNR 51 for the traffic noise spectrum used).

Finally the eaves were completely removed and a single brick parapet was constructed above the facade, returned to the side gable walls (Fig. 4). It was not possible to measure this system without windows in it, due to time constraints, but an improvement of 4 dB(A) was found, compared to the same facade system without the parapet - another indication that the roof/ceiling system should be considered when determining the overall attenuation of a building's envelope in practice.

3.0 COMPARISON OF MEASURED AND PREDICTED TRAFFIC NOISE ATTENUATION

If the sound levels inside a room due to road traffic noise are to be predicted the composite attenuation of the exposed facade(s) is normally calculated. In the Experimental Building a side wall of each room was exposed to traffic noise, as well as the facade under test. The side walls were constructed of 190mm blockwork and calculations were made using published sound transmission loss data for the various components to determine whether significant flanking sound was entering through this path.

In the case of the "best" facade with windows, consisting of cavity brickwork with wide-spaced (170mm) double windows, the predicted attenuation of the test facade only is 37 dB(A). If the side wall is included in the calculations the overall predicted attenuation is 39 dB(A), indicating that side wall flanking transmission is not a problem. However, for a cavity brick wall without any windows the inclusion of the side wall reduced the predicted traffic noise attenuation from 51 to 45 dB(A).

The highest measured attenuation of the cavity brick wall without any windows (without parapet but with improved ceiling construction) averaged only 30 dB(A), some 15 dB(A) below that predicted above, thus it is obvious that the roof/ceiling construction was a significant flanking path. There is little data available regarding the sound transmission loss of domestic roofing systems, except for some measurements reported by Cook (4). From his results, the overall attenuation for the traffic noise spectrum would be about 33 dB(A) for the roof/ceiling alone. Using these data, the predicted attenuation for the combined cavity wall, window and roof/ceiling was then calculated. The predicted attenuation was then found to be 34 dB(A), much closer to the measured values, which ranged between 29-32 dB(A).

4.0 DISCUSSION

Whereas undoubtedly openable single-glazed domestic type windows form a major path for traffic noise intrusion, simply installing a second window to form a double window is unlikely to provide a worthwhile improvement in overall attenuation if the room is immediately below a conventional tiled roof. In addition, if the main facade is of lightweight construction (e.g. timber frame) there is little point in improving the windows as the whole facade has poor attenuation.

For the brick veneer facade the addition of a second window increased the attenuation by only 2 to 3 dB(A) compared to that for single glazing. Similarly, for the cavity brick facade, the reduction in traffic noise was much less than predicted (see Table I). In these situations the attenuation provided by the eaves/roof/ceiling construction limits the overall attenuation that can be obtained.

Unfortunately, it is extremely difficult to improve the attenuation of a traditional tiled roof/ceiling system, although the installation of additional layers of fibrous cement on the eaves and gypsum plasterboard over the ceiling joists, with 50mm glass fibre between the joists did provide an additional reduction of 6 dB(A) with a cavity brick facade. Even this alteration required removal of the roofing tiles for execution.

A massive roofing system, such as suspended reinforced concrete has much better sound reduction properties, but for single-storey dwellings the cost is prohibitive and it certainly could not be a retrofit solution. For new single-storey buildings it may be possible to develop some new roofing systems, such as multi-layered wood-wool, gypsum loaded, and/or strawboard. However, there is little or no data available regarding the attenuation of such systems and more testing is required before recommendations could be made. The potential rain-noise problem associated with some alternative roofing systems, such as metal-decking, has not yet been satisfactorily solved.

5.0 CONCLUSION

It must be concluded that the simple approach to improving the acoustic environment of rooms exposed to high levels of road traffic noise, namely provision of a double window system, may not provide adequate noise reduction. The alternative path for noise transmission into the room, by the eaves/roof/ceiling construction has been found to be significant for traditional dwellings. In multistorey buildings however, this problem does not arise except for the top floor immediately under the roof. For the lower floors satisfactory noise reductions may be achieved if carefully selected double glazing systems and an alternative method of ventilation are installed. In this latter situation it should be noted that typical domestic quality aluminium framed windows are likely to degrade the overall (masonry) facade attenuation and consideration should be given to the installation of commercial quality units with heavy frames and very good seals.

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7.0 ACKNOWLEDGEMENTS

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TABLE I

TRAFFIC NOISE ATTENUATION OF DWELLING FACADES WITHOUT WINDOWS (CONCRETE TILED ROOF CONSTRUCTION)

FACADE TYPE	MEASURED NNR dB(A), AVERAGE	PREDICTED NNR dB(A)
100mm timber stud frame with 13mm gypsum plasterboard internal lining and fibrous cement external sheeting	23	24*
Brick veneer construction; 110mm external brick skin; 100mm timber frame and 13mm gypsum plasterboard internal lining	26	
Cavity brick construction; two skins of 110mm brickwork; 50mm air space	26	51* 45**
Cavity brick construction as above; extra lining to eaves; 50mm glass fibre between ceiling joists; extra plasterboard lining over ceiling joists	32	

* facade attenuation only considered

** blockwork side wall attenuation included

TABLE II

TRAFFIC NOISE ATTENUATION OF DWELLING FACADES WITH WINDOWS (CONCRETE TILED ROOF CONSTRUCTION)

FACADE TYPE	WINDOWS	MEASURED NNR dB(A), AVERAGE	PREDICTED NNR dB(A)	
100mm timber stud frame as in Table I	Single, 3mm glass	21		
	Double, 3mm glass, 50mm air space, 3mm glass	23		
	Double,3mm glass, 100mm air space, 3mm glass	23		
	Double, 3mm glass,100mm air space, 6mm glass	24		
Brick veneer as in Table I	Single, 3mm glass	23		
	Single, 6mm glass	23		
	Double, 3mm glass, 100mm air space, 3mm glass	25		
	Double, 3mm glass, 190mm air space, 3mm glass	26		
Cavity brickwork as in Table I (improved eaves & ceiling)	Double, 3mm glass, 180mm air space, 3mm glass	30	37*	34**
Cavity brickwork as in Table I (improved eaves & ceiling & with parapet)	Double, 3mm glass, 170mm air space, 3mm glass	34		

* facade attenuation only considered

** roof ceiling attenuation included

ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES FOR AIRCRAFT NOISE AND SONIC BOOM - CURRENT STATUS AND FUTURE NEEDS

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ABSTRACT

The environmental impact of airport noise continues to be a significant problem for airport operators, airlines, and land use planners. This is due, in part, to the increasing growth in commercial air traffic and the tendency for land around airports to become more heavily utilized, frequently for residential purposes. The current state of the art in airport noise prediction, impact assessment, and monitoring is reviewed and future needs considered. Emphasis is placed on situations, such as those involving low daily aircraft traffic, where current airport noise impact assessment methods need improvement. A similar overview is provided for military training activity of supersonic fighter aircraft. In this case, classical sonic boom prediction models for uniform, level flight must be replaced with statistical models to account for the complex flight paths of those aircraft engaged in air combat training. Structural responses, both damaging and simply annoying, to sonic boom are also considered.

1.0 INTRODUCTION

Effective methods to combat the environmental impact of noise around commercial airports include control of noise at the aircraft source, control of aircraft in flight to effect practical noise reduction along the sound propagation path, and promotion or implementation of several measures related to achieving environmental compatibility at the receiver—i.e., land use controls. Key factors in this source-path-receiver model that relate to airport noise assessment are considered first in this paper. A similar overview is presented for the environmental impact of sonic boom around air combat training areas.

2.0 AIRPORT NOISE IMPACT ASSESSMENT

2.1 Airport Noise Assessment at the Source. In 1958, when commercial jet aircraft began operation in the United States, the Federal Aviation Act was passed by the U.S. Congress mandating creation of the Federal Aviation Administration. In addition to regulating and fostering the safe development of a new and rapidly growing means of transportation, the FAA also began to respond to one of the stipulations of the initial enabling law: "Protection of persons and property on the ground." The result was the promulgation, in 1969, of the first noise certification rules to be imposed on airplane manufacturers. In the same year, the International Civil Aviation Organization (ICAO), established equivalent regulations in Annex 16. The noise emission limits specified in this annex for newly certificated aircraft were adopted by Australia in 1978 (Evenett). These FAA and ICAO noise certification rules have been continually upgraded since their first release to keep in step with, and help motivate, the development of quieter (and more fuel-efficient) aircraft engines. This trend is illustrated in the following table.

Table 1. Noise Certification Levels of Jet Air Carrier Aircraft Relative to Limits in Chapter 2, Annex 16, ICAO or FAR Part 36, Stage 2. (Relative EPNdB)

Stage in Noise Certification	Takeoff	Sideline	Approach
Before 1969	-2 to 17	0 to 4	2 to 15
1969-1975, Chapter 2, ICAO Annex 16	0	0	0
1976-1985, Chapter 3, ICAO Annex 16	-3 to -7	-6	-4
Future Potential	-6 to -14	-12	-8

This table shows the very significant decrease that has been achieved over the last 17 years in jet aircraft noise levels. Before noise certification rules were effective, the early generation aircraft produced noise levels that were as much as 17 dB above the initial noise certification limits specified by Chapter 2 of ICAO's Annex 16 and by the equivalent Stage 2 limits of FAA's Part 36. The latest certification limits (Chapter 3, ICAO Annex or FAA's Stage 3) have effected an additional 3 to 7 dB reduction, and as indicated in Table 1, the technology probably exists to achieve another 3 to 7 dB reduction. However, it remains to be shown that any such further reduction would be economically practical.

The net result of this source noise reduction has been a gradual shrinking of typical single takeoff and landing noise footprint contours. Counteracting this trend in reduced aircraft noise source levels has been the continuing increase in passenger enplanements—mitigated in part by the increase in passenger capacity of the wide-body jets. The net results of all these factors, projected into the future for all airports in the United States, is shown in Figure 1. This figure indicates the estimated number of people expected to be "seriously affected," according to the airport noise community reaction model of Bullen and Hede, for a conservative projection of airport noise impact for all U.S. airports carried out in 1979 (Bartel and Sutherland). The prediction is based on applying a cubic curve fit to the relationship presented in Bullen and Hede between this reaction metric and Day-Night Average Sound Level (DNL) since DNL was the noise metric employed in the airport noise impact forecast study. Figure 1 also shows the projected number of passenger enplanements based on the one conservative forecast model illustrated here. While it must be recognized that the numbers shown in Figure 1 are totals for the entire U.S., they indicate two significant trends.

- The total number of people "seriously affected" on any average day appears to have dropped slightly over the last 10 years but, within the accuracy of the projection model, no further marked decrease is anticipated by the year 2000. One observer (Wesler) has recently suggested the more optimistic view that by the year 2000, the number of people impacted around U.S. airports would drop to about 25% of today's levels.
- The number of daily passenger enplanements is expected to steadily increase without a corresponding increase in number of people impacted by the noise. This reflects the gradual quieting of the air carrier fleet as the noisier aircraft are retired, and the growth in passenger capacity of the newer aircraft.

It is interesting to note that the magnitude of these two quantities—one a measure of the environmentally-negative aspect, or disbenefit, of air transportation, and the other a measure of the benefit—are comparable with their benefit/disbenefit ratio (Richards and Ollerhead) expected to continue to grow. However, it is important to recognize that for individual airports this ratio can vary widely, from a value of much less than one (e.g., Dallas/Ft. Worth Airport) where the impacted population is small and the passenger traffic is high, to the other extreme, where population impacted is large and traffic is relatively low (e.g., LaGuardia Airport or Sydney, Australia (Hede and Bullen)).

Some airports in the U.S. are proposing to improve their own noise environments by accelerating the trend towards use of quieter aircraft. They are considering imposition of a variety of rules to exclude, either altogether or during certain hours, operations by Stage 1 (Pre-Stage 2) aircraft and to set a deadline, such as 1995, after which only Stage 3 aircraft would be permitted to operate out of their airport. This type of airport-specific exclusion rule is being criticized by the FAA as potentially too restrictive, but some forms of aircraft exclusion rules based on FAA's noise certification levels are being allowed (Wesler).

2.2 Noise Assessment of the Sound Propagation Path. There are a few options available to an airport operator to reduce noise impact around an airport. One of these is to employ, within strict limits dictated by flight safety, practical controls on the aircraft flight path. Such controls can consist, for example, of directions to pilots to take a specific route upon departure from the airport. Automatic Radar Tracking Systems (ARTS) are in place around most large airports in the U.S., to record the actual aircraft flight paths. These records are stored on magnetic tape for a short time as a backup in case of accidents.

Recently, techniques have been worked out to allow these records of flight tracks (and associated aircraft identification) to be integrated into computerized noise monitoring systems. As a result, effective means are now available for an airport not only to measure the noise an aircraft makes when flying over a particular noise monitoring station, but to record the identification and location of the specific aircraft which made the noise. This capability has been implemented in real time in some noise monitoring systems in Europe, but in the U.S. at present, the process involves a delay of several days between the time of the flight and the time when the flight path and aircraft identification can be obtained. Nevertheless, the net result is a vastly improved ability to identify offending aircraft which violate prescribed flight path corridors selected to minimize noise impact. For example, as illustrated in Figure 2, a hypothetical vertical rectangular "gate" can be established in space which bounds permissible variations in flight paths that fall within the range expected for a nominal aircraft noise exposure on the ground. Thus, aircraft which fly outside of this "gate," increasing the noise exposure on the ground, can be flagged and appropriate action taken to motivate the offending pilot(s) or airlines (assuming flight safety has not been a factor) to keep their flight tracks within desired bounds and thus minimize noise exposure of sensitive areas. Figure 3 illustrates such a pattern by showing the general clustering of the penetrations of the desired "gate" by most flight tracks of Airline B, and the clear evidence of excessive lateral deviations from the "gate" by some flight tracks of Airline A. The latter would cause undesirable increases in noise exposure for sensitive residential areas on the ground.

There is one other aspect of noise assessment along the propagation path of aircraft noise—the natural, uncontrollable effects of weather. The changes in air-to-ground propagation loss due to changes in air absorption with the weather are relatively modest when only overall frequency-weighted levels, such as Perceived Noise Level or A-weighted noise level, are considered. Changes in air-to-ground propagation loss would rarely exceed 3 to 5 dB for PNL or 2 to 3 dB for A-weighted levels for a wide range of temperature and humidity conditions (Sutherland).

2.3 Noise Assessment at the Receiver. In the recent study of community reaction to aircraft noise in Australia, Bullen and Hede examined a wide range of noise metrics, including several variations on the PNL frequency-weighted, energy-summation index, Noise Exposure Forecast. The preferred predictor of community reaction was a modified NEF, abbreviated as ANEF (for Australian NEF). It has a uniform 6 dB penalty for flights in the evening (7:00 p.m. to 10:00 p.m.) and night (10:00 p.m. to 7:00 a.m.) instead of a 12 dB penalty for nighttime flights only as in the standard NEF metric that was employed in the U.S. in the past. (Day-Night Average Sound Level is now used in most community noise assessments in the U.S.) The deemphasis of the night penalty and incorporation of an evening penalty is also consistent with the findings of others who have studied time-of-day corrections (Ollerhead, Fields).

However, it is important to recognize that most of the studies of community response to airport noise have failed to show that any one of the cumulative energy types of noise metric is overwhelmingly preferable as a more accurate predictor of community reaction. In fact, as shown by Winer, among others, there is a strong correlation between the various energy-type metrics. One example of this strong correlation is shown in Figure 4 by the comparison between computed DNL and NEF values at three airports. Thus, any one of these noise metrics—ANEF, DNL, etc.—should provide a reasonable noise metric for evaluation of community reaction, providing one uses consistent methods for their prediction or measurement. In other words, effective application of a given noise metric is probably more important than its ultimate precision.

However, there is always room for improvement in this area. Consider, for example, one of the simpler alternate noise metrics that has not been widely applied, the Time Above (TA) metric, which defines the length of time the environmental noise under study exceeds a specified threshold. This noise metric may have particular application for evaluating aircraft noise impact on schools since it can provide a direct measure of the amount of time that speech interference occurs in a classroom. However, as shown in Figure 5, from Winer, there is a poor correlation between Leq—the 24 hour noise energy metric without time-of-day weighting—and Time Above 65 dB(A). Since the latter type of metric would seem to provide a more direct and potentially more accurate measure of speech interference, which is one of the principal bases for annoyance by aircraft noise, further research may be in order to reexamine earlier studies, if possible, or conduct new studies of community reaction using the Time Above metric to define the noise exposure.

Another issue that may have particular relevance in some airports in Australia is the uncertain validity of depending solely on an energy metric for noise assessment at airports where the number of operations is relatively low. In this case, for the same overall DNL or ANEL value, the magnitude of the single event level, as expressed for example by the maximum level, can become very high. In fact, in current work at Wyle relating to the application of residential soundproofing around airports, we have found that one can not always rely on simply reducing the indoor DNL value to a target value of 45 dB as specified in noise codes in the State of California. Instead, it has become necessary in some cases to insure that sufficient noise insulation be added to reduce the single event noise level indoors to an acceptable level. We have found that this "acceptable level" corresponds to a maximum A-weighted sound level of about 75 dB(A). It is worth noting that Hede and Bullen found some evidence in their very thorough study of community reaction to airport noise in Australia that the noise metric N70, the number of aircraft per day whose maximum noise level exceed 70 dB(A), was significantly correlated with their global measure of community response, independently of the version of NEF (i.e., NEF2 $_{0,0}$) employed in their study. Thus their study would also suggest the potential need to reconsider reliance solely on an energy-type noise metric for assessment of noise exposure around airports.

3.0 NOISE ASSESSMENT FOR SONIC BOOM IN MILITARY TRAINING AREAS

Very different problems emerge when making an environmental assessment of exposure to sonic booms generated by supersonic-capable military aircraft during air combat maneuver training exercises. There is really little correlation with the type of methods employed for airport noise assessment, and the topic is covered very briefly here simply to illustrate the contrast in environmental assessment methods. Fundamentally, the "source noise" from the sonic booms is predictable in this case only in a statistical sense. Unlike the well-defined "carpet pattern" of sonic booms laid down by supersonic aircraft during straight and level cruise flight—such as for the Concorde—air combat maneuvers involve only short random bursts of supersonic speed by the aircraft, usually occurring as they dive to gain energy for an energy-consuming maneuver or as they turn or accelerate to, or decelerate from, supersonic speeds during complex flight maneuvers. The sonic booms created by these flight patterns can now be predicted with considerable precision using variations (Plotkin) of earlier sonic boom prediction models that were developed long before the Concorde became operational. However, such predictions are only accurate when the aircraft flight track can be defined. With reasonable assumptions about the nature of typical maneuvers, it has been possible to map out a sonic boom exposure contour which includes portions of a "carpet boom" during approximately constant speed portions of a maneuver and the much smaller focus booms associated with turns or other rapid changes in the aircraft velocity vector. The area covered by just one such focus boom, as shown by Plotkin, will typically be less than 0.1 square mile. The peak pressure of the focus booms on the ground, for typical flight training altitudes, will range from about 3 to 15 pounds per square foot. The typical "carpet boom," for the same kinds of flight operations, will have an area of 5 to 35 square miles and a peak pressure of 1 to 5 psf.

