Environmental Noise Measurement

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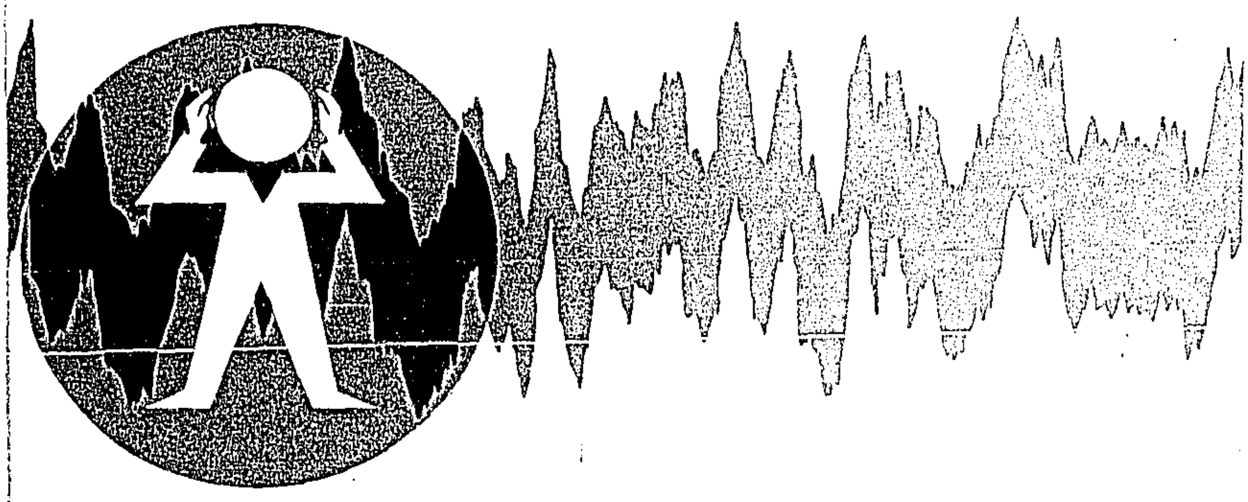
II-A-780



Brüel & Kjær

Introduction

This booklet answers many of the basic questions about environmental noise criteria and environmental noise measurements. It gives a brief explanation of the following:

Background

Environmental (formerly community) noise control has two basic objectives 1) to protect us today against noise intrusions which annoy us and disrupt our daily activities and 2) to protect us in the future against increasing noise levels that would further reduce the quality of our environment.

Noise control activities include legislating noise emission limits on equipment sold and used in our communities, influencing the location and the construction techniques of new highways and buildings, legislating noise emission limits at property boundaries and regulating aircraft flight procedures.

The basic unit of measurement for environmental noise, as recommended by ISO 1996/1, is the dB(A), but other measuring concepts, based on dB(A), are used to provide single-number criteria for describing fluctuating noise and to predict human reaction to the temporal qualities of noise.

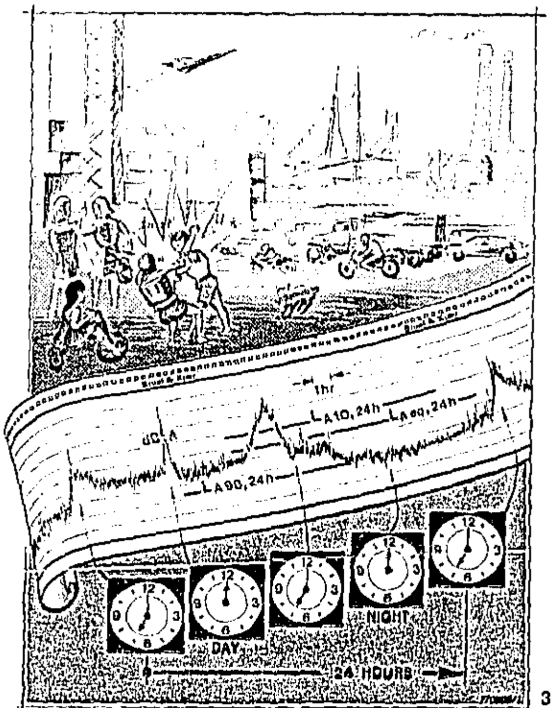
Brüel & Kjær's companion booklet *Measuring Sound* describes the fundamentals of acoustics and the use of Sound Level Meters. This booklet explains the specialized criteria and measuring techniques peculiar to environmental noise.

Ambient Noise

Ambient noise includes all sounds present in an environment. The ambient noise level may be measured at any moment, but it will vary widely with time, e.g., with the coming and going of trucks and aircraft. Traffic noise is higher at noon than at midnight and higher still during the morning and evening rush hours. Therefore a single dB(A) measurement says very little about ambient noise.

Complete noise histories can, however, be recorded graphically, but, such charts are unwieldy and cannot be condensed to fit easily into reports, furthermore, they are difficult to interpret and describe verbally. They give too much raw data, a frequent problem in dynamic measurements, which has created the need for simple noise descriptors.

One such descriptor, recommended by ISO 1996/1, is $L_{Aeq,T}$, the equivalent continuous dB(A) level which has the same energy as the original fluctuating noise for the same given period of time T. $L_{Aeq,T}$ is an excellent criterion for studying long-term trends in ambient noise. However, it does not convey any measure of environmental noise variations which is also an important factor when considering human response. To overcome this ISO 1996/1 recommends measuring percentile levels, $L_{AN,T}$, i.e. that dB(A) level which is exceeded for $N\%$ of a stated time period T. Percentile levels reveal maximum and minimum noise levels. They are used in baseline studies and in environmental impact statements to protect against new highways and new industrial plants degrading the acoustic quality of the environment.