To map out the cumulative environment created on the ground underneath such a supersonic training area, Galloway found that the random pattern of flight tracks could be modeled in the form of elliptically-shaped statistical distributions of the relative frequency or density of the flight tracks over a given area. Armed with this knowledge, it is possible to construct "contours" of the estimated cumulative noise exposure from sonic booms. Such a pattern is shown in Figure 6 by a small portion of the sample of random flight tracks observed in one training area by Galloway and the corresponding elliptical pattern of sonic boom levels. These contours can be assigned absolute values in terms of Day-Night Average Levels, given an estimate of the typical number of sonic booms reaching the ground for each supersonic training sortie. A recent experimental test program has shown that, on the average, about 0.04 booms per day would be experienced at any one location for every supersonic training sortie, e.g., a single entry into the supersonic combat maneuver training area by a single aircraft (Wyle). It should be noted that the noise metric used in this case to define the sonic boom environment is a C-weighted DNL. This metric has been recently standardized by the U.S. (ANSI Standard S12.4) for description of high energy impulsive sounds such as sonic booms. The C-weighting has been shown to be a more practical and valid means for measuring and assessing such sounds. There is still a strong need, however, to develop improved understanding of the way people and buildings respond to continuing exposure to such environments.

4.0 SUMMARY

A brief overview of several facets of airport noise assessment has been presented to illustrate just some of the different aspects of the problem from the viewpoint of a source, path, and receiver model. The potential need to consider alternate noise metrics was discussed. A very different approach to environmental definition was also very briefly illustrated for sonic boom exposure under supersonic air combat training areas. While suitable models are available for defining this environment, much is yet to be learned about the effects of continuing exposure to the relatively infrequent but high energy impulsive sounds involved.

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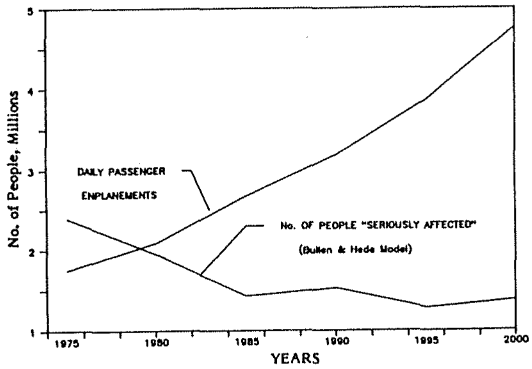

Fig. 1. Future Trends in Airport Noise Impact. People "Seriously Affected Compared to Daily Passenger Emplanements in U.S. Airports

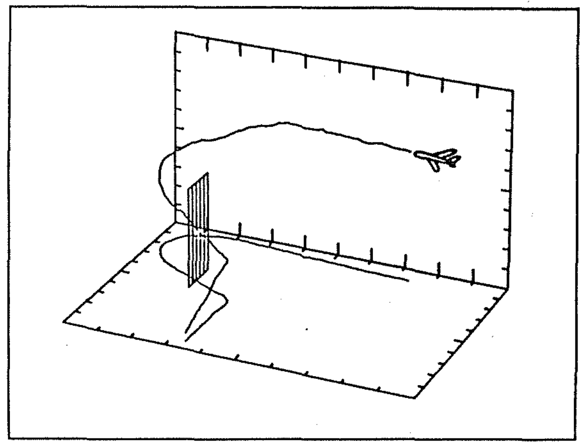

Fig. 2. Conceptual Illustration of Imaginary "Gate" for Monitoring Conformity of Flight Track to Desired Patterns

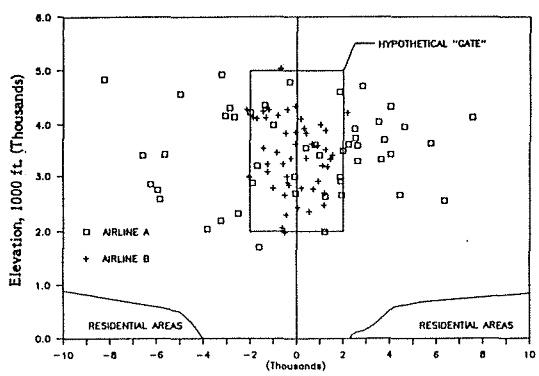

Fig. 3.: Hypothetical Pattern of Penetration of Gate by Non-Complying and Complying Aircraft.

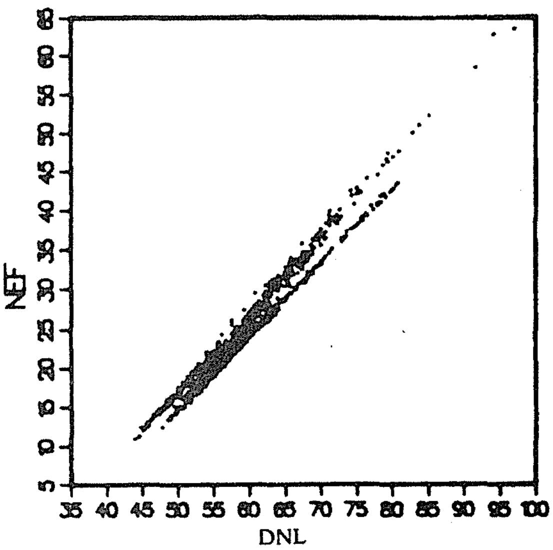

Fig. 4.: Correlation Between Day-Night Level and NEF at 3 Large Airports (Winer)

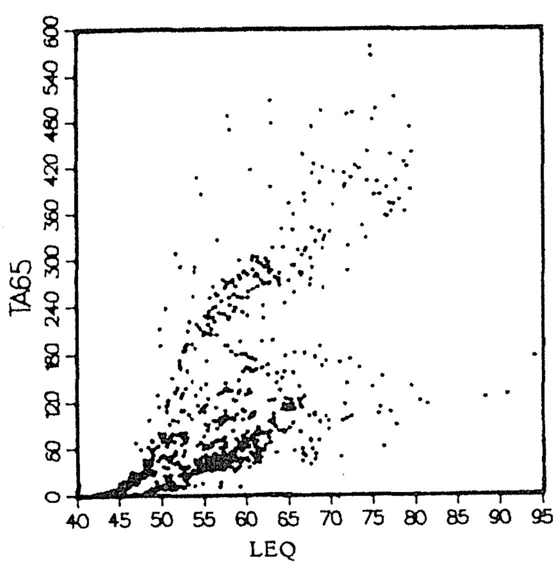

Fig. 5.: Correlation Between Leq and TA65 for Same 3 Airports (Winer)

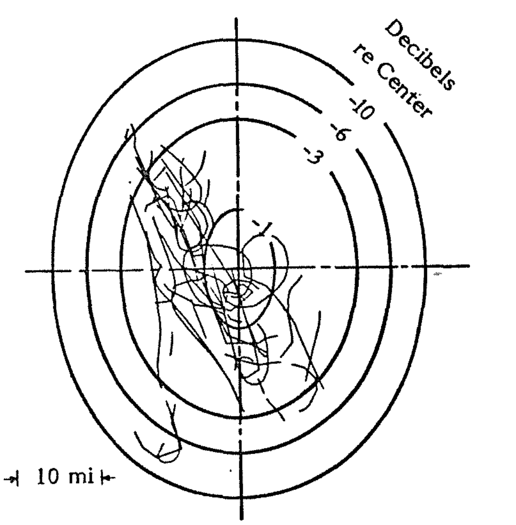

Fig. 6.: Statistically-Derived Contours for Mapping Sonic Boom Environments for Air Combat Maneuvers of F-4 Aircraft (Galloway)

PRODUCTION OF AUSTRALIAN NOISE EXPOSURE FORECASTS

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ABSTRACT

The Department of Aviation has been producing forecasts of the noise exposure of land adjacent to airports since the early 1970's. In 1982 following the publication of the results of a survey of community reaction to aircraft noise, the system was revised to the Australian Noise Exposure Forecast (ANEF).

The ANEF drawings not only detail the future noise exposure, but also the number and type of aircraft operating on each runway and includes advice on land use around the airport. Australian Standard 2021-1985 gives further guidance for planning and building in areas near airports.

1.0 INTRODUCTION

The aircraft Noise Exposure (NEF) method was first developed in the United States of America in the late 1960's. It was refined in Australia in 1982 to take account of the findings of a study conducted by National Acoustic Laboratories of the Commonwealth Department of Health. (1)

The ANEF system is a measure of the predicted noise exposure levels around airports. It is used for assessing average community response to aircraft noise and for land-use planning around airports. The noise exposure levels are calculated in Australian Noise Exposure Forecast (ANEF) units, which take account of:

(a) the intensity, duration, tonal content and spectrum of audible frequencies of the noise of aircraft take-offs, landings and reverse thrust after landing. (For practical reasons, noise generated on the airport from aircraft taxying movements, and engine running during ground maintenance are not included);

(b) the forecast frequency of aircraft types and movements on the various runways and flight paths; and

(c) the average daily distribution of aircraft take-off and landing movements in both daytime and night-time hours, (daytime defined as 7 a.m. to 7 p.m. night-time as 7 p.m. to 7 a.m.).

ANEF charts are produced by the Department of Aviation or Department of Defence for most airports throughout Australia. The charts are maps of the airport and the surrounding localities on which noise exposure contours of 20, 25, 30, 35 and 40 ANEF units have been drawn. These four contours define land areas around the airport which are affected by aircraft noise, the higher units denoting higher noise exposure.

2.0 METHOD

The contours are produced by a computer program used by both Departments. This Fortran program, Integrated Noise Model, Version 3 was written for the U.S. Federal Aviation Administration and is a public access program. (2)

The data base as supplied covers sixty six aircraft types. It consists of a series of noise versus distance curves at various engine thrust levels. The noise curves are in Effective Perceived Noise Level (EPNL) and Sound Exposure Level (SEL). Each aircraft is associated with an aircraft category, a set of departure profiles for each available trip length and a set of approach parameters. The data base has been supplemented by five extra aircraft types which are, or soon will be flying in Australia, but which were not included in the original data base.

The ANEF formula is given in Appendix 1. The size and shape of the contours are dependent on the following inputs;

(a) the forecast number of movements and also the proportion at night, night movements are weighted by a factor of 4;

(b) the aircraft types;

(c) the proportion of aircraft assigned to each runway; and

(d) the flight tracks to which the aircraft are assigned.

Forecasting is a difficult craft in as dynamic an industry as aviation. The longer we look into the future the more uncertain we are, however because of the logarithmic nature of the ANEF formula, errors of 20% in the forecast make less than one unit difference to the contours on the ground.

The aircraft types used for production of the ANEF can make an appreciable difference to the contours. Figure 1 illustrates a single event contour for a first generation Boeing 707 and for a modern Boeing 767. Both aircraft can carry over 200 passengers but the 767 has the advantage of modern quiet high bypass ratio engines.

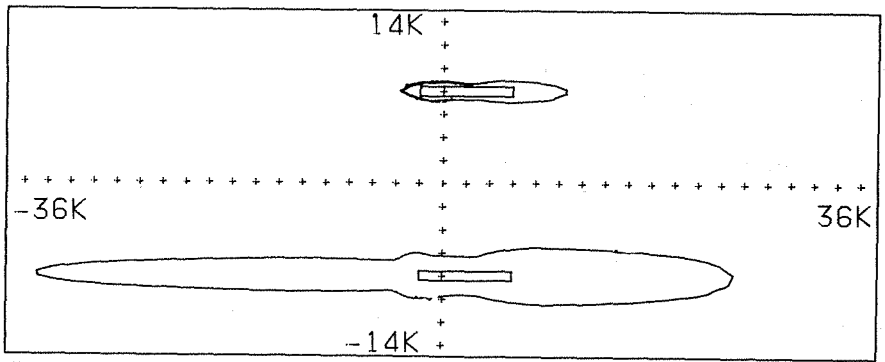
Both the proportion of aircraft assigned to each runway and the flight tracks also affect the shape of the ANEF contours. Figure 2 shows the tracks used for recent work for Melbourne Airport. The master planning of Melbourne Airport is presently being undertaken within the Department. Melbourne Airport will eventually require additional runways and the location of these runways has significant implications on regional planning around Melbourne Airport.

3.0 RESULTS

Australian Noise Exposure Forecast drawings are available for some sixty airports throughout Australia. When completed they are forwarded to the appropriate State and Local Government authorities to assist them in land-use planning.

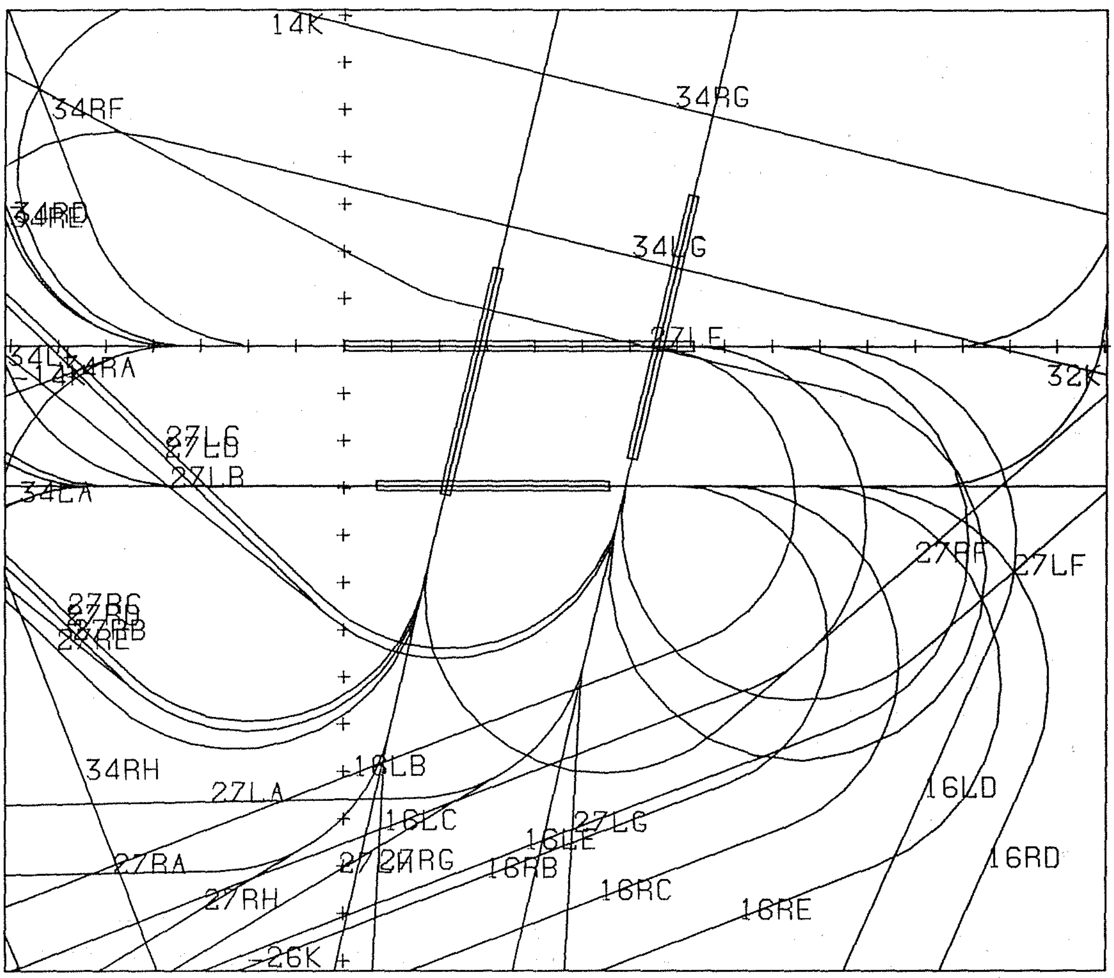
4.0 DISCUSSION

The Australian Standards Association has produced Australian Standard 2021-1985 'ACOUSTICS - AIRCRAFT NOISE INTRUSION -BUILDING SITING AND CONSTRUCTION'. (3) This publication assists organisations and others associated with urban and regional planning and building production on the location and construction of new buildings and on the acoustical adequacy of existing buildings in areas near airports.



FAA INTEGRATED NOISE MODEL VERSION 3
B707 & B767 SINGLE EVENT
CONTOUR 100 EPNL 1:200000

FIGURE 1



FAA INTEGRATED NOISE MODEL VERSION 3
ML PMP SW 2 ANEC V167
MELBOURNE 1:100000

FIGURE 2

The ANEF drawings produced by the Department of Aviation include the Land Use Compatibility Table (figure 3) which is similar to the table in AS 2021. The Standard also includes tables of aircraft noise in dBA versus distance from runway. Appendix 2 is a worked example of this procedure.

5.0 CONCLUSIONS

Planning for living around airports is a difficult exercise. To be successful it needs the assistance of three levels of government and also private companies and individuals. The Department of Aviation produces forecasts of future conditions which will help town planners. The Standards Association of Australia has produced AS 2021 to assist in design of appropriate buildings in areas where aircraft noise is a problem. It is hoped that this will assist State, Local Governments and private industry in avoiding town planning problems which have occurred in the past.

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APPENDIX 1 ANEF FORMULA

If the flight path of an aircraft is known, the average noise level at any point along and to the side of the flight path can be determined with accuracy. If the aircraft flies an operation on the same flight path Nday times in day-time hours and Nnite times in evening/night-time hours, the partial ANEF value due to that aircraft type on that particular flight path can be calculated from the formula:

$$ANEF_{ij} = EPNdb_{ij} + 10 \log (Nday + 4\ Nnite) - 88$$

where $ANEF_{i}j$ = noise exposure due to aircraft type i on flight path j.

$EPNdB_{ij}$ = noise level of aircraft type i on flight path path j.

Nday/Nnite = number of flights during the day and night respectively, of aircraft type i on flight path j.

LAND USE COMPATIBILITY TABLE

Building type	ANEF zones		
	Acceptable	Conditional	Unacceptable
Houses, home units, flats	Less than 20 ANEF (Note 1)	20 to 25 ANEF (Note 2)	Greater than 25 ANEF
Hotels, motels, hostels	Less than 25 ANEF	25 to 30 ANEF (Note 3)	Greater than 30 ANEF
Schools, universities	Less than 20 ANEF (Note 1)	20 to 25 ANEF (Note 3)	Greater than 25 ANEF
Hospitals, nursing homes	Less than 20 ANEF (Note 1)	20 to 25 ANEF (Note 3)	Greater than 25 ANEF
Public buildings	Less than 20 ANEF (Note 1)	20 to 30 ANEF (Note 3)	Greater than 30 ANEF
Commercial buildings	Less than 25 ANEF	25 to 35 ANEF (Note 3 & 4)	Greater than 35 ANEF
Light industrial buildings	Less than 30 ANEF	30 to 40 ANEF	Greater than 40 ANEF
Heavy industrial building	Acceptable in all ANEF zones		

NOTES ON BUILDING SITE ACCEPTABILITY:

1. The actual location of the 20 ANEF contour is difficult to define accurately, mainly because of variation in aircraft flight paths.

2. Within 20 ANEF to 25 ANEF, some people may find that the land is not compatible with residential use. Land use authorities may consider that the incorporation of noise control features in the construction of residences is appropriate.

3. An analysis of building noise reduction requirements by an acoustic consultant should be made and any necessary noise control features included in the design of the building.

4. Buildings containing offices, workshops, laboratories should have acoustic treatment appropriate for the relevant ANEF zone.

FIGURE 3

APPENDIX 2 EXAMPLE OF USE OF AS 2021

The first step for a developer or builder who is planning a project near an airport or adjacent to a flight path is to obtain a copy of the ANEF drawing for the airport. These can be obtained from the regional office of the Department of Aviation or from the Department of Defence in the case of military or joint user airports. The procedure of AS2021 should then be followed.

Let us assume that we wish to develop a house on Commonwealth property near the Endeavour Migrant Hostel in Sydney. We obtain from the Sydney Regional Office of the Department of Aviation a copy of the Sydney (Kingsford-Smith) Airport 1990 ANEF, drawing SS-4751. The Building site is marked up on the drawing and found to be between the 20 and 25 ANEF contours. In this area the incorporation of noise control features in the construction of residences is appropriate.

Landing Aircraft. The appropriate runway in this case is the east west runway at Sydney. We first need to determine the distance of the building site from the end of the runway (DL) and also the offset to the side of the landing path of the aircraft (DS).

The DL distance is 5100 metres
and the DS distance is 950 metres.

The height of the building site above sea level is 33m and the height of the nearest end of the runway is 6m. From Table 3.2 of AS 2021 we determine that the correction to DL is 500m, to be subtracted. The resultant DL is 4600m. From the Table of Forecast Daily number of movements on each runway we can determine the aircraft types and from the tables (3-4 to 3-19) of AS2021 we can determine the corresponding noise levels.

Aircraft types	Landing Noise Levels(dBA)	Table
F28	68	3.9
B747	72	3.7
B737	68	3.9
B727	70	3.5
DC9	71	3.13

Aircraft Take-offs. For take-offs the procedure is more complicated; the distance to the take-off end of the runway (DT) is 7625 metres and following the procedure of para 3.1.3 (d) of AS 2021, DST distance is 350 metres. The correction for height is:

(1) 160m for Domestic jet aircraft;
(2) 200m for International jet aircraft; and
(3) 290m for Domestic propeller-driven aircraft.

The corresponding DT and noise levels for take-off are:

Aircraft types	DT(m)	Take-off Noise Levels(dBA)	Table
F28	7465	82	3.8
B747	7425	81	3.6
B737	7465	82	3.8
B727	7465	88	3.4
DC9	7465	86	3.12

The noisiest aircraft in this case is a B727 take-off which is predicted to occur less than twice a day.

If we look at Table 3.3 of AS 2021 we see that the design level for relaxing or sleeping is 50dBA. However B727 movements are not allowed, except in emergencies or very exceptional circumstances to operate during the curfew from 11 pm to 6 am at Sydney airport. It is also unlikely that the east-west runway would be used. It might therefore be decided that 60dBA should be the design level.

We therefore need to design the building so that the aircraft noise reduction (ANR) is 28dBA (88-60). To achieve this, the building envelope, consisting of the roof and the exterior walls, doors and windows must be capable of reducing the outdoor noise by 28dBA.

Living room design. Let us assume that the living room is 4.5 metres x 4 metres with an external door and window. The building is a single storey building with a ceiling height of 3 metres with details as follows.

Components	Dimensions(m)
ceiling	4.5 x 4
external wall (one only)	4.5 x 3 - area of window
windows	2 x 1
external door	0.85 x 2.4

The aircraft noise attenuation (ANA) of each component is given by

$$ANA_c = ANR + 10 \log_{10} (S_c/S_f \times 3/h \times 2TN)$$

where S_c/S_f = area ratio of the component
h = height of room in metres (3m)
T = reverberation time of room in secs (0.5 secs)
N = number of components

ANA ceiling = 34
ANA wall = 31.2
ANA window = 24.5
ANA door = 24.5

The sound transmission data for various building components is given as Sound Transmission Co-efficients (STC) where STC = ANA + 5.

THE NOISE IMPACT OF FREIGHT TRAIN MOVEMENTS ON RESIDENTIAL COMMUNITIES IN WESTERN AUSTRALIA

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ABSTRACT

Railway operations share with other forms of transportation the characteristic of emitting high sound pressure levels, and any increase in operations can be expected to have an adverse effect on surrounding residential areas.

Measurements of pass-by noise levels were made adjacent to the railway line in the Leda/Wellard area in order to determine the possible noise impact of freight train operations on future residential developments at Kwinana townsite, Western Australia.

Measured time histories are compared with a prediction method recommended in "A Guide to Measurement and Prediction of the Equivalent Continuous Sound Level L_{eq}", a report commissioned by the United Kingdom Noise Advisory Council in 1978. This method incorporates various parameters including:

. The total length of the train.
. The train speed.
. The number of movements of each type of train in a reference time period.
. The maximum sound pressure level recorded at a reference distance.

Recommendations are given for the extent of noise buffer zones adjacent to the narrow gauge railway line for line-of-sight locations and when the track runs in a cutting.

1.0 INTRODUCTION

In order to prevent noise induced annoyance occuring in a proposed new residential development at Kwinana townsite in the Leda/Wellard area, measurements of pass-by noise levels of different types of freight trains were carried out alongside the narrow gauge railway line. The investigation was carried out on behalf of the Town Planning Department of Western Australia to establish suitable noise buffer zones as part of "A Planning Strategy for the South West Corridor".

Freight trains haul bauxite ore from the Jarrahdale mine site in the Darling Range 51 km through Mundijong along a 1 156 mm narrow gauge railway line to the Alcoa alumina refinery at Kwinana. About 10 000 tonnes of bauxite are railed along the line each week by the Western Australian Government Railways (Westrail). Bauxite trains are drawn by 'N' class diesel locomotives (6 000 gross tonnes) and the longest trains are up to 900 m in length and comprise a double header with 64 wagons. Other freight trains using the line have wagons for caustic soda (used in the digestion of alumina) and coal for supplying power to the refinery.

2.0 METHOD

2.1 Measurement Sites. Measurements were made of pass-by noise levels at a location adjacent to the railway line at a distance of 2.3 km along Millar Road after the turn-off from Mandurah Road. The microphone was 1.2 m above the ground and 17.5 m from the centre of the set of tracks. The railway line was at a slight gradient and at approximately the same level as the measurement location. There was a clear line of sight to the track.

A second set of measurements was taken at a location a distance of 0.6 km along Millar Road after the turn-off from Mandurah Road. This location was at approximately 150 m from the centre of the tracks with direct line-of-sight.

A final set of measurements was taken adjacent to the railway line and at a distance of approximately 50 m from the centre of the tracks running in a 3 m high cutting. This location was 1.6 km along Millar Road after the turn-off from Mandurah Road. The relative distances of these measurement locations from the railway line are illustrated in Figure 1.

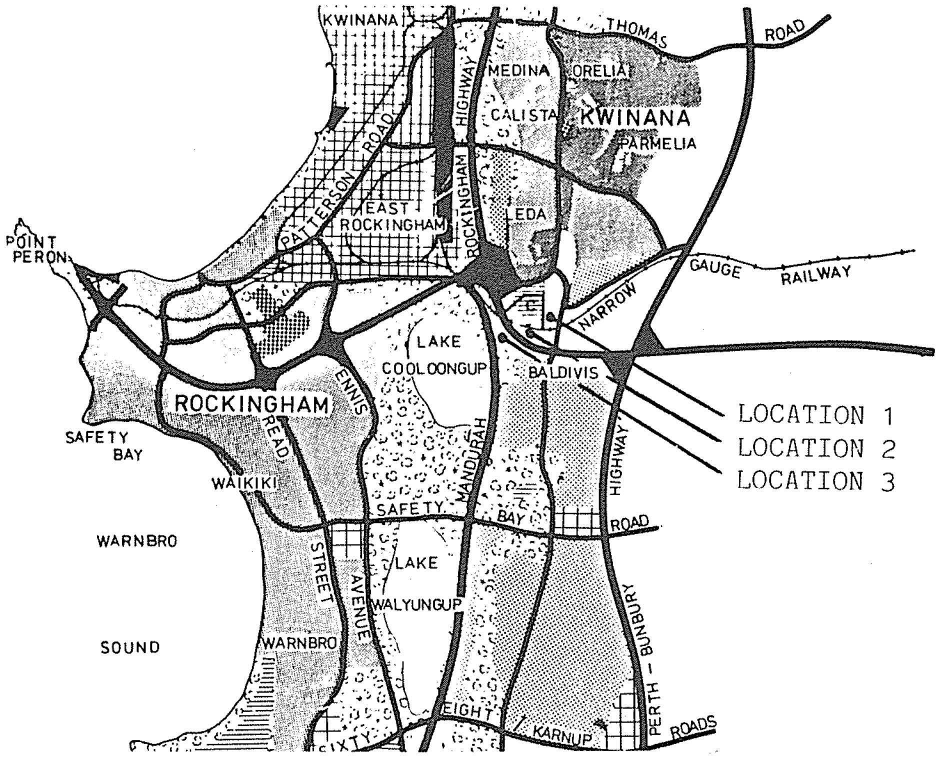

Figure 1. Measurement locations adjacent to the railway line.

2.2 Measurement Procedure. The noise levels from the train pass-bys were recorded on Bruel and Kjaer Level Recorder Type 2306 in conjunction with Bruel and Kjaer Type 2206 precision sound level meter. At the same time, single event noise exposure levels (L_{ax}) were recorded on Bruel and Kjaer Type 2218 precision integrating sound level meter. A portable sound calibrator was used to check the performance of the meters before and after measurement.

2.3 Prediction Method. The Noise Advisory Council published a report in 1978 entitled "A Guide to Measurement and Prediction of the Equivalent Continuous Sound Level, L_{eq}". The report recommended that the multiplicity of different methods used to evaluate noise from various sources be replaced by a single measure of environmental noise, namely L_{eq}. The document also describes a single event noise exposure L_{ax} and considered it to be useful for evaluating individual short-time events like railway noise.

L_{eq} for the noise at a receiver position due to railway operations over a period of time is determined using the total L_{ax} values for the different types of train in operation. The combined effect of n events each with its own single event noise exposure level L_{axi} is obtained from the expression:

$$L_{eq} = 10 \log_{10} \left[\frac{t_{ref}}{T} \sum_{i=1}^{n} 10^{L_{axi}/10} \right] \quad \text{(A-weighted levels)}$$

where T is the total time period in seconds and $t_{ref} = 1$ second. It is necessary to add the component L_{ax} values from the locomotive and the rail/wheel sources in order to derive a single total value to represent the passage of each freight train. The expression for the total L_{ax} to represent a train pass-by is:

$$L_{ax} = 10 \log_{10} \left[10^{L_{ax1}/10} + 10^{L_{ax2}/10} \right]$$

Locomotive noise is derived from a mathematical model and treated as a point source of sound with a cosine directivity pattern. An expression for L_{ax1} for the locomotive noise alone is as follows:

$$L_{ax1} = L_{amax1} + 10\log_{10} (^{d}/_{V}) + 8.6$$

where d is the perpendicular distance between the track and the receiver position (m),
V is the train speed (km/h),
L_{amax1} is the maximum A-weighted sound pressure level at the reception point.

It has been shown (Peters, Cato) that the sound pressure level/time history and hence L_{ax2} for the rail/wheel source can be predicted adequately from a mathematical model in which the sources are treated as a line of incoherent dipoles. Using this model the following expression has been derived:

$$L_{ax2} = L_{amax2} + 10\log_{10} (L_t/V) - 10\log_{10} \left[\frac{4D}{4D^2 + 1} + 2 \tan^{-1} \frac{1}{2D} \right] + 10.5$$

where L_{amax2} is the maximum A-weighted sound pressure level at a distance d from the track,
L_t is the train length,
$D = d/L_t$.

3.0 RESULTS

Measured data obtained for freight train pass-by noise levels at 17.5 m from the track are presented in Table 1. Measured values of maximum A-weighted sound pressure levels for locomotives (L_{amax1}), rail/wheel interaction (L_{amax2}) and total L_{ax} are indicated in columns 3, 4 and 5 respectively. Predicted values for L_{ax1} (locomotive), L_{ax2} (rail/wheel) and total L_{ax} are given in the last three columns of Table 1. Table 2 and Table 3 present noise level data at 150 m and 50 m from the track respectively.

Table 1: Freight train pass-by noise levels at 17.5 m

Type of freight train	Train Speed (km/h)	Measured			Predicted		
		L_{amax1}	L_{amax2}	L_{ax}	L_{ax1}	L_{ax2}	L_{ax}
Loaded:							
Bauxite. Two header 64 wagons	37	88	73	97	93	93	96
Bauxite. One header 35 wagons	32	92	74	101	98	91	99
Bauxite. One header 34 wagons	30	85	70	-	91	87	93
Caustic Soda. One header 11 wagons	47	Electric	81	90	-	92	92
Empty:							
Bauxite. Two header 64 wagons	60 64	98 94	80 81	103 100	101 97	100 98	104 100

Table 2: Freight train pass-by noise levels at 150 m

Type of freight train	Train Speed (km/h)	Measured		Predicted		
		L_{amax1}	L_{amax2}	L_{ax1}	L_{ax2}	L_{ax}
Loaded:						
Bauxite. Two header 64 wagons	37	61	50	76	69	77
Bauxite. One header 35 wagons	31	66	51	81	69	82
Empty:						
Bauxite. Two header 64 wagons	62	72	64	84	81	86

Table 3: Freight train pass-by noise levels at 50 m

Type of freight train	Train Speed (km/h)	Measured L_{amax1}	L_{amax2}
Loaded:			
Coal. One header 19 wagons	-	Electric	78
Caustic Soda. One header 12 wagons	-	Electric	78
Empty:			
Bauxite. Two header 64 wagons	62	87	76

4.0 DISCUSSION

The limited investigation of freight train pass-by noise levels at 17.5 m and 150 m from the track revealed that on average empty trains are noisier than loaded trains. Train speeds varied from 60 to 64 km/h for empty trains and 30 to 47 km/h for loaded trains with corresponding differences in maximum A-weighted sound pressure levels of 10 to 11 dB(A) for locomotive noise and 7 to 14 dB(A) for rail/wheel noise.

Empty trains hauled upgrade by a double header and comprising 64 bauxite wagons have pass-by times of up to one minute and high noise levels and would have the greatest impact on residential communities adjacent to the narrow gauge railway line.

The single header hauling 35 bauxite wagons was the noisiest of the loaded freight trains by approximately 4 dB(A) while the freight trains (caustic soda and coal) drawn by electrical power units were the quietest.

Predicted total L_{ax} levels for freight train movements using the Noise Advisory Council method were generally within 2 dB(A) of measured values taken at 17.5 m.

For railway noise, surveys have shown (Fields) that the 24 hour L_{eq} dB(A) level gives a slightly better correlation with the degree of annoyance than do other noise scales.

The tolerable criterion relates to an L_{eq} range of 60-65 dB(A), producing sporadic to widespread complaints, with 40% of the population highly annoyed. The clearly acceptable criterion relates to an L_{eq} range of 50-55 dB(A), producing no public reaction to the possibility of sporadic complaints with 20% of the population highly annoyed. A more satisfactory situation which could be regarded as a long-term goal has been set at 55 dB(A) L_{eq} for further comparisons.

A daytime L_{eq} (7.00 a.m. - 11.00 p.m.) due to freight train operations at 17.5 m and 150 m from the track was determined using individual L_{ax} values for the different types of train. A daytime L_{eq} of 67 dB(A) was estimated at 17.5 m. A tolerable criterion relates to an L_{eq} range of 60-65 dB(A) and a level of 67 dB(A) may be regarded as being undesirable but not necessarily the limit of acceptability. Steps would be necessary to reduce the noise impact.

A daytime L_{eq} of 55 dB(A) was estimated at 150 m which can be considered acceptable for the types of freight trains operating with clear line of sight to the track.

5.0 CONCLUSION

The investigation verified that the main sources of sustained freight train noise are the propulsion system and the interaction between the wheels and the rails. Noise from the propulsion system increased as the motive power demand increased and relatively high noise levels occured as empty trains moved up the gradient at higher speeds. Wheel-rail noise increased rapidly with speed.

The Noise Advisory Council prediction method can be considered reliable for predicting A-weighted single event noise exposure levels, and hence L_{eq} for freight trains for any combination of speed, train length, and distance from the track.

Where the L_{eq} level measured between 7.00 a.m. and 11.00 p.m. does not exceed 55 dB(A) there is unlikely to be any significant disturbance due to noise and no special precautions would need to be taken. This corresponds to separation distances of approximately 150 metres for line-of-sight locations and for various types of freight trains in operation.

Where the site noise level exceeds 55 dB(A) L_{eq} (7.00 a.m. to 11.00 p.m.) then it may be possible to take steps to reduce the level by means of a barrier such as an earthmound or substantial fence. The effectiveness of the barrier would, of course, be dependent upon the height and the length.

Where the site noise level cannot be reduced below 65 dB(A) L_{eq} (7.00 a.m. to 11.00 p.m.), similar to that existing at 17.5 m from the track, then no new noise-sensitive development should be permitted.

6.0 ACKNOWLEDGEMENT

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DEVELOPMENT OF THE RAILWAY NOISE CONTROL STRATEGY IN NEW SOUTH WALES

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ABSTRACT

This paper highlights current fundamental procedures for railway noise investigation in New South Wales which aims at formulating a long-term railway noise control strategy. The overall investigation has been planned in five main studies, starting with a worldwide literature survey and then followed by four studies which pertain to railway noise source characteristics, noise propagation, community noise and railway noise control measures. A phased railway noise reduction in New South Wales would be expected as the final result derived at the end of the investigation. The development of this investigation was originated from a departmental committee comprising representatives of the State Pollution Control Commission and the State Rail Authority.

1. INTRODUCTION

This paper describes the approach being used to develop an in-depth investigation of railway noise problems in New South Wales with a view to setting up a long-term railway noise control strategy.

2. BACKGROUND

Problems of railway noise are apparent from the increasing number of complaints of railway noise operations received by the SPCC as shown in Figure 1. This reflects public concern in noise pollution for which an effective noise control strategy is necessary. This concern may be caused by a number of factors, amongst which are:

(i) resident awareness of train noise pollution, and

(ii) increase in noise generation due to an increase in railway operation in NSW.

Unfortunately, it is rare to find published information on railway noise in Australia. Therefore, a summary of government publication [1-3] has been complied as shown in Figure 2 which strongly supports a continuing growth of the NSW railway system. Findings are briefly described as follows:

Train routes remain unchanged. Efforts are concentrated on upgrading railway lines to cater for bigger traffic flow (eg. line duplication, quadruplication).

Since 1977, the State Rail Authority (SRA) rail fleet has been expanding with

- more powerful locomotives (90 percent of the fleet are of diesel type) at the rate of 4 locos per month [5].
- extensive developments of high speed trains; the XPT service, for example, with the recorded speed of 183 km/h.
- the use of new rolling stock of bigger capacity.
- trends of using longer trains (of 40 cars or more) hauled by powerful locomotives for freight transportation.
- new/extended railway development projects are in progress aiming at expanding transport facilities, such as East Hills - Campbelltown line, Maldom - Dombarton new coal freight line.
- maintenance and construction works to support those operations.

Because of these trends, there is an immediate need for a prediction tool that can assess, predict and control the impact of railway noise as required in Environment Impact Statements received by the Commission for Section 27 approval under the Noise Control Act.