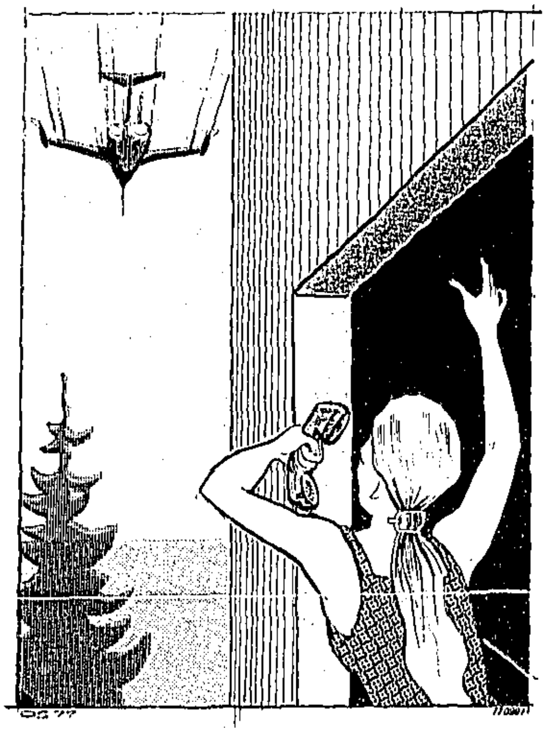


Noise Intrusions

Noise intrusions are characterized by their transient quality. Typical examples are motorbikes, trucks, aircraft, road drills and sirens. Their noise stands out far above all other sounds, and they interrupt without warning such personal activities as sleep, study, entertainment, relaxation and conversation. Noise intrusions are especially annoying when they are needless, e.g. the acceleration of a noisy motorbike or a car operating with a faulty silencer.

National standards frequently guarantee the availability of new and quieter automotive vehicles by limiting, through legislation, their maximum allowable noise emission. It then becomes the responsibility of local authorities to set maximum operating noise levels to ensure that silencer systems are properly maintained, that replacement silencers and tyres preserve the original low noise emission and that the vehicles are not operated in a manner that produces excessive noise. Noise enforcement limits are usually set as the maximum allowable dB(A) level created during a vehicle pass-by.

Aircraft noise emission is also controlled by national standards, so too is airport noise by regulating flight procedures to protect the maximum number of people from fly-over noise, particularly during nighttime hours.



Property Boundary Noise

Property boundary regulations protect us against noise intrusions from neighbours, industry, commercial establishments and construction sites.

Noise codes are most useful during evenings and weekends and also during warm seasons when windows are open and there are outdoor activities. The noise of industry may well be masked by traffic noise during weekdays, but in the evenings and on Sundays the same noise can be very offensive.

Inappropriate noise also plays a large part in human reaction: we accept our neighbour's motor mower on Saturday morning, but we are terribly upset if he operates it on Sunday afternoon. We are also offended if a discotheque spreads noise throughout the neighbourhood because doors and windows are left open.

Audible pure tones frequently cause even low-level noise to be intolerable. We find audible pure tones in noise emitted by power transformers, turbine generators and air-moving equipment.

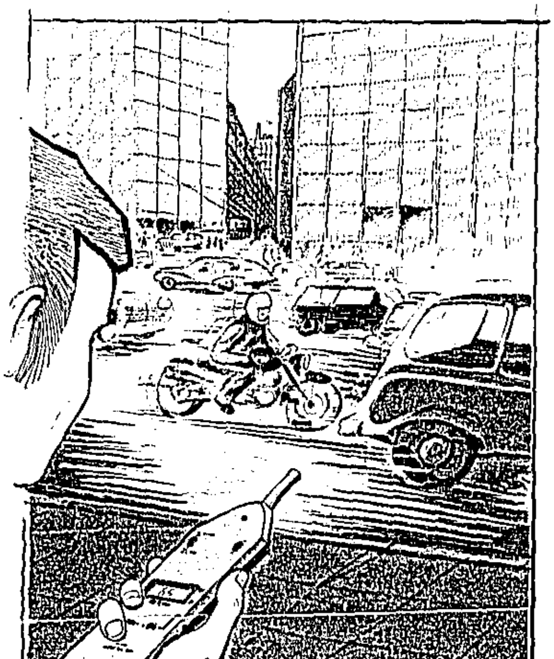
Noise emission limits at property boundaries are usually expressed in dB(A). Some noise codes recognize the excess irritation caused by prominent pure tones in noise spectra and legislate also against them.

Measuring dB(A)

The most common measurement in environmental noise is the dB(A) level. It can be measured with a simple Sound Level Meter having an A-weighting filter to simulate the subjective response of the human ear. The dB(A) level is used to report ambient noise and noise intrusions. It is also used in computing $L_{Aeq,T}$ and $L_{AN,T}$.

Ambient noise should be measured with the Sound Level Meter switched to its "F" (Fast) time weighting. The range of ambient noise fluctuations should also be reported, e.g. 54 to 58 dB(A). When measuring noise intrusions, the maximum level should be reported, to assist in this some Sound Level Meters have a Max-Hold mode in which electronic circuitry captures and holds on display the highest measured dB(A) level. In automotive noise enforcement, the Max-Hold feature is an advantage because it does not require an experienced operator and the data is more credible in court testimony.

Graphic Level Recorders are available for recording the noise history of transient events and of long-term environmental conditions.



Equivalent Continuous Level

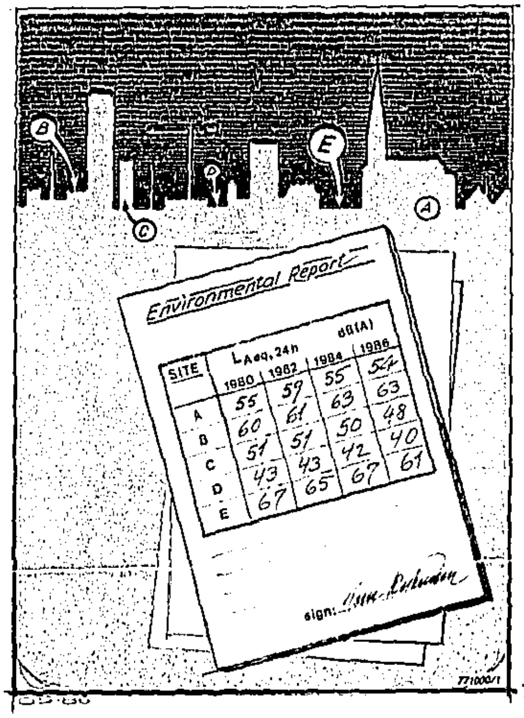
For studying long-term trends in environmental noise, it is convenient to use a single-number descriptor e.g. to define an entire day's noise history. The descriptor most often used is $L_{Aeq,T}$, i.e. that continuous dB(A) level which would have produced the same A-weighted sound energy in the same time T as the actual noise history.

The simplest instrument for measuring $L_{Aeq,T}$ is an Integrating Sound Level Meter. It both monitors noise and computes $L_{Aeq,T}$. When reporting $L_{Aeq,T}$, the period of observation T is frequently understood to be 24 hours unless otherwise stated. Quite often $L_{Aeq,T}$ measurements are also required for intermediate periods (normally two to three within a 24 hour period) to determine how noise varies with time and hence community activities.

Variations on $L_{Aeq,T}$ are L_{dn} and *CNEL*. In L_{dn} measurements 10 dB is added to nighttime levels from 2200 to 0700 hours to account for the fact that people are less tolerant of noise during their sleeping hours. *CNEL* has in addition 5 dB added to evening levels from 1900 to 2200 hours.

In most cases the calculation of $L_{Aeq,T}$ is based on closely spaced samples of the instantaneous sound pressure. There is however a method known as *"Taktmaximalpegel"* in the Federal Republic of Germany which bases the calculation on the maximum A-weighted sound levels ocurring in successive intervals of 3 s or 5 s. These levels are designated $L_{Tm,3}$ and $L_{Tm,5}$ respectively and can be measured directly on special Sound Level Meters.

A Noise Level Analyzer is available for measuring and reporting all the descriptors mentioned above as well as the statistical data described in the following.



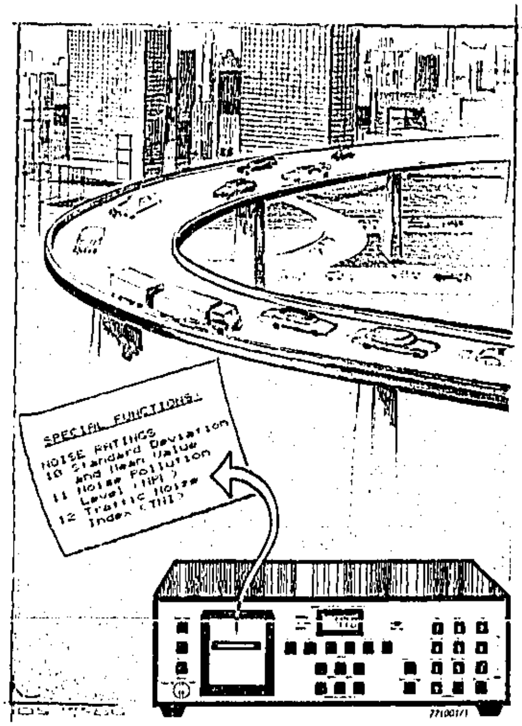
Statistical Amplitude Distribution

Human response depends greatly upon the range with which noise levels vary in a given environment. For a given $L_{Aeq,T}$ we would find a higher, more steady, level more tolerable than a lower background level with frequent noise intrusions.

The statistical descriptor for the variation of noise is $L_{AN,T}$, i.e. that dB(A) level exceeded for N% of the time T. For example, $L_{A90,T}$ is used to estimate the residual background noise level in the environment whereas $L_{A1,T}$ or $L_{A10,T}$ is used to estimate maximum levels. The complete range of $L_{AN,T}$ levels, known as the cumulative distribution, can be measured directly using specially designed Sound Level Meters or Noise Level Analyzers; these instruments are also capable of measuring the corresponding probability distribution of the noise levels.

$L_{AN,T}$ and $L_{Aeq,T}$ values are used to evaluate existing noise environments in order to control the impact of predictable noise sources such as highways and construction sites.

Two environmental noise ratings make use of the descriptors mentioned here and on the previous page. The first is called the Traffic Noise Index, *TNI*, and the second is called the Noise Pollution Level, *NPL*. Both ratings can be measured directly using a Noise Level Analyzer.