3. RAILWAY NOISE INVESTIGATION

The current development covers only the air- and structure-borne railway noise. It is proposed that the investigation be divided into five main studies starting with the literature surveys and then followed by four studies which pertain to noise sources, noise propagation, community noise surveys and railway noise control techniques. Railway noise control strategies will be derived at the end to the study by combining technical and economic feasibilities of all options with the aim of a phased reduction in railway noise. A summary of the studies is shown in Figure 3.

3.1 Literature Survey

A worldwide literature survey has been carried out to identify train noise problems and the methods to solve approaches for acceptable solutions, particularly in the field of computer modelling. Published information is available in a wide range of research areas, such as train noise characteristics and their propagation problems, community reaction toward railway noise, train noise control techniques and control cost.

3.2 Study of Railway Noise Characteristics

The objectives of this study are to establish a train noise data bank for the SPCC and to develop a technique for predicting noise levels generated by railway operations.

Noise sources will include the whole spectrum of railway activities, such as locomotive noise, wheel/rail interaction noise, audible warning signals, train noise from elevated structures, station and railway depot noise etc. One particular noise source type which requires extensive investigation work relates to the speed dependent noise sources (locomotive noise, wheel noise for example). At present analytical techniques for predicting moving train noise do not exist. Therefore, noise measurements made of an existing railway system must be used to empirically estimate noise levels. All measurement data (tapes, graphs) will be retained and will form part of the SPCC noise library. They will be analysed and all pertinent results be stored in the Commission computer system. This data will be updated with new measurements whenever they are available. For the NSW railway system, it is anticipated that approximate 200 various train noise source types need to be classified.

Computer software will be used for mathematical analysis of railway noise characteristics as well as for the prediction technique for noise sources. In general, analyses of measured data are expected to establish:

- noise source directivity,
- noise source spectra, and
- the effects of operational conditions on noise emission (eg. speed, track condition, etc)

Noise measurements can also be used to validate the train noise prediction procedure. The noise data bank can be used to assess the effectiveness of the current railway noise control strategy by comparing the time history of train noise at specified locations.

3.3 Railway Noise Propagation

The objective of this study is to develop computer software which is capable of predicting noise levels resulting from various railway operations.

Computational techniques will take into account noise levels generated by railway operations and estimate noise levels adjacent to noise source locations by allowing for attenuation with distance, topographic shielding including man-made noise barriers as well as meteorological effects. Results will be in the form of current railway noise indices such as Lmax, Leq 24-hour.

Computer software will be validated by comparing with actual measurement data until acceptable prediction schemes are achieved.

3.4 Community Noise Surveys

The purpose of this study is to establish community acceptance to railway noise. The surveys will be designed to ascertain:

(1) The importance of railway noise as a problem in NSW,

(2) Estimation of proportion of NSW residents annoyed by railway noise,

(3) Relationship between resident annoyance and railway operations, and

(4) The most suitable noise index to be used for railway noise control.

We are aware of some investigations carried out overseas on this matter, particularly in the USA, UK and Japan. However, it is noted that people in different countries may respond differently to railway noise.

It is anticipated that the following procedures will be carried out during the study:

(1) Selection of survey sample: number of locations for the test sample will be selected with the co-operation of the State Rail Authority.

(2) At each test site, the investigation will involve;

social surveys to collect response from residents,

establishing noise contours using the computer model; knowledge of the exact railway operations as supplied by the SRA. Some actual measurement at site will be required to cross check with the computer output.

The application of computer modelling will help us to obtain community acceptance data with minimum measurements and, consequently, at a low cost (approximately 1500 measurements have been made in one of the community noise survey study in England [4]).

(3) Final results from the study will be derived from standard statistical analysis. From this, noise indices will be recommended which closely relate to resident response to railway noise in NSW.

3.5 Railway Noise Control Techniques And Economics

The investigation at this stage is expected to study the feasibility of techniques for reducing railway noise impacts. The economic aspects of these techniques will also be considered. Control techniques can be broadly classified as follows:

(1) Noise emission control from the sources of railway operations,

(2) Control of noise propagation between sources and receivers such as natural topography and noise barriers,

(3) Reduction of noise intrusion at the receiver, primarily through architectural design and treatment or through proper land use and zoning.

4. STRATEGY FOR RAILWAY NOISE CONTROL

Results from the above studies will be used as a basis to develop a control strategy. It is expected that the results will show a considerable need for a phased reduction in railway noise.

5. CONCLUSION

In addition to a long-term noise control strategy for New South Wales, other benefits can also be derived from the studies:

- Comprehensive data that covers all parameters needed for the prediction of noise levels generated by a railway system in operation.

- Development of a computer model which will then be capable of predicting noise levels over a specified area resulting from various railway operational conditions.

- By combining the social survey information (reaction of residents), computing results (noise contours resulting from railway operations) and noise measurements (random data for cross-checking computer outputs), the investigation is expected to show the extent of annoyance to train noise at different noise levels and provide information which can be used as noise control criteria. "Acceptable levels" for railway noise will then be confirmed.

With these facilities, the Commission will be in a good position to provide the community objective advice on railway noise.

ACKNOWLEDGEMENTS

The author wishes to thank the State Pollution Control Commission for permission to publish this paper.

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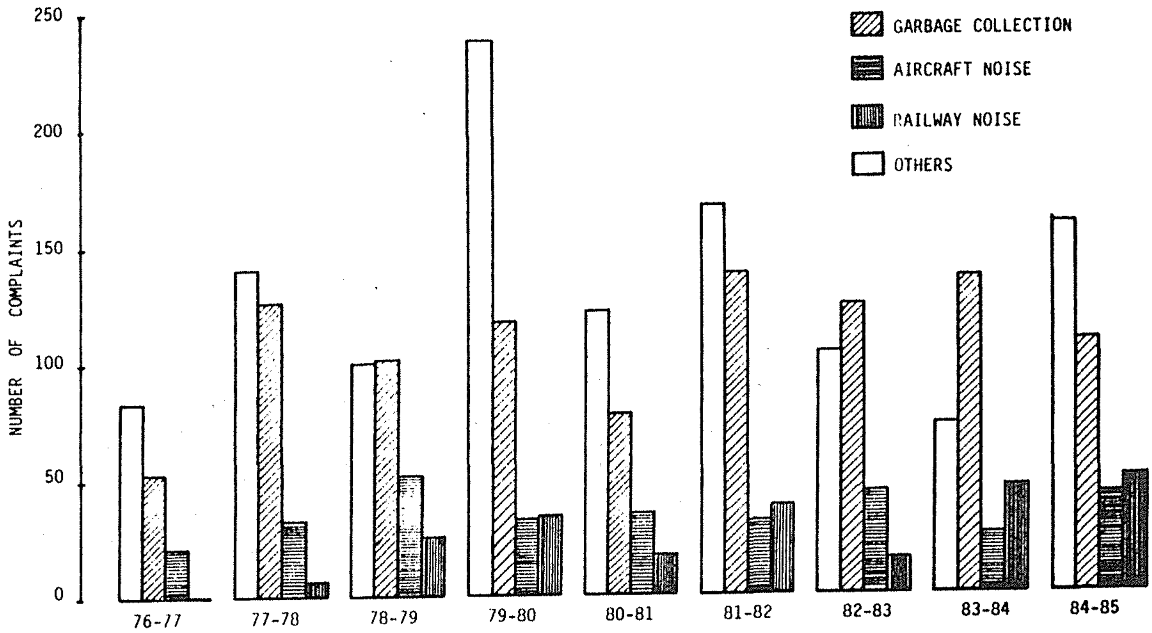

Figure 1. SPCC NOISE COMPLAINT STATISTICS - TRAFFIC NOISE IN/FROM PUBLIC PLACES

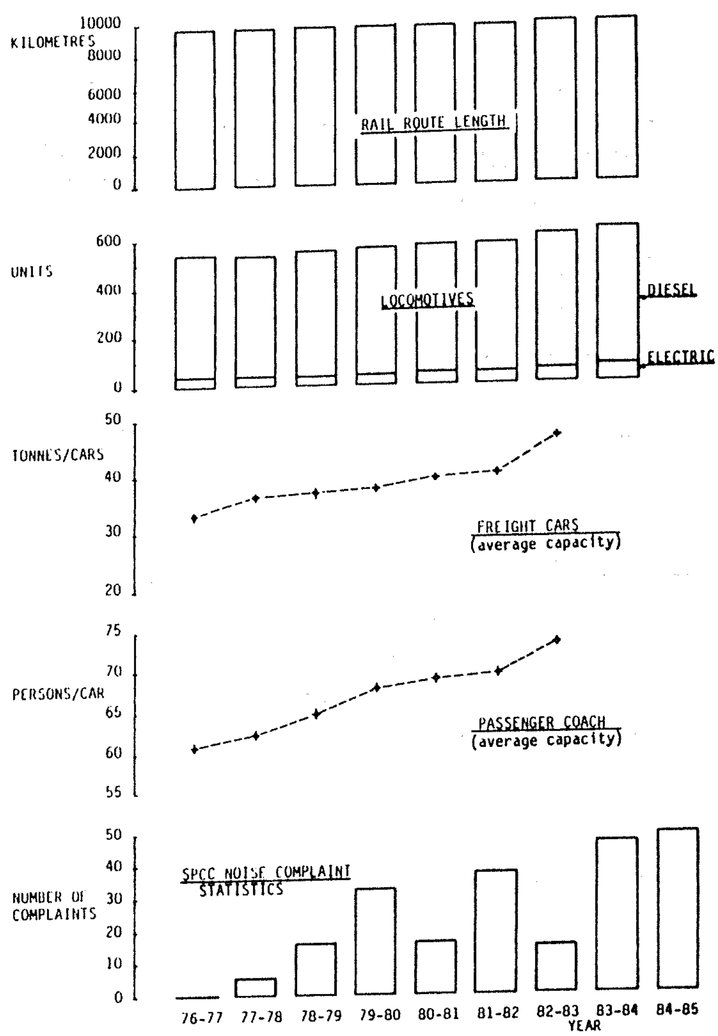

Figure 2. RAILWAY INFORMATION FROM NEW SOUTH WALES STATE

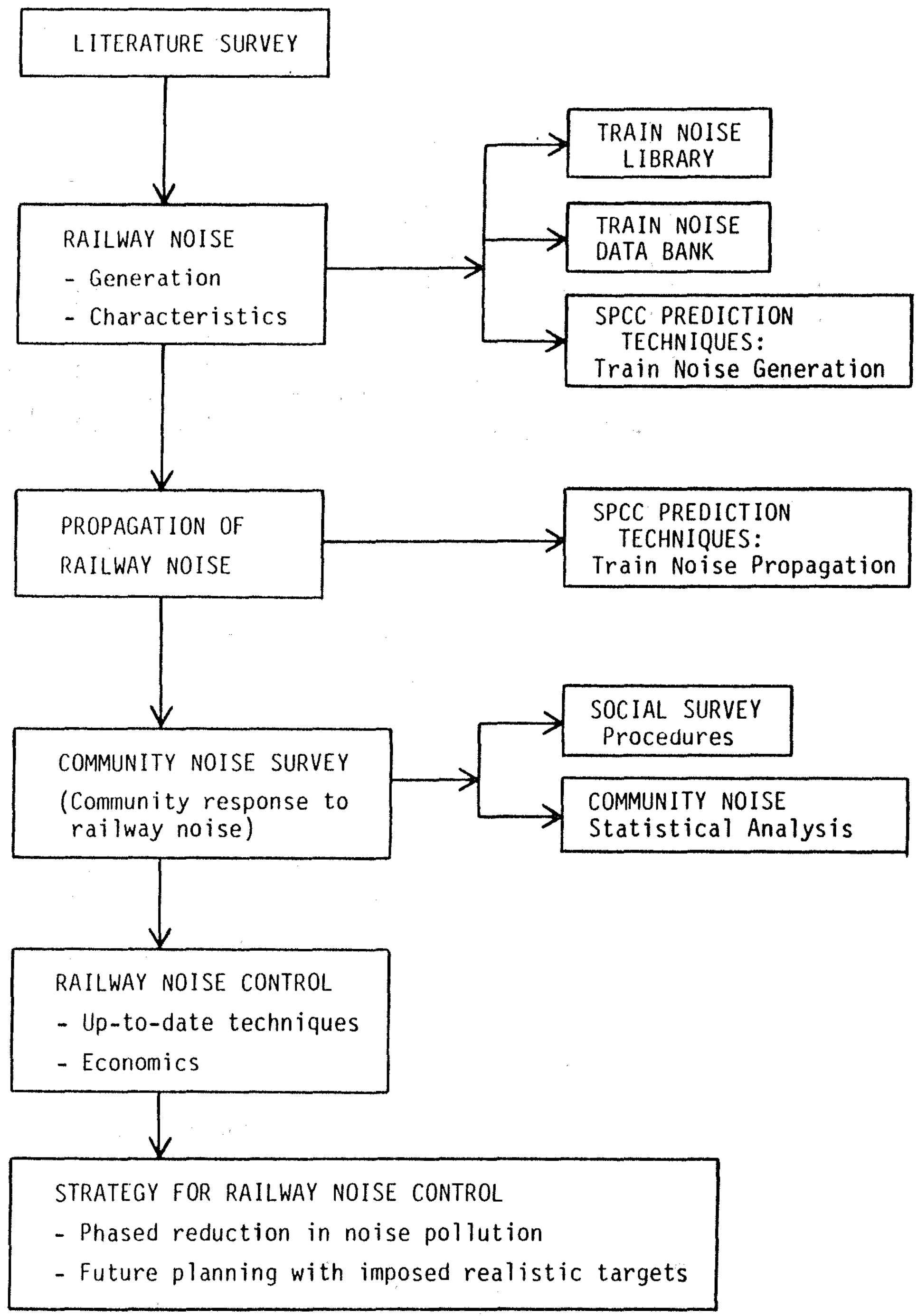

Figure 3. Sketch layout of the main procedures for the railway noise investigation.

NOISE PROPAGATION PREDICTION MODEL - ITS PERFORMANCE AND VALIDATION

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ABSTRACT

A method for the prediction of noise propagation and immission is important when imposing into an environment changes which may affect existing ambient noise, for example by developing a new or expanding industry, new roads, railways and other noisy activities.

Recently, the State Pollution Control Commission has developed a computerised noise propagation prediction model, where real noise sources are substituted by an equivalent monopole point, line or plane source. Transmission path attenuation is estimated from algorithms taking into consideration factors influencing outdoor sound propagation,such as frequency, enclosure, source and immission point heights, distance from source to immission point, topography including buildings and barriers, ground cover and meteorological conditions.

The model estimates immission point noise level from both steady state and fluctuating sources.

The model accuracy has been checked against real field situations in different seasons.

The paper will describe the model, its performance and results of its field validation.

1. INTRODUCTION

The process of outdoor sound propagation modelling involved many activities such as

- development of a mathematical and computer model of sound propagation
- laboratory and field validation of the mathematical and computer model
- development of methods of gathering and storing of noise source and other acoustic data.
- monitoring of ambient noise in rural/industrial areas.

Development of noise propagation prediction model was initiated by the State Pollution Control Commission in conjunction with the Australian Environment Council. Both the Commission staff and consultants were involved in the task. The mathematical and computer models have been developed by R. Tonin and Associates Pty Ltd.

The laboratory and field validation of the model, determination of sound propagation constants, development of methods for gathering noise source data, monitoring ambient noise, have been done by the Commission and Dr. F. Fricke of Sydney University, as consultant.

As a result of these activities a sound propagation prediction computer model GENERL (General Environmental Noise Extrapolation Ranking and Listing) has been developed. The model is a package of seven computer programs written in BASIC language for the following set of instrumentation

- Hewlett Packard controller type HP 9845
- Hewlett Packard 8" flexible disc memory type HP 9895A
- Hewlett Packard plotter type HP 9872T
- Hewlett Packard time clock type HP 98035A
- Summagraphics digitizer type MG1724
- Digital Frequency Analyser of Bruel Kjaer type 2131.
- Analogue tape recorder class B (AS 2680-1984 requirements).

2. STRUCTURE OF THE MODEL

The model GENERL is based on the assumption that any noise source can be represented by point, line or plane source which radiates sound energy in all directions as if it is in free field. It is assumed also that sound propagation from such a source in any other than free field environment will be affected not only by geometrical energy spreading (A_{div}) but also by:

- enclosure or other noise control devices (A_{encl})
- source directivity (A_{dir})
- absorption in the air (A_{atm})
- barrier or barriers placed between the source and receiver (buildings, topography) ($A_{barrier}$)
- presence of ground and ground cover (A_{ground})
- wind and temperature gradients (A_{met})

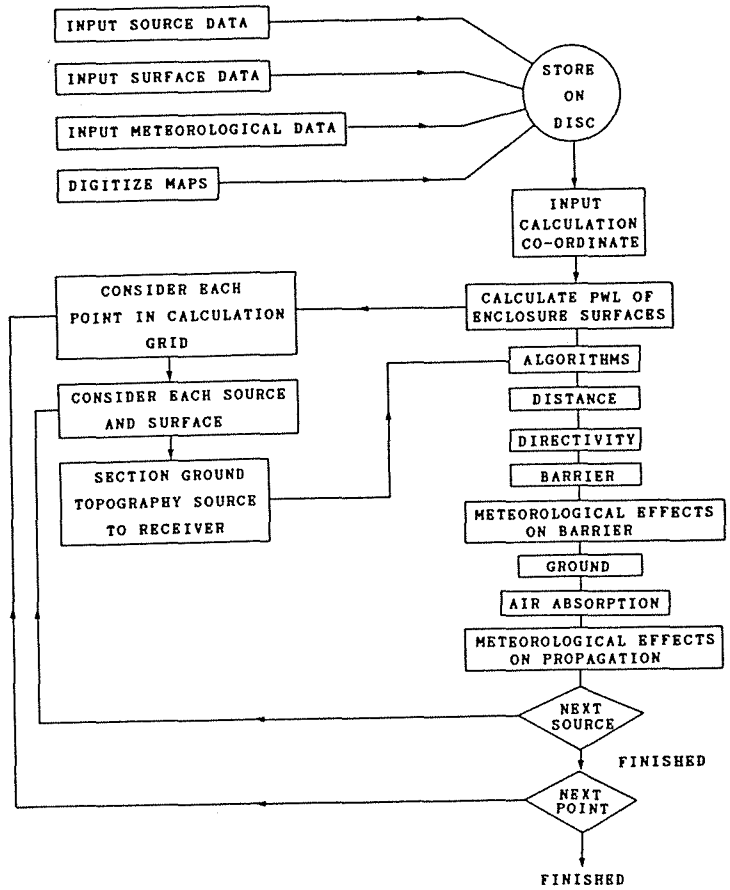

Fig.1. The flowchart of program GENERL for the "static" model.

In practice GENERL models the noise sources and sound propagation conditions and calculates the sound pressure level caused by one or more noise sources located in enclosure or an open ground at a required distance from the source. The attenuation due to factors listed above are frequency dependent with the exception of geometrical divergence and directivity which are not considered in the model as frequency dependent. The unweighted sound pressure level is calculated for each octave band frequency. The calculation structure can be simply presented by formula:

$$L_{oct} = L_{W\ oct} - (A_{oct\ encl} + A_{div} + A_{dir} + A_{oct\ atm} + A_{oct\ barrier} + A_{oct\ ground} + A_{oct\ met})$$

where $L_{W\ oct}$ is the known sound power level of noise source and the subscript $_{oct}$ signifies a particular octave band of noise.