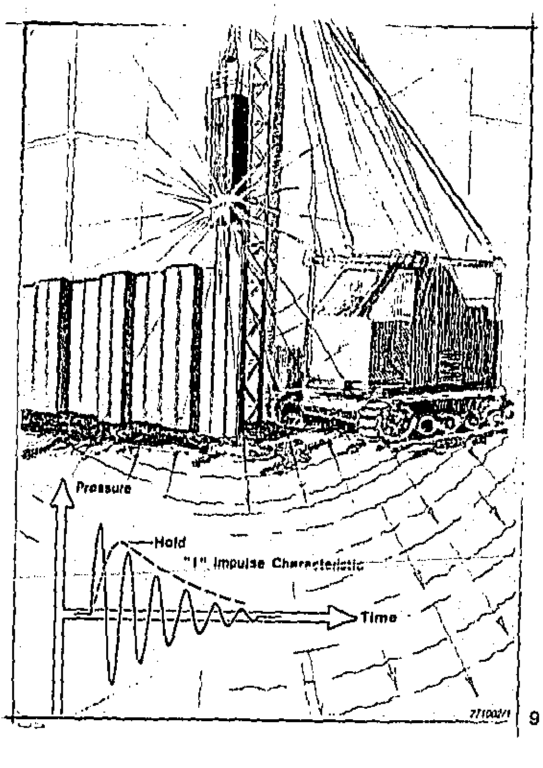


Impulsive Noise

Impulsive sounds are greater contributors to human annoyance than slower transient sounds even when both produce the same reading on a Sound Level Meter set to its "F" time weighting. The greater annoyance is partly due to their startling effect as well as to the fact that the human ear responds faster than the circuitry in the the Sound Level Meter and therefore perceives a higher "reading" before the sound begins to decay.

Some national standards for measuring environmental noise require the use of Sound Level Meters also equipped with an "I" (Impulse) time weighting to evaluate sources such as pile drivers, forge hammers and punch presses all of which emit impulsive noise. In the "I" mode the rise time of the circuitry is about 4 times faster than in the "F" mode. This simulates the response time of the human ear. The circuitry also incorporates a hold feature which captures and holds the maximum displayed level for as long as reqired by the operator.

In the Federal Republic of Germany L_{Tm3} and L_{Tm5} are quite often measured using the "I" time weighting.

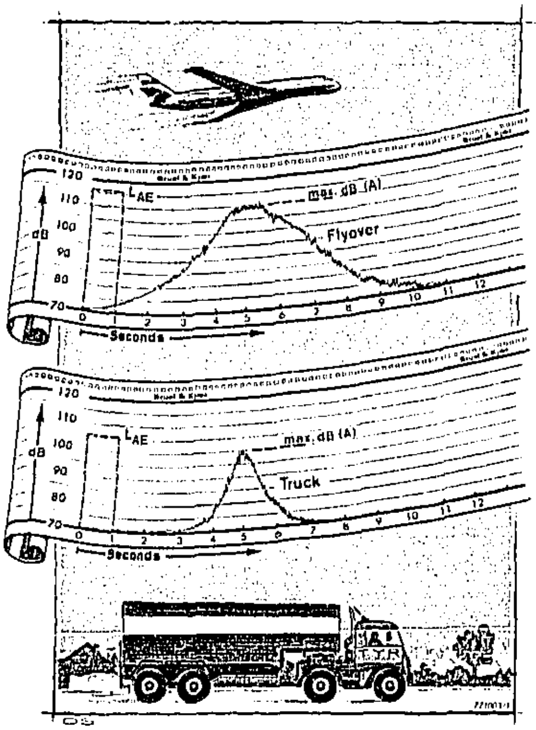


Transient Noise

The most commonly encountered transient noise levels come from vehicle pass-bys and aircraft flyovers. In nearly all cases the maximum dB(A)* level of a transient needs to be measured. However, this does not say anything about the acoustic energy of the transient which is an important subjective consideration. To overcome this ISO 1996/1 recommends measuring the Sound Exposure Level (*SEL*), L_{AE}, which is a measure of the acoustic energy in a transient noise. *SEL* is defined as that level which, lasting for one second, has the same acoustic energy as the transient noise.

The *SELs* of a series of unrelated transient noise events can be compared with each other because they are a measure of acoustic energy: furthermore they can be combined on an energy basis like normal sound levels and then quite simply be converted to an $L_{Aeq,T}$ value acting over any specified time *T*.

SEL can be measured directly on certain Integrating Sound Level Meters and on a Noise Level Analyzer. The latter can also be used to monitor environmental noise levels and print out periodic reports, at preselected time intervals, of various environmental noise ratings.



* Most flyover noise is measured in dB(A). However, some regulations require the use of dB(D). The D-weighting filter amplifies spectral components between 1 and 10 kHz to account for the presence of annoying pure tones in jet noise spectra.