They are two main structural parts of the model. One of them, the "static" model deals with steady state noise sources, the second, the "time domain" model, takes into account the fluctuating nature of noise sources. The structure of the computer model for noise propagation prediction is given for the "static" model in Fig.1 and for the "time domain" model in Fig. 2.

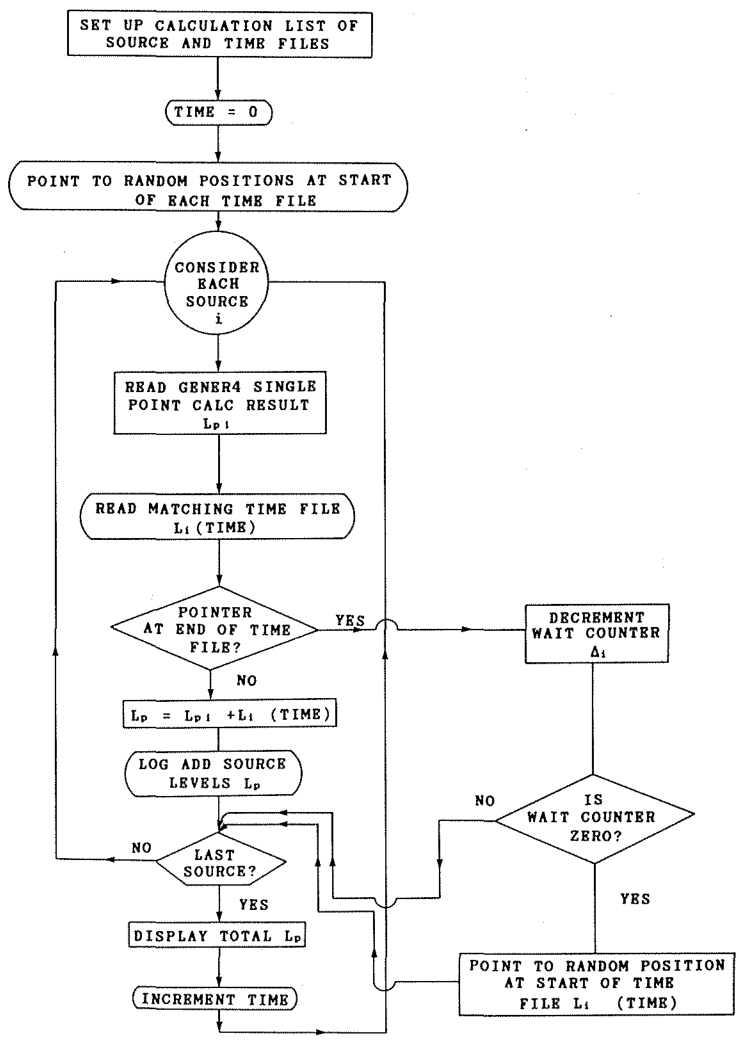

Fig. 2. The flowchart of program GENERL for the "time domain" model.

3. MODEL FUNCTIONS AND PERFORMANCE

The model in its computerised form consists of a package of seven programs which generally follow the functions of the model and consecutive steps of the model usage. It was the hardware memory limitation which caused a division of the model software into separate functions.

The first three of the programs deal with data storage and data input for the model. The next three perform the computation and provide the output facilities. A separate program performs operations related to the "time domain" part of the model.

GENERL has an option for creating a data base which stores information about noise sources and noise control measures. The data are stored in forms which allow data to be retrieved and entered straight into files for noise immission level calculation. The data are stored using a special coding system covering all possible source categories and noise control measures. The coding and data base are proposed to be applied by all users of GENERL.

The terrain data of sound propagation sites are entered into the program by digitising its topographical contours together with ground cover data. Weather conditions are simulated by meteorology files which consist of the air temperature and humidity, wind speed and direction, and temperature gradient data.

The model GENERL, as far as noise level estimation is concerned, produces the following outputs:

(i) in the "static" model:

- an octave band frequency analysis of an immission noise level in dB(Lin) and overall level in dB(A) for a point receiver; this output is a result of a "single point calculation" procedure
- a "noise contour" in overall dB(A) over a preset terrain area of interest; this output is a result of a "multiple point calculation" procedure.

(ii) in the "time domain" model:

- an octave band frequency analysis in dB(Lin) of L_{eq} sound pressure levels of fluctuating noise sources from source noise tape recording
- a graph of time history of noise source sound pressure level for each of 31.5 Hz to 16 kHz octave bands and overall Lin and A-weighted levels
- an A-weighted immission noise percentile level L_{A1}, L_{A10}, L_{A90} and any L_{AX} at a point receiver.
- a graph of time history of one of the above statistical levels.

Up to 50 sources can be taken into account simultaneously for noise level calculation in the "static" model. In the "time domain" calculations, the noise from up to 25 sources can be predicted.

Other outputs of GENERL are:

- topographical contour map plotting (i.e. contours, names, labelling, etc.) with any data which were digitised in and stored
- plotting of terrain vertical sections between any two points within digitised map
- graphs of sound power, sound pressure level spectra stored in data base.

All the above mentioned plots and graphs can be executed on screen computer printer or plotter. Accuracy in map plotting depends on the number of digitised points, and it can be very high.

An example of single point calculations is given in Fig.3. The calculation was done for the model testing site at distance of 400m NW from source. The map of testing site is presented in Fig.4. This is also an example of map plotting performance of GENERL. In this test a gas gun was used as a sound source.

400 m NW distance

RECEIVER CO-ORDS ; X= 365.2 Y= 394.5 Z= 34.2861

Source : SNW

	dB(A)	31.5	63	125	250	500	1k	2k	4k	8k	16k
		FREQUENCY Hz									
Power level		133.9	135.7	139.5	145.7	133.6	133.3	136.7	136.6	126.5	126.5
Distance		63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0
Directivity		-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6	-4.6
Barrier		5.3	5.6	6.2	7.2	8.9	11.2	12.8	15.6	18.6	21.7
Air Abs.		.0	.1	.2	.4	.8	1.6	3.7	10.6	34.8	109.1
Wind & Temp		.4	.4	.5	.2	.5	.7	.9	.7	.7	.7
Ground		-5.7	-5.4	-4.7	-2.9	2.7	-.6	-.5	-.5	-.8	-1.9
	74.8	75.5	76.7	79.0	82.3	62.3	62.0	61.3	51.8	14.8	-61.4
TOTAL	74.8	75.5	76.7	79.0	82.3	62.3	62.0	61.3	51.8	14.8	-61.4

Fig.3. Single point calculation result. Sound pressure level at 400m NW distance from sound source (see map in Fig.4).

Plots of noise contours which are outputs of the multiple point calculations are given in Fig.5 and Fig.6. They are the noise contours as for single point calculation, but for different meteorological conditions. The plot in Fig.5 represents the noise contour for down wind condition (wind direction SE), the plot in Fig.6 is for the opposite wind direction, i.e., NW direction.

The meteorological data for the single point calculation are given in Table 1; for the noise contour in Fig.5 - in Table 2 and for the noise contour in Fig.6 - Table 3.

Table 1. Meteorology data for the single point calculation in Fig.3.

WIND SPEED m/s	WIND DIR'N (deg clock)	HUMIDITY %	TEMP deg C	GRAD degC/100m
6.0	140	55.0	10.5	-1.40

Table 2. Meteorology data for the noise contour in Fig.5.

WIND SPEED m/s	WIND DIR'N (deg clock)	HUMIDITY %	TEMP deg C	GRAD degC/100m
6.2	45	42.0	17.0	-3.30

Table 3. Meteorology data for noise contour in Fig.6.

WIND SPEED m/s	WIND DIR'N (deg clock)	HUMIDITY %	TEMP deg C	GRAD degC/100m
6.2	225	42.0	17.0	-3.30

The output of the single point calculation consists of not only a frequency analysis of the noise level at the receiver, but also gives a frequency analysis of sound power level of the noise source and values of all attenuation factors occurring along the noise propagation path between the source and receiver. Such an output is given for each source when more than one source is considered in the calculation of noise level at the receiver. The final result of the calculation for many sources (named "TOTAL" on the print Fig.3) is a sum of each source contribution to the noise level at receiver.

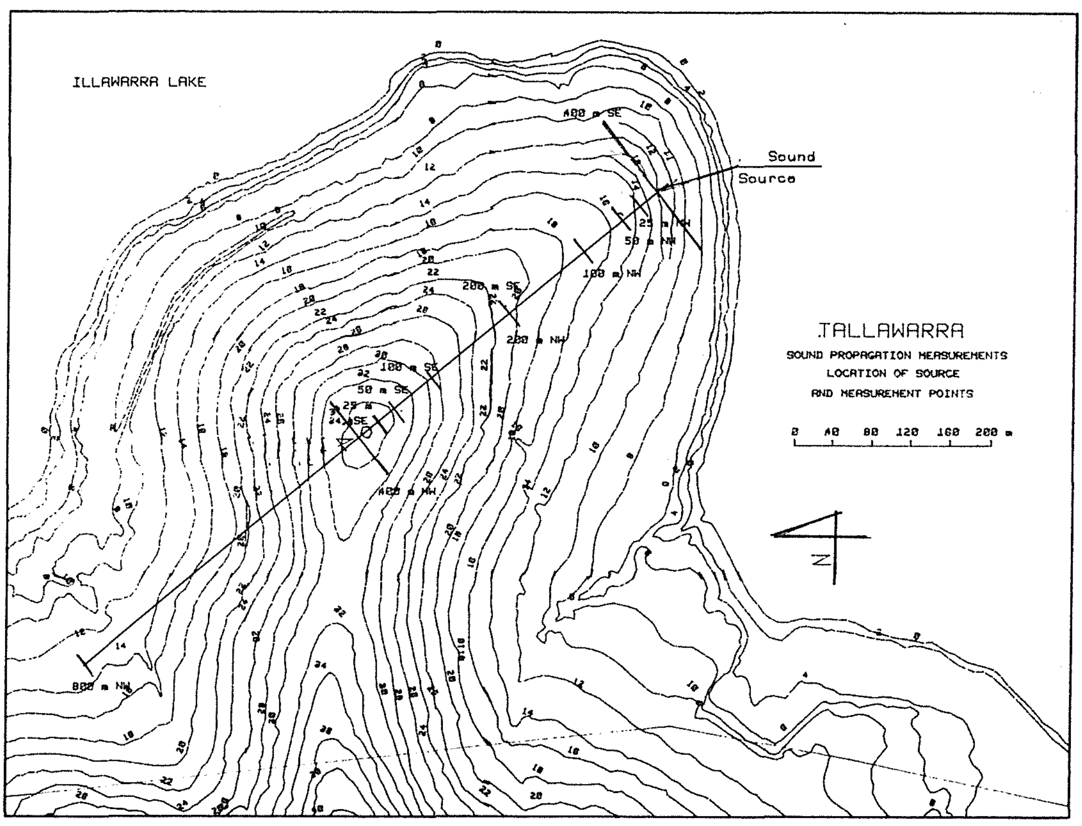

Fig.4. The map of the model validation site plotted using program GENERL.

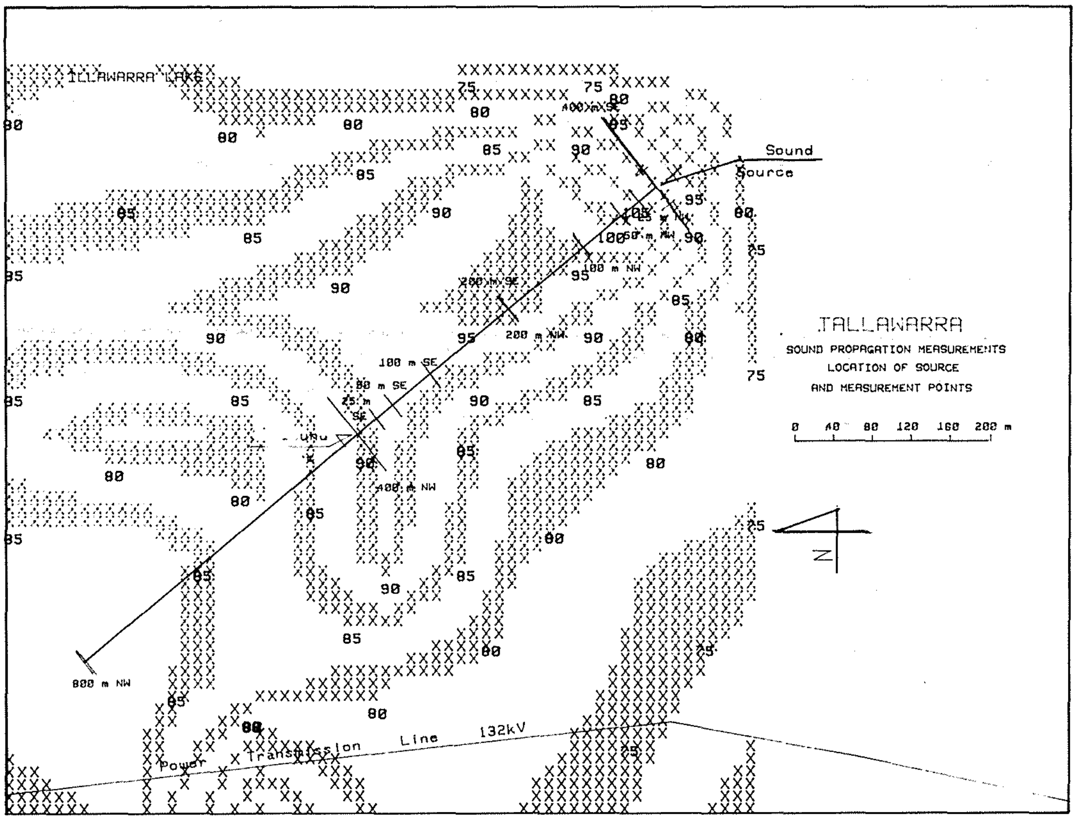

Fig.5. The noise contour in dB(A) with wind from SE direction.

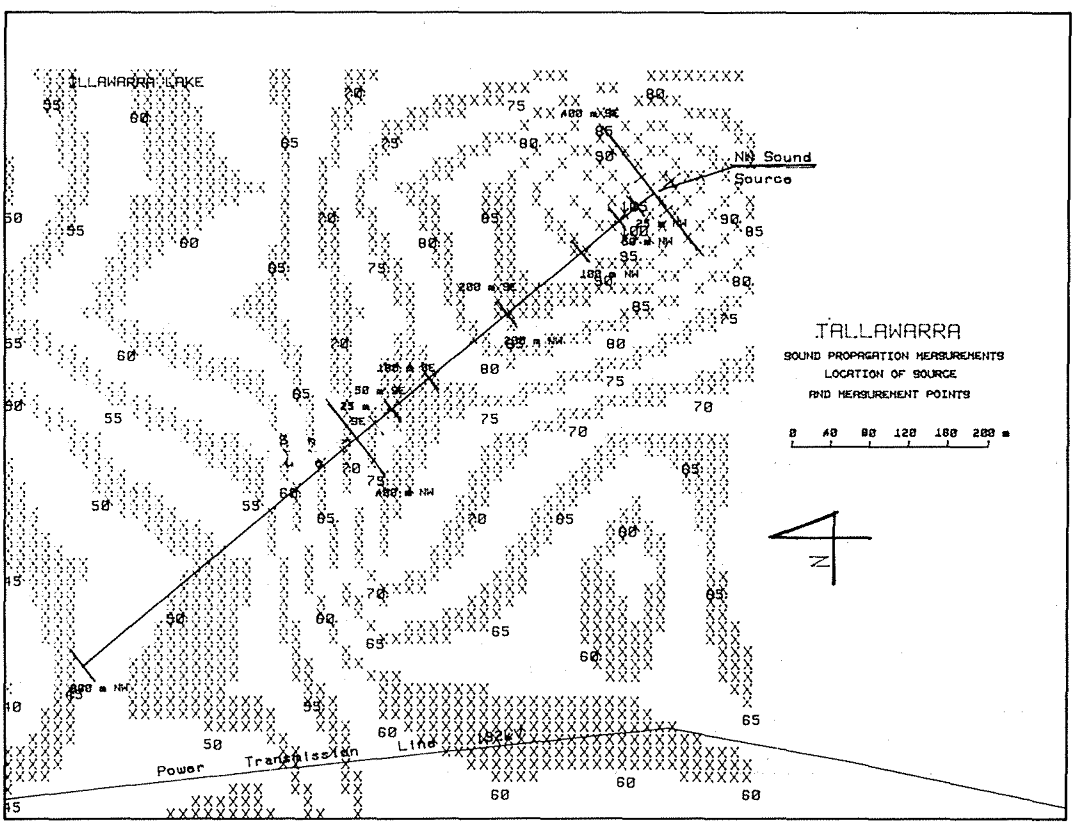

Fig.6. The noise contour with wind from NW direction.

The model allows also a check on the effectiveness of introduced noise control measures on the propagation path, such as enclosures or barriers.

The noise contour examples show (Fig.5 and 6) what influence wind direction may have on noise level at the same spot. E.g., the noise level at a distance of 200m NW from the source is 95 dB(A) for down wind and 85 dB(A) for up wind.

The output of the "time domain" model gives the digital values of percentile noise levels and plots also time history graphs of noise source and noise level at receiver. The calculations of sound attenuation along propagation path for the "time domain" model is performed by the "static" model. L_{eq} at receiver from each source separately is obtained as a result of this calculation. Then the time domain model imposes on L_{eq} at receiver fluctuation peculiar to the source and simulates the real sources operation by applying special technique which allows the statistical calculation to be performed on random, cyclic, intermittent noise.

4. VALIDATION OF THE MODEL

The model accuracy was tested against real situations on a few sites and during different meteorological conditions. Various types of sound sources were used in the tests, such as steady state broad band, octave band, impulse and fluctuating sources. The filed validation was performed to check the "static" as well as "time domain" model.

During tests, the weather conditions were also recorded. The weather data for all tests consist of the air temperature and humidity, wind speed and direction measured at 2m above the ground. Some of the tests were accompanied by simultaneous monitoring the boundary layer profiles, some by continuous recording of nearby meteorological stations.

Table 4. The calculated and measured noise level in dB(A) for NW sound propagation path on site shown in Fig.4.

Distance from source (m)	25	50	100	200	400	800
Calculated noise level (L_c) (MET1) L_c-L_m	110.2 0.7	103.3 3.0	91.9 0.1			
Measured noise level (L_m) St.dev.	109.5 0.9	100.3 1.0	91.8 1.05			
Calculated noise level (L_c) (MET6) L_c-L_m		106.3 4.8	96.6 4.4	84.5 2.8		
Measured noise level (L_m) St. dev.		101.5 0.9	92.2 0.2	81.7 0.5		
Calculated noise level (L_c) (MET7) L_c-L_m			95.4 3.7	83.2 1.4	73.1 5.1	
Measured noise level (L_m) St. dev.			91.7 0.5	81.8 0.6	68.0 0.7	
Calculated noise level (L_c) (MET9) L_c-L_m				83.4 2.7	74.4 8.5	56.4 3.4
Measured noise level (L_m) St. dev.				80.7 0.2	65.9 1.0	53.0 1.1

In Table 4, the results of tests performed at Tallawarra were compared. This validation concerns the stage when the model accuracy was aimed to be 5 dB(A). At most of the test points the difference is less than 5 dB(A) except the point at 400 m from source.