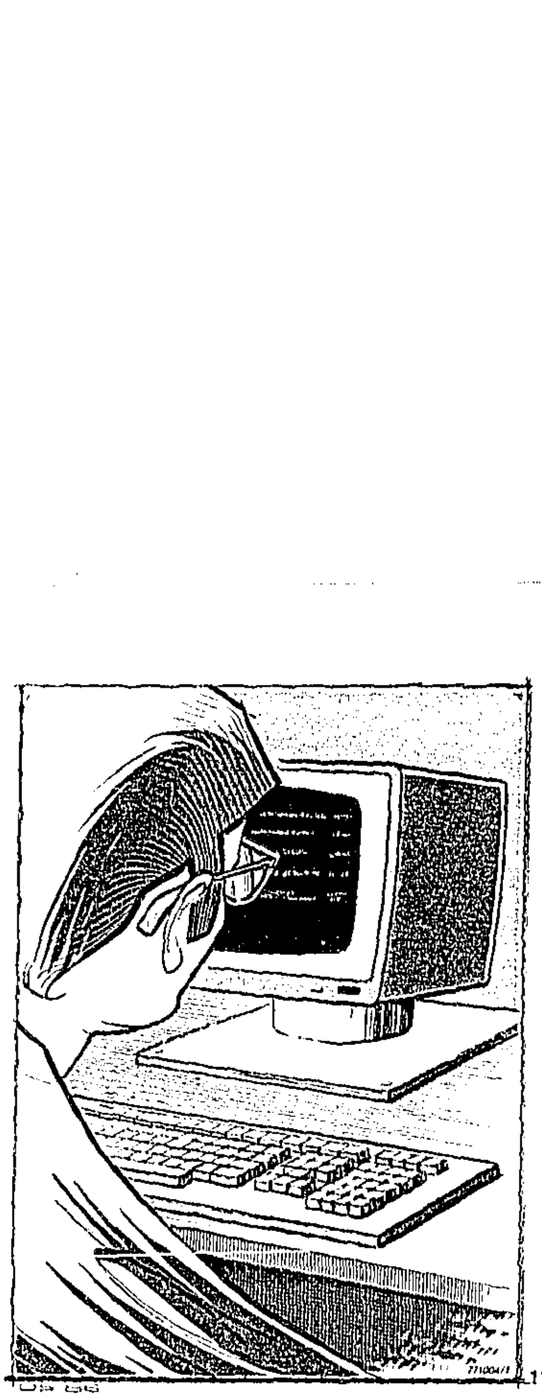
Airport Noise Monitoring

With the multitude of flight operations around even medium-sized airports, it is not possible to answer complaints or reprimand violators without documenting the time and level of excessive flyover noise. This necessitates a system for monitoring airport noise automatically.

The first requirement is one or more outdoor noise monitoring terminals (NMTs) each equipped with a microphone unit which can operate year-round under all weather conditions. The NMTs must transmit noise data to a computer based central processing station at the airport and also be capable of remote calibration.

The central processing station must, for each NMT, detect all noise levels which exceed certain thresholds and legal limits, identify the corresponding NMTs, report all data above the threshold and report the time of day of the maximum dB(A) level of the event (normally with "S" time weighting). Quite often the system will also be required to calculate and report the *SEL* and the $L_{Aeq,T}$ of the event as well as overall statistics, i.e. selected values of $L_{AN,T}$ for each NMT.

Airport noise monitoring enables airport authorities to identify and caution offending pilots and airlines. Equally important, airport noise monitoring can provide well-documented data which airport authorities can use to discuss present conditions and long-term trends with local residents as part of their program to improve community relations.



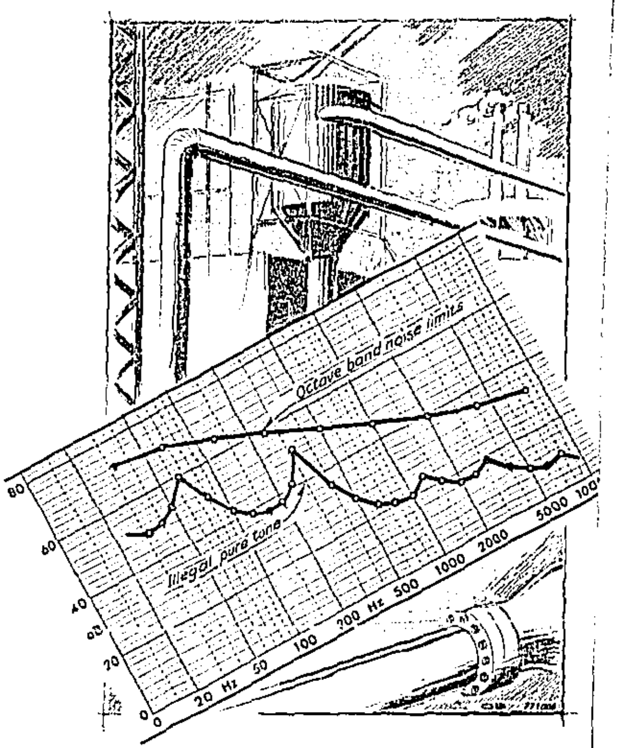
Identifying Pure Tones

When pure tones are present in a noise spectrum, the dB(A) level is not adequate to predict human response because pure tones, especially at high frequencies, are much more annoying than a broadband noise of the same level.

Pure tones are often present in sounds emitted by industrial equipment such as blowers, electrical generators, high-speed machinery and power transformers. Although our ears can detect prominent pure tones in a noise spectrum, it is not possible to confirm or quantify them with a Sound Level Meter alone; One-Third Octave Band Filters must be used.

Some environmental noise regulations limit the emission of pure tones at property boundaries. One noise code confirms the presence of a pure tone if its one-third octave band level exceeds the arithmetic average of the two adjacent bands by (1) 15 dB for bands centered on 25 Hz to 125 Hz, (2) 8 dB for bands centered on 160 Hz to 400 Hz and (3) 5 dB for bands centered on 500 Hz to 10 kHz. If a pure tone is confirmed, then its one-third octave band level must be at least 10 dB below the specified octave band limit for broadband noise.

Field measurements are made with a Sound Level Meter Fitted with a set of One-Third Octave Band Filters.



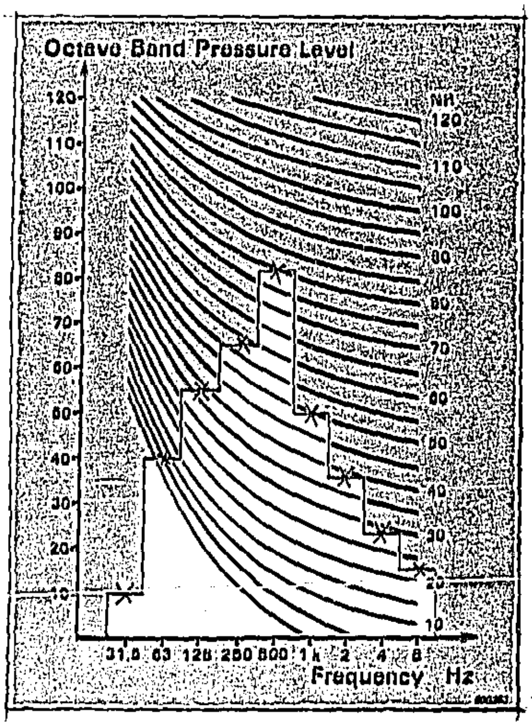
Octave Band Analysis

Community authorities must often work with local industry in evaluating various proposals for noise control, e.g. will a proposed noise barrier or enclosure be effective in shielding nearby residents? They must also work with building contractors to ensure that apartments are insulated from outdoor noise as well as from each other.

Octave band frequency analysis is required to investigate a noise source and to predict the necessary insulation characteristics of noise barriers and enclosures and to measure noise reduction between common walls of adjacent apartments. Octave band analysis is also invaluable when an existing noise control system must be redesigned because this will assist in defining the minimum modifications necessary to enable the system to meet required specifications.

Octave band analysis is performed using a Sound Level Meter fitted with a set of Octave Band Filters.

In cases where noise levels are steady, Noise Rating curves (NR-curves) are sometimes used with octave band data to determine the annoyance level of environmental noise. In keeping with the characteristics of human hearing, NR-curves put more weight on higher frequencies. When the octave band spectrogram of a particular noise is superimposed on these curves, the rating number for the noise as a whole is obtained by noting where the spectrogram penetrates the highest numbered curve; in the example shown the Noise Rating is 80.

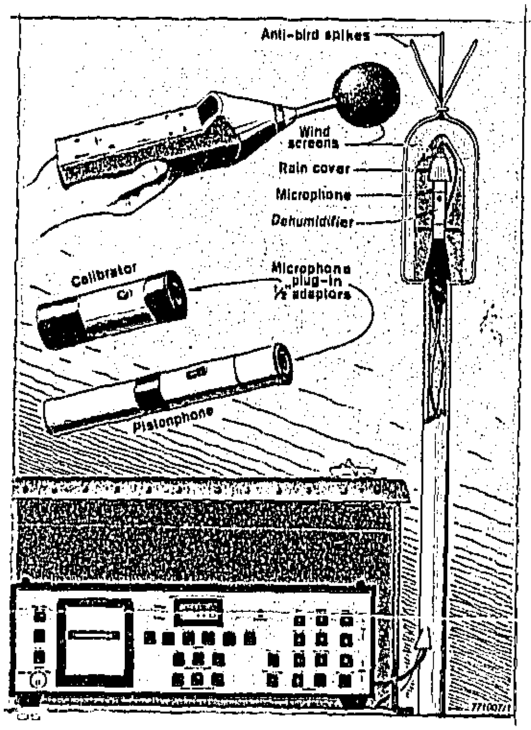


Field Equipment and Accessories

When measuring noise outdoors, precautions should be taken against wind which can create extraneous noise as it passes over the microphone. A suitable windscreen may be fitted over the microphone to prevent this. Windscreens should be used whenever there is a noticeable breeze or when standard procedures require them. They also shield the microphone from dust and dirt.

When outdoor measurements have to be made for a day or more under humid conditions then use should be made of back vented microphones fitted with a dehumidifier accessory. If measurements are to be made in the rain, then a rain cover should be mounted on the microphone. The electronics, which in most cases will be a Noise Level Analyzer, must be placed in a suitable weatherproof shelter and connected to the microphone assembly via an extension cable. The effects of other environmental conditions can be considered negligible.

An acoustics calibrator is required to verify that the chain of sound measuring instrumentation is measuring properly and accurately. Calibrations are usually performed before and after each day's measurements or whenever standard procedures require them.