The test point of 400 m NW from the source was placed just behind the top of the hill (see Fig. 4). Usually around the hill tops the air is subjected to local turbulence stronger than along or up to the hill. The meteorological conditions were different from those measured 400 m away.

In conclusion, the model after the first tuning is considered to be already an efficient tool to predict noise propagation. Accuracy of prediction depends strongly on accuracy of the meteorological condition data along the noise propagation path.

The above described basic model is still being tested and validated. The updated version of its "static" part is being developed in Fortran 77 for IBM PC and compatible computers. The Fortran 77 version will include options for adapting the model to different hardware configurations (e.g. without digitizer or plotter). Arrangements are being made for this version to be available for purchasing by any institution or person.

AN OPTICAL ANALOGUE FOR ROAD TRAFFIC NOISE FOR USE IN THE DESIGN OF HIGH DENSITY URBAN DEVELOPMENT AND IN TEACHING

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ABSTRACT

In the high residential density, high rise types of urban developments that occur in Hong Kong and Singapore, levels of road traffic noise to which dwellings are exposed are also high. Various constraints on development also mean that conventional noise control strategies - setback, barriers and insulation - are inappropriate. Solutions have to be found through building layout and design.

To achieve these solutions it is suggested that a rapid acoustical assessment technique is required which can give the urban designer insight into the likely noise exposure of sensitive uses at any stage of the design. An optical analogue of road traffic noise generation and propagation may prove a useful tool in this respect.

Optical modelling may also have a role as a medium for teaching noise control, not so much to acousticians, but to students involved in various aspects of urban development or design.

1.0 INTRODUCTION

Where land is in short supply, urban development or redevelopment requires that the population be housed at high residential densities. For a variety of reasons, the response in some areas of the world has had to be the provision of housing in high-rise buildings. Hong Kong and Singapore are two examples of housing programmes relying extensively on vertical urban development. One side effect of vertical development is that a large proportion of the population can be exposed to high levels of ambient noise, and this noise is generated predominantly by surface transportation.

For example, urban Hong Kong has some population densities up to 200,000 persons per square kilometre, though design densities in newly developed areas are considerably lower. The scarcity of suitable building land has produced vertical development of nearly all land uses, with residential tower blocks commonly of 30 storeys or more. Some 40% of the population is in public housing and further new housing is provided in comprehensively developed estates with dwellings, shops, schools and transport termini in closely spaced building blocks. For example, 3,000 to 5,000 residents may be accommodated within a single tower and the total population of any particular estate may be 15,000 to 30,000 residents. These comprehensive developments are designed and built within surprisingly short periods and planning staff are under considerable pressure to produce results as quickly as possible. For example, a target of 35,000 new flats each year was reported by Messling (1982).

2.0 HIGH RISE BUILDINGS AND TRAFFIC NOISE

The high population densities in these developments are serviced by a relatively small and closely-spaced network of roadways with most parts of the network carrying heavy traffic. The majority of dwellings in the residential towers are located at relatively short horizontal distances from the roadways and generally there are few dwellings within buildings which do not have an unobstructed view to at least some part of the roadway network. This combination of high traffic volumes, short distances and lack of shielding can expose a large proportion of the population to high levels of ambient noise in their homes. Brown and Lam (1986) compared the noise levels outside of the dwellings of the Hong Kong population to those outside of the dwellings of the English population and showed, Figure 1, that half of the Hong Kong population was exposed to L_{90} noise levels some 20 dB higher than was half of the English population. (The difference is slightly exaggerated as the English population also included dwellings in non-urban areas). They attributed this difference to the form of the urban development in Hong Kong.

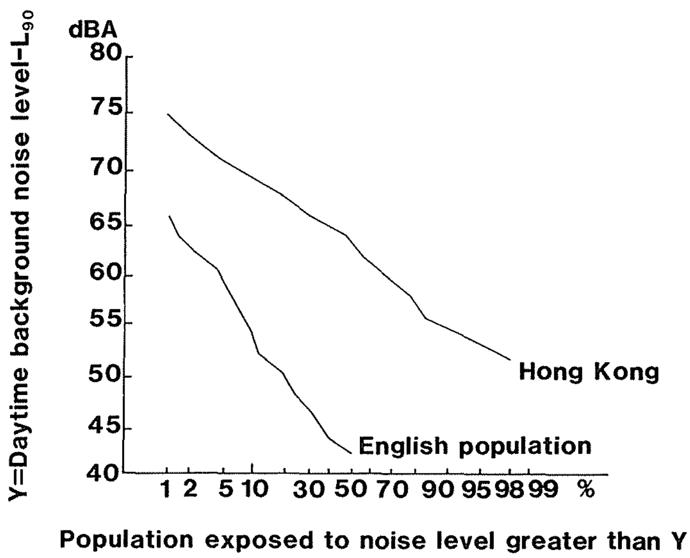

Figure 1. Background noise exposure of the population of Hong Kong and England (reported in Brown and Lam, 1986)

However, in passing it should be noted that urban development need not reach the exaggerated vertical form of Hong Kong before similar adverse acoustic conditions predominate. The important parameter is the proportion of the population in the urban area who live in dwellings to which there is unobstructed propagation of noise from a roadway. This proportion will be high in any city where the whole of the roadway network within the residential areas carries high volumes of traffic and will usually occur when residential densities are high. By contrast, where much of the residential street network carries low-volume access traffic only, and this will be in low density, low rise developments or where the residential street system is severely limited by capacity (as in much of Tokyo), the proportion of the population exposed to high levels of noise is likely to be low. It is not that there is less traffic noise generated in low-rise urban areas, but that the brunt of the traffic noise problem is borne by that smaller proportion of the population living near to the roadways carrying heavy traffic volumes. Their dwellings, in turn, act as acoustic barriers reducing the noise exposure of the rest of the population.

Recognizing that high-rise urban development will generally result in high levels of noise exposure for residents, what can be done about it?

3.0 REDUCTION OF TRAFFIC NOISE IN HIGH RISE DEVELOPMENT

3.1 Conventional Solutions

Leaving aside quieting the source itself, conventional strategies for the reduction/prevention of urban traffic noise problems are to:

- increase the physical separation of dwellings and roadways
- construct roadside barriers
- acoustically insulate dwellings

The nature and economics of urban development in many parts of the world render these conventional solutions inappropriate. First, there is often no possibility of increasing the separation of roadways and dwellings because of the limited availability of land - the very reason for high-rise development in the first place. Second, while devices to reduce noise from roadways have been adopted routinely in some highly developed countries such as the United States (U.S. Dept. of Transportation, 1980) France (Min. de l'Environnement, 1978) or Japan, barriers at the side of roadways are expensive. Besides, they are singularly inappropriate for high-rise development because the acoustic shielding they provide is generally only effective for the lowest floors, leaving the majority of dwellings in any tower blocks unprotected. Third, insulating the building envelope against noise is unlikely to be feasible because of the costs involved unless insulation is also required for thermal comfort. However, in tropical climates, all ventilation in lower cost housing generally has to be through open windows.

3.2 Urban Design Solutions

However, there is a paradox that, while ordinary solutions are not appropriate, the form of new high density development can often provide unique opportunities for noise reduction by an alternative means - through site and building layout. This is for two reasons. In the first place, the bulk of the buildings within any one development site is likely to be large and this provides opportunities to place dwellings and other noise-sensitive uses in acoustic shadows cast by other buildings. Secondly, where new areas are being developed, residential and service buildings can often be designed in conjunction with the transport system. Comprehensive planning of this sort provides flexibility which can be exploited to produce a major reduction in the transport noise levels to which much of the development is exposed. In some cases this flexibility can include not only the simple spatial re-arrangement of building blocks but also variation in the height and shape of some of the blocks and changes in the relative elevation of roadways and dwellings. In addition, effectively covering the roadway noise sources to a greater or lesser degree by physically incorporating them into the design of the buildings, transport terminals or landscaping works, may also be possible.

These types of solutions have been known and advocated for many years (U.S. Dept. of Transportation, 1974; Bar, 1977; U.S. Dept. of Commerce, 1978; Ontario Ministry of Housing, 1980) and even in 1930, the New York Noise Abatement Authority recognized that the "new architecture" of buildings on podia set back from the roadway had the potential to *give relief from noise in the storeys just above the setbacks* (Brown et al, 1930). But this potential for using some building elements to shield others has rarely been grasped - at least not in lower-cost housing projects. It is important to ask why.

4.0 THE DESIGN PROCESS

There appear to be two difficulties in incorporating external acoustic considerations into the design process. Firstly, designers are already faced with a multitude of hard constraints in the design work: achieving the required residential densities and service provisioning, foundation requirements, scheduling of construction, mimimizing costs etc. They are also congnizant of the softer architectural constraints of aspect, view and aesthetic appeal of the final form. Any additional constraint requires additional effort and skills - and urban design professionals have generally not been well equipped in their training either to recognize or manage the problem of high external noise.

Secondly, rearrangement of building shape or location requires that the problem of noise be considered at a very early stage of a design. This itself requires that acoustic conditions that will prevail after the completion of the project be known. Some excellent prediction procedures are available for this purpose, but present methods require that the geometry of roadway sources and building outlines are well established. A detailed geometry is required on which to perform computations (for example, using the U.K. Department of the Environment procedure (1975) or that developed by the French Centre d'Etudes des Transports Urbains (Min. de l'Environnement, 1980)) or on which to build the sophisticated scale models needed for acoustical modelling (as in Japan (Yamashita, 1979) or The Netherlands (Kranendonk and Nijs, 1980)). However, in the trial-and-error process which is required in fitting together the jigsaw of an urban development, a fixed geometry is the very thing which is not available. If time and resources are short during design, the present complex and time-consuming procedures for predicting levels of transportation noise can only serve in an evaluative role, usually after a final design is available, rather than in a creative role in the design process. It is reasonable to expect reluctance on the part of a designer to go back and alter a design which meets all other constraints merely because late acoustic evaluation of that design has demonstrated high levels of noise.

What is required to alter this situation is a rapid-assessment technique which can give the urban designer insight into the likely noise exposure of sensitive uses at any stage of the design. The technique should quickly be able to assess the acoustic ramifications of any changes in location of buildings and roadways and their geometry. In summary, an ideal technique should:

- be simple, and preferably easily used and manipulated by the designer without specialist consultation
- provide immediate feed-back so as not to impede the design process
- require little data beyond that normally available to the designer and certainly not so much data as to discourage testing of concepts and alternatives
- be able to play a role in educating designers in the potential noise reductions available through layout of building elements.

It is suggested here that scale modelling using an optical analogue can go some way towards meeting these criteria.

5.0 OPTICAL MODELLING

In the type of urban complexes considered here, road traffic noise arrives at receptor dwellings by a direct path from the source roadway, by a path reflected off some other building element, or by refraction around some intervening barrier or building element. On a small-scale physical model of the development, if one uses a row of lights as an analogy for the roadway noise source, some parts of the development will be directly illuminated by the source (the illuminated zone). Where buildings or other barriers intervene, other parts will be shielded from the light source (the shadow zone). As a first, coarse approximation, it can be said that, when using a model such as this, severe transportation noise problems would not exist at dwellings and other noise-sensitive uses located in shadow. Problems may exist at dwellings which are fully illuminated. On this basis, crude optical modelling of urban designs has potential to indicate which parts of a proposed development are exposed to high levels of noise, and which parts are afforded some protection.

It is important to note some limitations to the analogy. Firstly, the transition from "acoustic illumination" to "acoustic shadow" is blurred because of refraction of sound into the shadow zone. Though light is also refracted around the edge of an intervening barrier, the analogy for modelling purposes is not good. Secondly, when sound travels from roadways to dwellings along a path close to the ground surface, the noise at the receiving point is significantly reduced by the ground effect on sound propagation. The optical model cannot cope with this, though as propagation generally is well above the ground surface in any high-rise development, the effect can in most cases be neglected. Limitations imposed by the poor modelling of refracted sound needs further investigation.

Models of 1:100 and smaller scales have been constructed with roadway sources represented by rows of small incandescent light bulbs and the building modelled from some reflective material such as white plastic, foam or cardboard. Scaling the height of the road vehicles above the roadway using incandescent light sources has been a problem, and investigation of alternative light sources is warranted. Dimensional accuracy in the construction of the model is not critical, except for those edges of building and ground planes which act as barriers and cast shadows on buildings at greater distances from the roadways. Experience is that viewing in a completely darkened room aids interpretation of the model where building elements which are in light and those which are in shadow, hence exposed and not-so-exposed to noise, are clearly distinguishable.

In no sense is crude model such as this intended to be used in a quantitative fashion, but this is not its purpose. Its primary function is to give a designer an indication of the extent of high noise exposure and low noise exposure within a development and, of more importance, which building elements effectively act as barriers and which have the potential to act as barriers through design modification. With an appropriately constructed model, the designer can have the hands-on experience of trying different designs by relocating or re-orienting the building elements, by placing roadways in cuttings or changing slopes of cuttings, or by adding new building elements and other forms of shielding. Many of these changes can be quickly tested merely by using hand-held sheets of opaque material. Experience is that, in a very short time, a designer untrained in acoustics can become aware of the broad constraints and possibilities concerning the external acoustic environment and, in particular, be able to consider these along with the other constraints in the project. This "feeling" for the noise levels throughout the development must be supplemented at a later stage by detailed calculation or perhaps by quantitative acoustic modelling, but this two-stage approach is likely to be far more productive than a single post-hoc evaluation of a completed design.

6.0 SUMMARY

In the comprehensive design of high density, high rise urban development, considerable potential exists for reducing the proportion of the population exposed to excessive levels of road traffic noise through building design and layout. This potential has not been realized in the past because of the difficulty urban designers have in incorporating acoustic considerations into the early stages of a project when the necessary flexibility to alter the design still exists. Non-quantitative optical modelling can be used to sensitize designers to acoustic constraints and opportunities, and perhaps even as a first-stage design tool. Designer sensitivity to the improvements which can be achieved in the acoustic environment is developed merely by observing and manipulating the optical model.

A related matter is the potential for optical modelling to serve as a medium for teaching noise control, not so much to acousticians who already have a wide range of design tools taught and available to them, but to students involved in various aspect of urban development or design.

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RATIONALE AND METHOD OF AN ONGOING STUDY OF THE EFFECT OF NOISE ON CARDIAC ARRHYTHMIAS DURING SLEEP

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ABSTRACT

This paper described the rationale, and method being used by the National Acoustic Laboratories and the Royal North Shore Hospital to determine relationship of traffic noise to the frequency or severity of cardiac arrhythmias in susceptible people during sleep.

1.0 INTRODUCTION - RATIONALE OF THE STUDY

Some investigators experimenting with the effects of noise on sleep have recently included measures of heart rate, heart rate variability and even finger pulse amplitude in laboratory and field studies of people exposed to noise during sleep, with fairly consistent results. Thus laboratory experiments showing significant correlations between heart rate and bursts of narrow and broad band white noise (Osada, 1969), brief pulses of pure tones (Johnson et. al., 1973), and recorded traffic noise (Muzet and Ehrhart, 1980; Muzet et. al., 1981) have been supported by field experiments in which people living near busy highways were studied in their own homes (Hofman et. al., 1981; Kumar et. al., 1983; Wilkinson and Allison, 1983; Vallet et. al., 1983(a); Wilkinson and Campbell, 1984). These correlations, though small, have been consistently positive even though the noise type, its overall level and time schedule, the significance of the noise source and the methods of defining noise bursts or peaks and heart rate response have differed somewhat between studies.

Two studies have also shown consistent, and statistically significant correlations between heart rate variability (measured by the coefficients of variation of the interbeat intervals) and minute by minute average noise level and the standard deviation of the noise level (Hofman et. al., 1980; Vallet et. al., 1983(b)). Also Wilkinson and Allison (1983) reported greater heart rate variability associated with higher than lower level peaks of traffic noise; and greater HR variability after noise peaks than before when the data were collapsed over noisy and quiet nights and over all noise peaks.

These heart rate and heart rate variability effects seem to form a pattern of response to noise peaks which are not necessarily associated with any particular type of noise source nor have any connotation of threat, which could mean that many people are being affected in this way by common environmental and neighbourhood noises at night (or by day in the case of shift workers). Moreover, it would appear that these responses do not habituate - i.e. diminish or disappear on repeated exposure to the noise. Thus Johnson et. al. (1973) found that heart rate and finger pulse amplitude responses occurred to tone bursts during sleep but not when the subjects were awake and that these responses failed to habituate during the night or between nights. These results were obtained in two separate experiments involving 20 and 10 subjects, and 15 and 30 consecutive nights, respectively. Similar results were obtained in two laboratory studies by Muzet and Ehrhart (1980) and Muzet et. al. (1981) using recorded traffic noise as the sound stimuli. Hofman et. al. (1981) also found no habituation of heart rate response in their subjects who slept at home and were studied for 20 nights (10 with windows open, 10 with windows double glazed).

The above studies were all carried out with 'normal' people. It is known however that when people with pre-existing heart conditions are placed under psychological stress the increase in the frequency of cardiac arrhythmias is much more marked than the increase in heart rate (De Silva and Lown, 1978). It is possible therefore that cardiac arrhythmias are markedly increased by noise during sleep. Because of the large number of people exposed to excessive traffic noise (OECD Environment Directorate, 1984; Australian Environment Council, 1985) and the vulnerability of some of them, particularly e.g. after coronary occlusion it is important that this matter be investigated under realistic conditions. Such a study is now being conducted in Sydney by the National Acoustic Laboratories and the Royal North Shore Hospital. An outline of the methods being used is given.

2.0 EXPERIMENTAL DESIGN AND METHOD

2.1 Brief Description. The study involves continuous recordings of traffic noise in the bedrooms and also outside the dwellings of volunteer subjects living near a busy Sydney highway. Each subject is fitted with a Holter cardiac monitor, which records two channels of ECG continuously, before retiring. Sleep stage is recorded continuously throughout the night using a four channel electroencephalograph and FM tape recorder. One channel of the ECG is also fed to the tape recorder to enable subsequent computer analysis of heart rate. Continuous video recordings of traffic passing the dwelling during the night are also made for subsequent analysis.

2.2 Noise Type and Study Location. Traffic noise was chosen before other noise sources because this is the main noise to which Australian people are exposed during sleep. Thus all Australian airports except Perth operate under a curfew from 11 pm to 6 am, suburban passenger trains stop operating in the early hours and interstate freight and passenger trains are active at night on relatively few lines. On the other hand the present protocol could be applied unchanged to study responses to other noise sources if required.

It was decided to study people in their own homes primarily because of the strong 'laboratory effect' associated with laboratory studies of sleep (cf. Agnew et. al., 1966; Lester et. al., 1969). Observing people in their own homes follows a precedent set by U.S. and several European studies of heart rate (cited above). Replication of their findings concerning effects on heart rate is a worthwhile objective in itself.

Having decided to study people exposed to nocturnal traffic noise in their own homes selection of the houses to be visited in our request for participants was carried out according to the following criteria.

(1) The roadways concerned should have had an Annual Average Daily Traffic Volume (AADT) of 30,000 vehicles or more for at least the past three years. Data on AADTs for Sydney roadways were obtained from a report produced by the N.S.W. Department of Main Roads (Department of Main Roads, 1983).