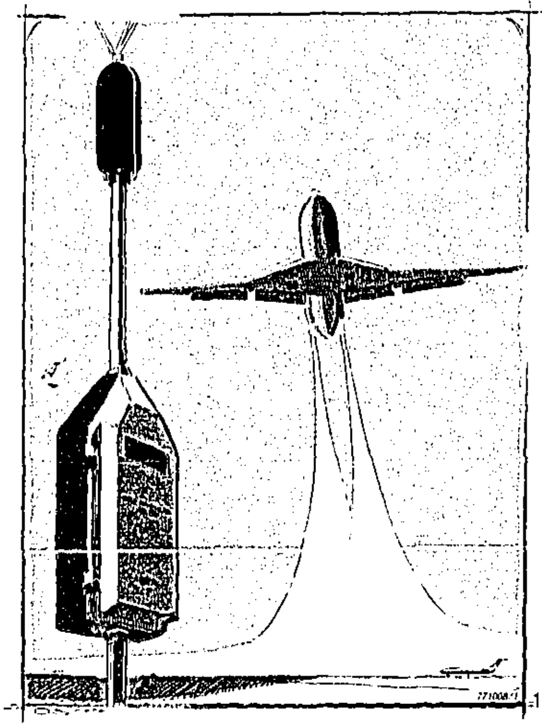


Permanent Outdoor Microphone Units

A permanent Outdoor Microphone Unit must withstand the rigours of outdoor conditions for long periods without maintenance. It must be free of the effects of temperature, humidity, snow, rain and air pollution; and it must deter birds from perching on, and soiling, the microphone assembly.

The various components and protective devices of a permanent outdoor microphone unit must be designed as a system to preserve the frequency response and omnidirectional characteristics of a Sound Level Meter.

The built-in electronics must be capable of driving long lines, if necessary, back to a data acquisition station. They must also have a built-in calibrator which can be remotely actuated from the data acquisition station.

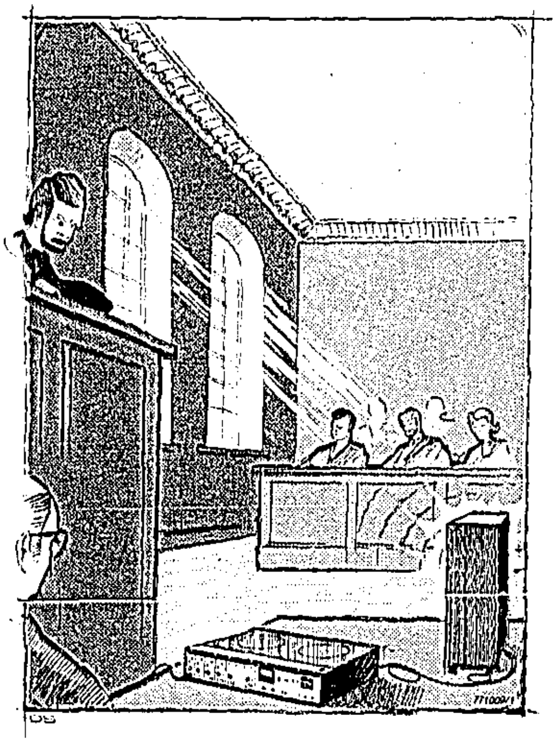


Tape Recorders

The role of Tape Recorders has changed over the years. They are seldom necessary anymore for temporary signal storage because analysis equipment such as Noise Level Analyzers, Modular Sound Level Meters, Integrating Sound Level Meters, Graphic Level Recorders and Octave and One-Third Octave Band Filters are all available as compact battery-operated instruments for direct measurements in the field.

Tape Recorders are essential, however, when you wish to analyze data exhaustively by various methods and when you wish to store today's data for evaluation to possible new criteria in the future. Tape Recorders are also valuable in court testimony for demonstrating annoying sounds.

Portable Instrumentation Tape Recorders usually have two or four channels and use Sound Level Meters for their input and operate from internal batteries.



The Measurement Report

Environmental noise data is often used in legal proceedings. In fact, you should always collect data with the assumption that it may some day have to be examined in court testimony. Therefore it is of utmost importance that the conditions of the measurement be carefully documented in a formal measurement report.

The following information should be reported.

1. Model, manufacturer and serial number of each instrument used.
2. Date of last laboratory calibration.
3. Statement of on-site calibration verification before and after each series of measurements.
4. Time and frequency weighting networks used.
5. Location of micophone and description of area.
6. Time and date of measurement.
7. Weather conditions.
8. Residual noise level, if measuring noise intrusions.
9. Names of observers.
10. Description of the measurement and all instrument readings.

A comprehensive and carefully documented formal report has the best chance in any legal proceedings or in any noise control negotiations settled out of court.

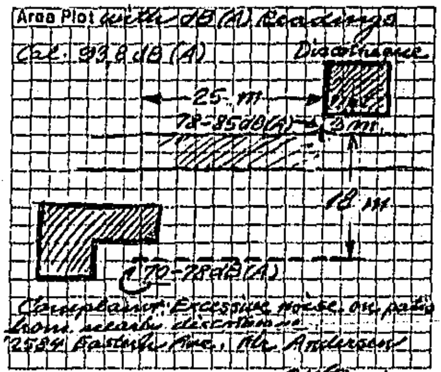
Noise Investigation Report

Place: City of New Hope

Date: 7.8.86 Time: 2145

Instruments: B&K SLM 2230 · 1028340
B&K Calibrator 4230 · 1168789
Properties #35-6210A & 35-62110

Weighting: "A" Response: "F"