(2) The dwelling (house, flat, home unit) should be situated at the margin of the roadway or within 15 metres of it.

(3) The ratio of trucks to other vehicles should be relatively high.

(4) There should be significant night-time traffic.

(5) The dwelling should be fairly close to traffic lights, preferably on a hill.

(6) The dwelling should be within 30 minutes travel by car of the Royal North Shore Hospital, St. Leonards (Sydney).

The last requirement (6) was included because each volunteer subject is required to attend R.N.S. hospital for medical examination and 12 lead ECG before any experimental work is undertaken.

2.3 Choice of Subjects. Males aged 40 years of age or more were chosen primarily because of their relatively high risk of coronary heart disease.

Preference is given to individuals with symptoms and signs of heart disease, first, because this group has been largely ignored in previous research on the effects of noise on sleep; and second, because of experimental work with animals indicating that animals with partially occluded coronary arteries were thereby made more susceptible to ventricular fibrillation associated with sympathetic responses to psychological or 'neurogenic' stimuli (Verrier and Lown, 1984).

2.4 Experimental Design. ECG and EEG recordings commence at about 11 pm and are continued until about 7 am the next morning. All night-time urine is collected for catecholamine estimation. Subjective reports of sleep quality are also obtained soon after awakening.

Each subject is studied on three nights. The first is a 'familiarisation' night. 'Placebo' earplugs (earplugs made of comfortable foam with poor attenuation properties) are worn on one further night, and E.A.R. earplugs on another. The order in which the subject uses the two earplug types is counterbalanced between subjects.

2.5 Noise Recordings. External noise recordings are made using a Bruel and Kjaer outdoor sound level meter 4921 and one-inch microphone type 4145. The SLM is mounted on a tripod and positioned outside the house in accordance with Australian Standard AS2702. Indoor noise recordings are made using a Bruel and Kjaer sound level meter type 2203and half-inch microphone type 4165. The SLM and microphone are mounted on a tripod 1.2 metres from the floor with the microphone at normal incidence to the direction of the window nearest to the road traffic. The output of both indoor and outdoor SLMs is fed to a (4-hour) video recorder (National Panasonic type AG-6800). Two such recorders are used, the second being switched to take over from the first, after four hours' recording, by means of a Kambrook timer.

2.6 Monitoring the Traffic. Video recording of the traffic is also carried out continuously by means of a video camera and the video recorders referred to above. The camera is mounted on a small van by means of a telescopic mast on its roof. The base of the mast is set in a ball joint to permit placement of the mast in a vertical position regardless of the angle of tilt of the vehicle.

Analysis of the traffic is carried out subsequently by viewing a replay of the tape.

2.7 Data Reduction. Although previous researchers have identified approximate thresholds for sleep disturbance in terms of both Leq(A) and peak measures, no comprehensive study has examined the range of possible measures to determine the optimum one (or ones) for the prediction of sleep disturbance and/or heart rate. The present study will attempt this. These measures may be grouped as follows:

(a) Threshold exceedance measures; i.e.

  (i) the amount of time the ambient noise exceeds nominated thresholds (e.g. 35 dBA) and

  (ii) the number of times in a specified period the noise level crosses threshold from below (number of events exceeding threshold).

(b) Maximum levels: identification of the 30 highest peak levels occurring during the night.

(c) Measures of variability, e.g. the standard deviation of the dB(A) levels, in each minute of the night.

(d) Energy measures, e.g. Leq(A) for each minute during the night.

(e) Isolated peaks. This involves identification of each peak which is 10 dB above any other peak within the previous or subsequent 30 seconds.

(f) Statistical measures, e.g. L10, L50, L90 (A weighted) for specified time intervals and SLM time response characteristics.

These analyses are to be carried out using a Bruel and Kjaer community noise analyser type 4427, Metrosonics DB604 statistical noise analyser and PDP-11 computer.

Physiological data are to be analysed by standard methods. Sleep stage is determined from the EEG record using the Rechtschaffen and Kales (1968) criteria. Heart rate is computed by replaying the FM recording of one channel of the ECG through an A/D converter into the PDP-11 computer. Arrhythmias are identified from the paper (full disclosure) record from the Holter monitor. Urine analyses for catecholamines (adrenalin and noradrenalin) are also carried out by standard methods.

2.8 Data Analysis. The data analysis, which is currently in its early stages, will take three forms. First, intra-subject correlations will be calculated between noise and cardiac variables, e.g. between minute by minute outdoor Leq(A) and heart rate in beats per minute for those periods when the subject was asleep. Subsequently, the number of subjects with statistically significant correlations on 'normal', earplug and placebo earplug nights will be compared. The differences here will be tested for significance by non-parametric methods.

Second, repeated measures analyses of variance will be carried out for the urinary biochemical and subjective variables. The aim is to determine whether or not these variables are related to the experimental (normal, earplug and placebo earplug) conditions, and therefore the overall, average noise level during the night.

Finally, correlations will be run between dependent (cardiac, biochemical and subjective) variables. These correlations will use data on all nights for all subjects.

The data will also be analysed to determine the relation between noise measured between 12 midnight and 6 am and L_{10} (18 hour) (the latter determined from further measurements using digital techniques), and also typical facade attenuations of Australian dwellings located on major roads.

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THE EFFECT OF NOISE ON SOCIAL COHESION AND CREATIVITY IN A TERTIARY STUDY ENVIRONMENT

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ABSTRACT

This paper presents a case study of a noise problem experienced in the painting laboratories at the D.D.I.A.E. The students observed were involved in the study of painting and drawing when exposed to adverse noise. Creativity and social cohesion were felt to be the most important psychological areas affecting their performance.

The aim of this research was to develop a video which could be used for teaching purposes. Video also allows information to be obtained through observation, rather than relying totally on questionnaires.

More importantly it is felt that the presentation of such material in film form has a far greater influence than a written report. This statement is given support by the actions taken within the D.D.I.A.E. following this video's presentation where previous written and verbal argument had failed.

1.0 INTRODUCTION

This paper investigates a problem experienced at the D.D.I.A.E., the effect of noise on creativity and social cohesion within a classroom setting.

In an attempt to understand the psychological intrusion of noise upon Visual Art Students, both empirical and selfreport measurements were taken. The empirical data took the form of a survey. Selfreport measures were obtained through interview and hidden camera.

The analysis of the research material showed the extent to which noise disrupted social order and personal performance and the compounding effects brought about by the presence of other environmental stressors.

In order to study the psychological processes used by the individual to confront noise as an environmental stressor a dual approach was taken. This consisted of the synthesis of Lazarus's "Environmental Stress Model" and Banduras's "Reciprocal Determinism Model".

2.0 METHOD

In the painting laboratories at the D.D.I.A.E. dust and noise from the adjoining workshop provides an ideal environment for research on the effects of noise on students in a study environment. In order to tackle this complex analysis, a multimethodological approach was adopted. Visual observations give an insight into individual as well as social responses. This process was expanded by two selfreport methods of interview and questionnaire, the former allowing individuals an input and the second providing empirical data. The group observed consisted of first and third year visual arts students who use this facility for a minimum of six hours a week.

There is no simple definition of an environmental stressor. Most of the research literature suggests that a stressor is a mechanism which brings about a physiological and/or a psychological change which is detrimental to the individual. In the present study we exclude the internal forms of stress and look purely at the external or environmentally created stress. This approach follows Selye's physiological model (1976).

The following model represents a synthesis of two models (see Figure 1) one proposed by Richard Lazarus (1978) and the other by Albert Banduras (1977). Laxarus's model concerns the definition of stress. He says it contains three parts. Firstly, primary arousal, which is the psychological process of discriminating threatening environments from benign. Next, secondary reappraisal serves to assess the individuals' coping resources in dealing with a threatening situation. The last part of Lazarus's model is reappraisal which is a change in how the environment is pereived due to change within one's self or within the environment.

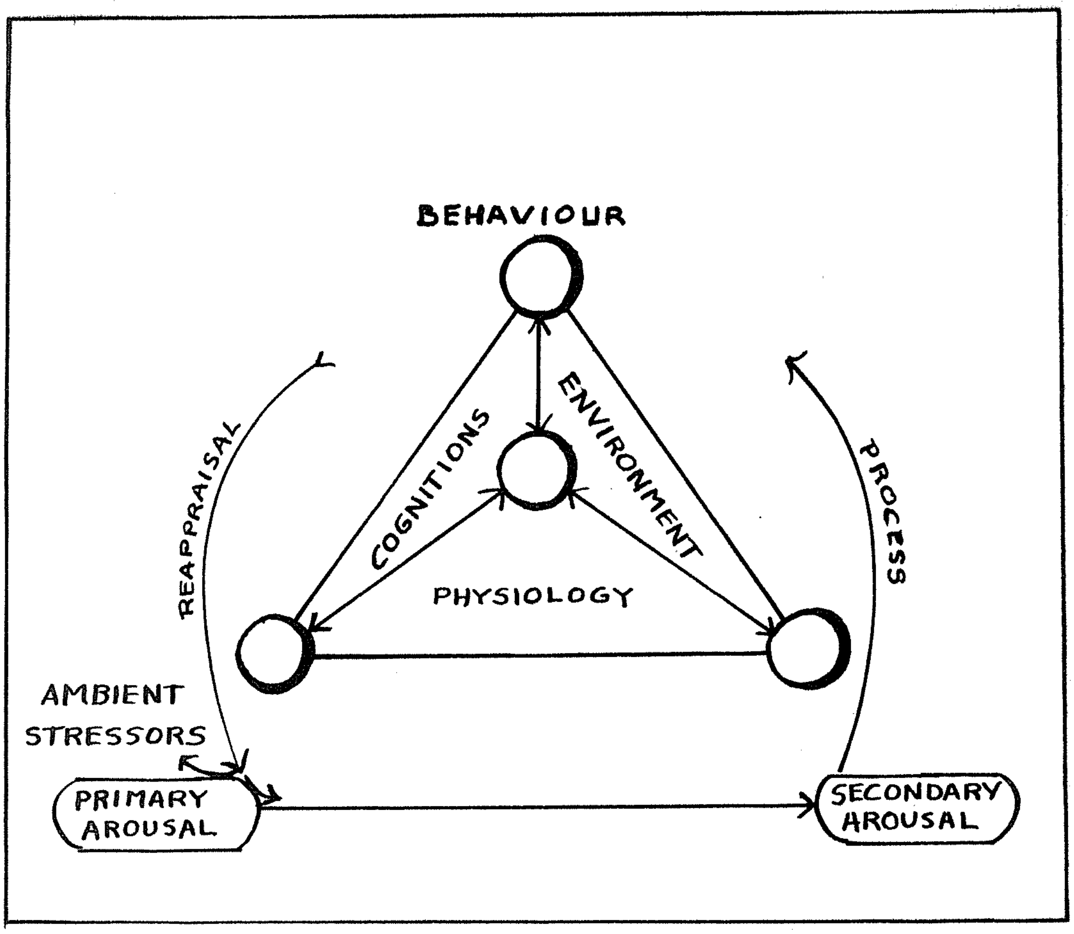


FIGURE 1 Synthesis of Environmental Stress Response Models by Lazarus and Banduras

Reappraisal is viewed as a complex component open to the influences of many variables. Banduras's model of reciprocal determinism illustrates this. The model shows the components of cognition, behaviour, psychology, physiology as reciprocal, with each component acting upon the other components within an integrated system. All of these variables and their relationships affect the reappraisal which the individual makes when coping with stress situations.

The video was filmed in Z-Block of D.D.I.A.E. (see Figure 2). Z102 is the drawing studio and Z103 is the workshop. The camera was mounted on a partition between these rooms. Noise is generated in the workshop and because partitioning is only thin ply extending halfway to the ceiling, noise and dust propagates throughout the building.

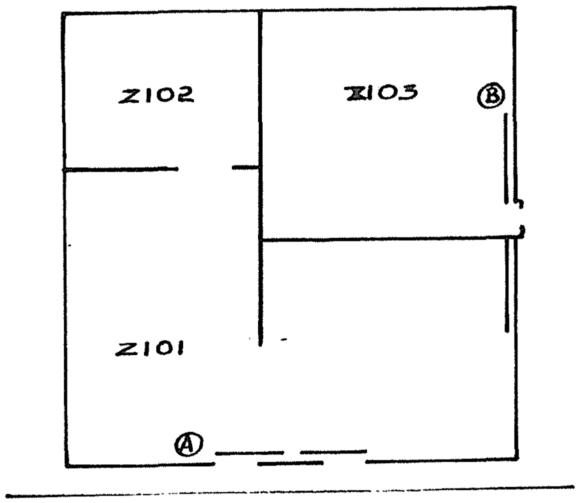


FIGURE 2 Arts Laboratory Building
Z Block - Level 1

Visual observations of students working in the drawing studio were taken using a hidden camera.These students were observed under three conditions - quiet, classical music, and workshop noise.

3.0 RESULTS

3.1 Video Data

Quiet Footage Students show a great deal of concentration and application to their work in this environment.

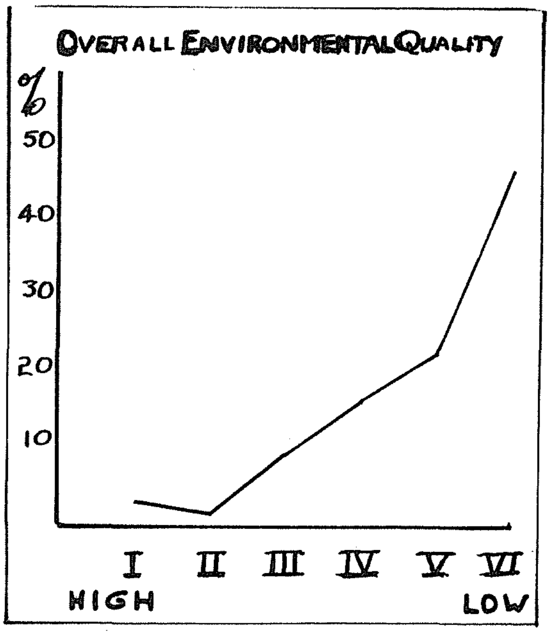
Classical Music With the introduction of the first noise condition, it was observed than an increased arousal level diminished the groups' concentration and encouraged skylarking and other non-work related activities.

Workshop Noise Under the extreme stress of loud intermittent noise, Consisting of electric saws and hammers, more pronounced arousal was noticed and study patterns appeared to be quite fractured. This can be exemplified by a student who arrives to participate in the class and leaves immediately the next burst of noise begins.

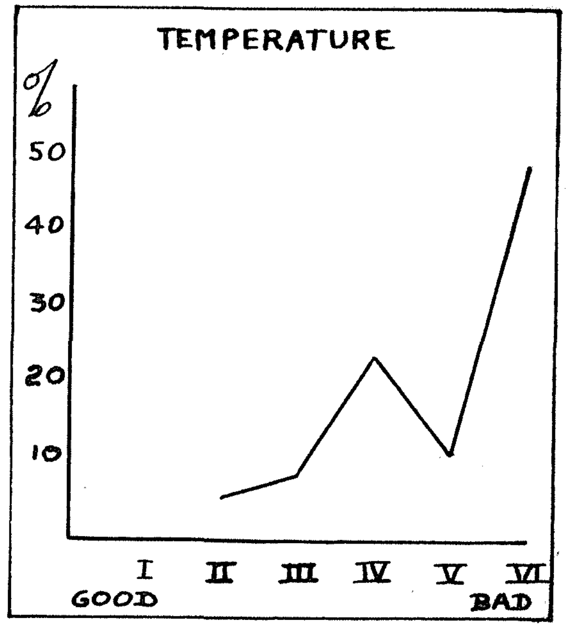
3.2 Statistical Data

To highlight the selfreport data the following empirical data was generated. Graph 1 is an analysis of overall environmental quality based on Joyce Kasmar's (1970) environmental description scale. The individual's response is rated on a one to six scale, with one representing an ideal environment and six indicating an environment of extremely poor quality. In this study the majority, some 85%, of the students responded to the upper end of the scale designating the painting laboratory as low quality environment.

Another ambient condition which previous research has shown to influence environmental quality is temperature. As shown in Graph 2 85% of the students indicated that temperature affected environmental quality.



GRAPH 1

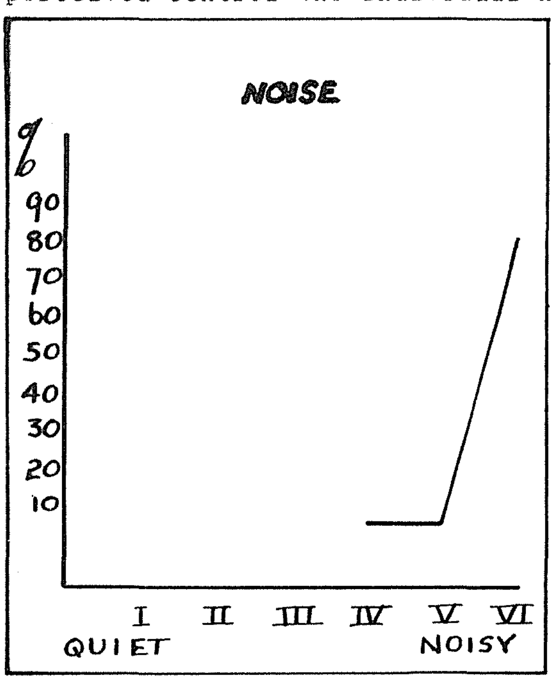


GRAPH 2

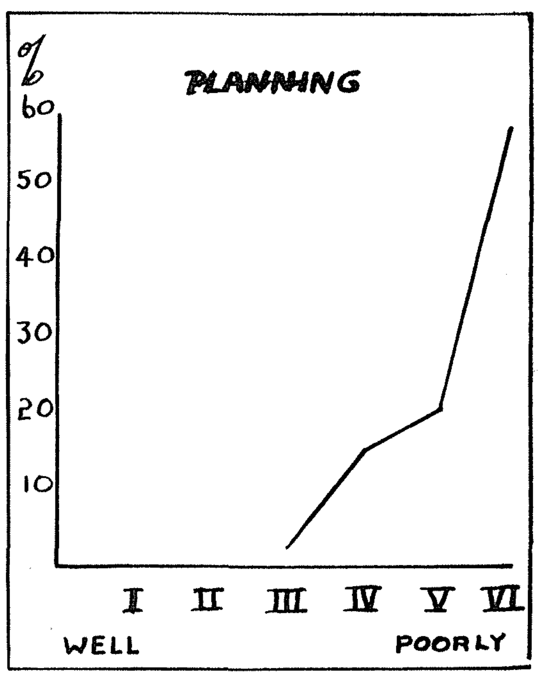
The individual's response to noise is presented in Graph 3.

All of the subjects rated to the upper end of the scale and some 82% thought the noise to be extreme.

Graph 4 shows the student's attitude towards the overall plan of the environment, and as shown, all rated it to the upper end of the scale. Attitude towards the layout of the environment gives a measures of the perceived control the individual has over ambient conditions.



GRAPH 3



GRAPH 4

These pronounced results coupled with other research supporting the detrimental effects of noise on performance and behaviour after exposure provides, impetus for closely examining the design of the painting laboratory environment.

3.3 Psychological Factors

Four psychological factors - creativity, sensitivity to noise, aggression, and social cohesion, were investigated.

Six environmental factors which individuals associated with a reduction in creativity were unpleasant, repelling, gloomy, cramped, disorganized, and poorly planned. The pesent environment was seen as being disorganized and depressing, whereas a creative environment was envisaged as being happy, vibrant, uncluttered and well organized. Such work conditions would lead to increased creative performance because of the reduction in stress and the individual's ability to pursue tasks without adversity.

One would expect temperature to have a dramatic impact on an individual's sensitivity to noise. Our research demonstrated that temperature was both an environmental stressor and a catalyst for noise pollution.

A two way relationship exists between sensitivity to noise and aggression, i.e. people found that aggression heightened their sensitivity to noise, and a noisy environment increased feelings of aggression. Following other research, one would conclude that this aggression and noise sensitivity relationship would also be influenced by the individual's perceived control of environmental stressors.

Significant environmental conditions which affected social cohesion were temperature, noise, poorly planned environment, and stuffy conditions.

4.0 DISCUSSION

4.1 Planning

A poorly planned environment allows subjects little or no control over ambient environmental factors and this will influence individual performance. Research has shown that lack of control enhances the effect of other environmental stressors which may be present. This leads to a breakdown in social cohesion. This is more pronounced when the individual finds rapport essential for pyschological well-being and task performance such as in the setting studied. We concluded that this is a poorly planned environment with some 97% of the subjects rating it in the upper end of the scale. This, as stated by all students interviewed, increased their sensitivity to noise.

4.2 Aggression

Three major factors were of significance in heightening agression - noise, temperature, and control (represented by planning). All of these factors have been shown by previous research to cause heightened arousal. When this arousal cannot be channelled in an appropriate direction it is turned inwardly to bring about a feeling of aggression. Our research showed noise to be the most dramatic of these ambient stressors.

4.3 Social Cohesion

For a study environment to be effective, group rapport is essential. Many factors could influence this but our study was limited to those factors contributed by the environment. Again the previous three ambient conditions were of major significance. Combined with these was an added need for the feeling of spacious surroundings. Individuals found that closeness or stuffiness reduced interaction. Again because temperature, control, and noise were rated so highly on the upper end of the scale indicating them to be adverse conditions, social cohesion can be said to be affected by these environmental stressors.

5.0 CONCLUSION

It is clearly shown that people need to communicate with each other in a study environment. When the environment intrudes upon this communication it becomes a stressor to the individuals within that environment. If the individual must cope with the environment, and if this coping is effective, reappraisal occurs through the Banduras model. In the environment studied, stress is continual and all components of the reappraisal process were found to be affected. The individual must adapt, mediate or retreat from the environment.

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COMMUNITY RESPONSES TO THE NOISE CONTROL ACT 1982

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ABSTRACT

In 1982 the New Zealand Parliament enacted the Noise Control Act which has as its long title "An Act to provide for the abatement of unreasonable or excessive noise".

The provisions of the Act are briefly reviewed and a brief background to the introduction of the Act is presented.

The effect of the introduction of the Act in increasing complaints of noise in Christchurch City is presented. An analysis is made of the sources and types of complaint received for both Christchurch City and from a limited survey over other local authorities, and an indication is given of the possible reasonableness of such complaints.

The predominance of music as a source of complaint is discussed and examples of sound levels measured from popular music concerts held outdoors and the noise from bands at an indoor venue are given.

The problems associated with setting objective sound levels for music are discussed.

1.0 INTRODUCTION

Noise problems have been a matter for legal consideration under the provisions of the common law for a long time, cases being noted in the 1880's, but statute provisions for control of noise have a relatively recent history. At the time of the formation of a Board of Health committee in the early 1970's, set up by the Minister of Health because; "The general public is becomming increasingly conscious of the intrusion of noise upon the individual" (Board of Health, 1974), little specific statute law existed. Under Town Planning legislation noise was mentioned as an objectionable element associated with the use of land that could be controlled under the provisions of that Act. In 1972 the acts controlling the duties of local authorities were amended to permit the making of bylaws regulations, controlling, or prohibiting the making of noise where such noise was likely to cause nuisance or annoyance to persons residing in the vicinity. Non-specific nuisance provisions of the Health Act were stated, and held by the courts, to apply to noise emitted from industries and trade premises affecting nearby residents. Despite the seeming lack of specific provisions the Board of Health committee did not recommend the introduction of any new or specific noise control legislation.

In 1978 the Health Act was amended specifically making noise that was offensive or likely to be injurious to health a nuisance under the Act and permitting the local authority to take action to abate the noise. In 1981 two bills dealing with the control of noise, one by the Minister of Health the other by an opposition member, were introduced. One specifically spelt out provisions relating to noise from residential premises and gave powers to the police to issue directions to reduce noise emitted, the failure to comply leading to seizure or disconnection of the equipment producing the noise. The other, government sponsored bill, placed a duty on every person to take the best practicable means to minimise or reduce noise emitted to a reasonable level. The bill made it the responsibility of local authorities to receive complaints at any time and to enforce the provisions.

The Act as finally introduced in December 1982, with it's provisions to come into force on the 1 June 1983, combined some features of both the above bills. The Act bound the Crown and required local authorities to designate officers as noise control officers. It placed a duty on the occupier of any premises to adopt the best practicable means of ensuring the emission of noise from those premises does not exceed a reasonable level. Failure to do so can lead to the issue of an abatement notice enforceable, if necessary, by the seizure and impoundment of the noise source. Appeal provisions exist against an abatement notice. Excessive noise is defined as noise emitted by any musical instrument, any electrical appliance, any vehicle off the road, any machine operated on residential premises, or persons attending a gathering at any residential premises or place of assembly if the noise unreasonably interferes with the peace or comfort of any person. In such cases a noise control officer or a police constable, if satisfied the noise is excessive, may issue a direction prohibiting the noise. Failure to comply with a direction could lead on conviction to a fine of $2000 with a $200 fine per day for a continuing offence. Power of arrest is given to a constable for any person failing to comply with a direction. A noise control officer requires a constable to accompany him or her to enter a dwellinghouse. Provision exists in the Act to introduce regulations specifying the emissions of noise from premises, appliances, vehicles, or machinery; prescribing standards for alarms; and specifying the times at which specified noises, may or may not, be emitted from premises, appliances, vehicles or machinery. No such regulations have yet been introduced.

2.0 METHODS

2.1 The Local Authorities Survey 1983 This survey was carried out by the use of a questionnaire forwarded to local authority health inspectors through the medium of the journal of the Institute of New Zealand Health Inspectors. A rather poor response was obtained, replies being received only from officers of 8 of 28 cities; 18 of 106 boroughs; and effectively 13 of 100 counties. While the sample was small, results were received from a good spread of authorities in both the North and South Island and the data covered local authorities with a total population of 843,000, about a quarter of the total New Zealand population at that time. Questions asked related to total noise complaints in the period 1 June to 31 December 1983; complaint type and source (whether residential or industrial/commercial; and the time of day and the day of the week the noise first occurred.

2.2 The Christchurch City Council Area Survey This was undertaken from records held in the City Health Department of all noise complaints received for the calender years from 1971 to 1985 and from a card system developed for complaints received since the 1 June 1983. These complaints, and those received previously have been classified to make some distinction between the types of noise complaint on the basis reported here. Since the card system, and a 24 hour answering or recording system has been available, it has been possible to obtain records of when the noise first occurred and since an after hours complaint investigation service has been in effect to enable analysis of the method of dealing with complaints and the perceived reasonableness of complaints.

2.3 Sound Level Measurements All sound level measurements reported have been obtained using Bruel and Kjaer type 4426 or 4427 noise level analysers with Type 4165 ½ inch microphones and Type 2312 alphanumeric printers. The equipment was calibrated prior to the measurement periods with a Type 4230 calibrator.

3.0 RESULTS

3.1 The Local Authorities Survey 1983 When those cases with no complaints or incomplete records were ommitted useable results were obtained from a total of 32 local authorities. These reported a total of 2189 complaints being received in the period of 1 June to 31 December. Residential sources of noise comprised 82.4 percent of this total the remainder being about industrial or commercial sources. Using Spearman's rank difference correlation method a comparison was made between the number of complaints and the populations in each of the types of council areas. The correlation for cities was 0.738; for boroughs 0.773; and for counties 0.666, all significant at better than the 0.05 level of confidence. While these show some positive correlation between total complaints and population an examination of the rate of complaints per 1000 population revealed a wider spread. In the case of cities the range was 0.57 to 4.11, with a mean of 2.44 and a standard deviation of 1.47. In the case of boroughs the range was 0.49 to 6.57, a mean of 2.29 and a standard deviation of 1.57. For the counties the range was 0.09 to 1.69, a mean of 0.69, and a standard deviation of 0.61. The major differention between the categories of local authorities relates to a counties/boroughs and cities split. It would appear housing density and population mix may be determining factors but this was not investigated. A larger percentage of indust- and commercial sourced complaints were apparent in the cities, 20.5 as compared with counties, 15.6, or boroughs, 9.8.

Music related complaints from residential sources predominated, 68.2 percent of the total complaints reported. About a third of the industrial or commercial sourced complaints referred to music being played. Machinery noise from industry accounted for about 18 percent of complaints in this category but over all complaints they accounted for only 3.2 percent of the total.

The majority of noises complained of occurred outside the normal working hours of 8.30 a.m to 5.00 p.m Monday to Friday. Up to 88 percent in cities, 78 percent in boroughs, and 63 percent in counties. Forty-eight percent of noise complaints related to noises occurring on Saturdays and Sundays.

The above is a brief summary of the findings a fuller report having been published in Moody (1984).

3.2 The Christchurch City Council Area Survey Christchurch City is part of the major metropolitan area of the South Island of New Zealand and in 1985 had a population of almost 167,000. It contains the major commercial and industrial areas of the metropolitan area and has a large proportion of the private rental housing stock in the area.

In the tables below the period from 1971 to 1982 and that of 1983 to 1985 have been separated to distinguish the period before the introduction of the Noise Control Act and that following.

TABLE 1

Causes of Complaints of Noise - 1971 to 1985
Residential and Industrial/Commercial Sources

Cause of Complaint	1971-1982		1983-1985		1971-1985	
	Resid.	Indust.	Resid.	Indust.	Resid.	Indust.
Music	62.8	19.5	86.1	47.2	83.5	40.2
Motor Vehicles	14.0	12.2	2.6	3.7	3.9	5.5
Machinery	4.8	27.4	2.2	14.3	2.5	17.6
Compressors	-	12.8	-	4.2	-	6.4
Burglar Alarms	1.0	2.1	1.1	7.7	1.1	6.3
Fans	-	5.4	-	5.3	-	5.3
Construction	4.3	5.8	1.2	4.7	1.6	5.0
Behaviour	3.8	2.1	2.5	6.0	2.6	5.0
Panel Beating	1.5	0.4	0.4	-	0.5	0.1
Animals	-	-	2.2	-	1.9	-
Other	7.6	12.2	1.7	7.4	2.4	8.6
Number	393	467	3071	1372	3464	1839

The predominance of complaints referring to music as a source is apparent in the case of residential sources, and this pattern has persisted over the fifteen year period. It was also apparent in the local authority survey for the period June to December 1983. In that survey music related complaints accounted for over 80 percent of the residential complaints in boroughs and cities and about two-thirds of the residential complaints in counties. The effect of the introduction of the Noise Control Act on the 1 June 1983 shows in the increase in complaints to the extent that 88.7 percent of the total residential sourced complaints over the 15 year period were received between 1983 and 1985.

Complaints of music from industrial or commercial premises are now one of the major categories in this grouping. The local authority survey for 1983 revealed that this was predominantly associated with cities in that 39.5 percent of industrial or commercial sourced complaints were music related compared with 23.5 percent in boroughs and 14.3 percent in counties. The Noise Control Act introduction appears to have increased total complaints in this category with 74.6 percent of the 15 year total occurring in the 1983 to 1985 period.

When complaints for Christchurch City are examined for the period from 1 June 1983 to the end of 1985 it is clear the majority occur outside the normal working hours of 8.30 a.m to 5.00 p.m Monday to Friday. Almost 77 percent of noises leading to complaints commenced outside this time. When those complaints occurring between 8.30 a.m and 5.00 p.m on Saturdays and Sundays are included the percentage rises to 85.5 percent. Over half the complaints refer to noises occurring between 9.00 p.m and 2.00 a.m. In the survey of local authorities of noise complaints for the period June to December 1983 a similar pattern emerged. Overall 73.6 percent of complaints related to noise outside the working hours as above although differences were noted on this pattern on the basis of the type of local authority. In counties 46.7 percent; in boroughs 65.2 percent; and in cities 78.6 percent fell into this pattern. Including Saturday and Sunday complaints in the 8.30 a.m to 5.00 p.m time period as above gave respective percentages of 63.3; 77.5; and 88.3.

TABLE 4

Analysis of Complaints of Excessive Noise - Dealt with by After-hours Service - 1984-1985

Category	% of Category	% of Total
<u>Noise Considered Unreasonable</u>		
Noise reduced by telephone request	16.9	8.7
Noise reduced after officer's visit	73.8	38.0
Noise reduced after police visit	8.7	4.5
Equipment seized and removed	0.7	0.3
Total Unreasonable Noise	100.1	51.5
<u>Noise Not Considered Unreasonable</u>		
No noise on arrival of officer	50.5	20.6
Sound audible but not unreasonable	30.6	12.5
Complaint cancelled before action	18.9	7.7
	100.0	40.8
Complaints unable to be actioned	100.0	7.6

The complaints unable to be actioned included such matters as barking dogs, burglar alarms where keyholders were not available, and complaints about outdoor concerts. Of the 51.5 percent of complaints considered actionable over 90 percent were satisfactorily resolved by the noise control officers, at least on that particular occasion. Police assistance was only required in only 103 cases either because of the possible threatening situation or to carry out the seizure of equipment. In only eight cases has this action been necessary in the 21 months.

Where measurements have been taken of music being played difficulty is often experienced in determining, on sound level grounds, the intrusive nature of the noise. A series of measurements taken near a hotel about which 149 complaints had been received over a period of two and a half years reveal this difficulty. On nights when bands were playing at the hotel the mean L_{10} levels during the periods the band was playing was 50.2 dBA compared with a mean L_{10} of 49.5 dBA for periods when the band was not playing . The respective mean L_{95} levels for the same periods were 42.5 dBA and 39.8 dBA. New Zealand Standard 6802 (Standards Association, 1977) suggests that noise abatement procedures should be commenced when the corrected noise level exceeds the background (L_{95}) by 10 dBA or more, or if the corrected noise level exceeds 45 dBA at a residential boundary. Taking the L_{10} level as the corrected noise level there is little difference between levels with or without the band playing.

In the case of outdoor concerts there is no doubt that measured sound levels reveal a substantial intrusion of sound above pre-existing sound levels. Two major concerts were held at one outdoor venue a year apart. The mean L_1 levels during the concert rose to 75.9 dBA, with a standard deviation of 3.89; the mean L_{10} levels were 62.7 dBA, with a standard deviation of 6.61; and the mean L_{95} level was 52.7 dBA, with a standard deviation of 4.74. These can be compared with respective levels at the same site without concerts of 50.3 dBA; 45.8 dBA; and 38.0. The placement of the speakers had a notable effect on the areas from which the majority of complaints were received. When the speakers were facing towards the south-east 46 complaints were made from an area spreading 5 kilometres to the south-east with a spread of 3.5 kilometres. When the speakers faced the north-west 49 complaints were made from an area spreading 5.5 kilometres to the north-west with a spread of 2 kilometres for the bulk of the complaints. A similar pattern was noted at a concert at another site, this concert being attended by 65,000 people. Thirty complaints were received over a distance of 4.5 kilometres with a spread of 4.7 kilometres to the south-west of the venue. The speakers were facing this direction. Sound levels at a monitoring site about 500 metres to the south-west direction over the concert period gave L_1 levels of 76.5 dBA; L_{10} levels of 71.6 dBA; and L_{95} levels of 52.3 dBA compared with post-concert levels of 58.1 dBA; 53.3 dBA; and 46.5 dBA respectively. At one complaint site 3 kilometres from the concert venue levels measured were L_1 63.8 dBA; L_{10} 59.3 dBA; L_{95} 46.3 dBA compared with those for the same period at the closer monitoring site of L_1 77.3 dBA; L_{10} 72.8 dBA; and L_{95} 49.5. Given such levels and the spread of complaint areas the small proportion of the total population exposed who complained appears surprising.

5.0 CONCLUSION

The introduction of the Noise Control Act obviously created a climate of opinion that any "unwanted sound" heard by citizens of Christchurch City would be able to be stopped immediately. It would also appear from the number of complaints received that Christchurch has a serious problem with noise. There is no doubt that noise has become the major environmental pollutant complained about in the city. A closer examination of the figures reveal, however, that it is a relatively small proportion of the population who complain about noise. Even if it is taken that each complaint since June 1983 (4378) was made by a separate individual these represent only 2.6 percent of the total population. With about 63,000 properties residential, industrial and commercial, in the Christchurch City area the premises complained about (1676) in this period represent about 2.7 percent of the total. It will be appreciated that 40 percent of complaints investigated by the after-hours service are not considered actionable. Given that the after hours service has an average response time of about 20 minutes in almost 70 percent of these cases they were not actionable because the noise was not occurring on, or before, the arrival of the officer. Measurements of noise from bands playing inside commercial premises appear to give few grounds for action on present criteria for such sources.

The outdoor concert demonstrably, on sound level grounds at least, provides evidence of significant intrusion into the pre-existing noise climate. Yet even here the number of complainants are limited. From the wide areas of the city from which complaints are received these represent less than 1 percent of the total population in the geographical area covered. We have attempted to control such concert noise by placing sound level limits of a L_{10} level for the period of the function of 65 dBA and for the sound not to increase the pre-existing background level by more than 10 dBA. In Auckland City permitted levels are a L_1 of 90 dBA and a L_{10} of 80 dBA at residential boundaries of the stadium (Auckland City Council- n.d). In New South Wales the standard is that the L_{10} dBA from the entertainment over 30 minutes shall not exceed the pre-existing background level (L_{90}) by more than 5 dBA at the nearest residential boundary (State Pollution Control Commission, 1985). In Victoria the allowable noise level is the L_{eq} value, 5 dBA above the L_{90} level when measured indoors of a dwelling when the music is playing (Environment Protection Authority, 1984). In London a suggested standard was a L_{eq} 5 dBA above the pre-existing L_{eq} for concerts held on less than 3 days a year and a L_{eq} 1 dBA above the pre-existing Leq for those held more than 4 days a year (Greater London Council, 1978). In Reading, England a standard of 10 dBA (L50) above the existing background for the area was applied (Wallis and Marks, 1983).

It is clear that solutions to control of noise from music in general, and outdoor concerts in particular, are still to be sought and there appears to be little consistency in the types of criteria that are applied. There is no doubt the subjective nature of response to the just audible playing of music makes it difficult to classify on an objective scale. More research is obviously needed on subjective responses to noise from music before we can determine if features of the music in acoustic terms are the determinant of responses, and therefore making it subject to some sort of objective control standards. If, however, the responses relate to the psychological state of the recipient then it may be that behavioural control measures are needed. This distinction needs to be further examined before adequate, and acceptable, control measures can be implemented.

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AUTHOR INDEX