Signed: A W Clark

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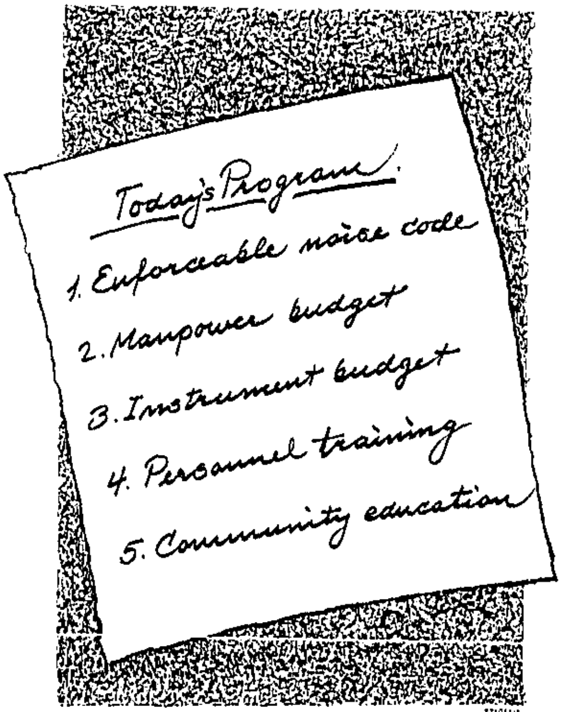
Reducing Noise Levels Today

An early step in any noise control program is to have a technically qualified person draft a noise code that follows successful codes in similar sized communities and can be enforced within the allowable budget of manpower and money. The noise limits must not be higher than prevailing local or national codes. And the code should provide for successively lower limits in future years as technological improvements and other noise control forces are reflected in quieter products. Lastly, there should be adequate plans for training personnel who will be involved in enforcing the noise code.

The code should cover vehicle noise, industrial and residential boundary noise and any other noise considered to be a public nuisance. The noise code must define the measurement location with respect to the sound source, the maximum allowable noise levels and the Sound Level Meter time and frequency weightings. If the community has an airport, restrictions should be set on sideline (lateral) and flyover noise.

The proposed legislation should be accompanied by favorable publicity so the public will view it as a means to improve the community and not as an interference with their freedom of action.



Planning for the Future

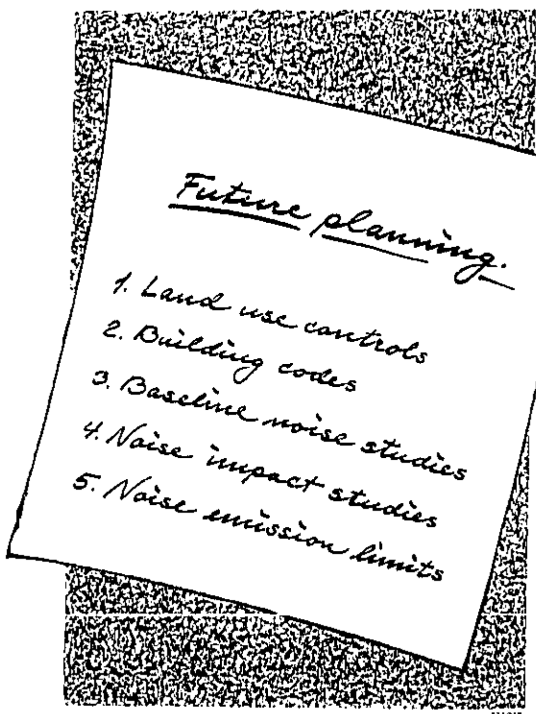
Land-use planning is a major factor in preventing future noise problems. For example, land-use planning can prevent the building of single-family homes in areas where an airport is expected to expand in the future or where a new motorway is planned.

Building codes can require adequate acoustic insulation to shield apartment dwellers from their neighbours and from highway and aircraft noise.

Boundary noise limits and zoning controls give communities the authority to control the noise impact of new industry and commercial establishments.

At higher levels of government, noise emission limits on new vehicles and other powered equipment are a great help in lowering ambient noise levels in the future.

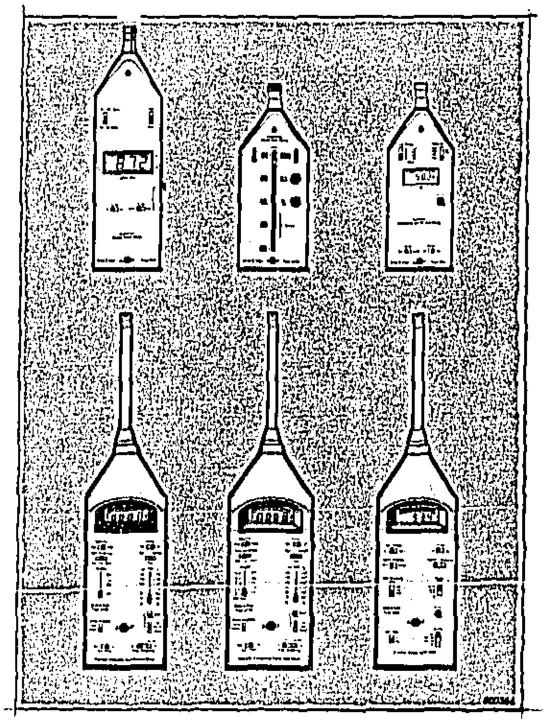
Finally, a well-organized program for periodic environmental noise studies will prove whether or not the battle against noise is successful.



Sound Level Meters

Most environmental noise investigations begin with measurements using a Sound Level Meter. The scope of the measurements will usually decide what type of instrument should be used and with which standards it must comply. A wide variety of Sound Level Meters is available covering requirements for simple noise surveys, where only dB(A) levels need to be measured, to elaborate measurements where Equivalent Continuous Levels ($L_{Aeq,T}$), Sound Exposure Levels (*SEL*), maximum, minimum, impulse and peak levels are required. Furthermore, there are Sound Level Meters available for national standards which differ from international standards.

Octave and One-Third Octave Band Filter sets are available for the three more elaborate instruments shown here in the bottom row.



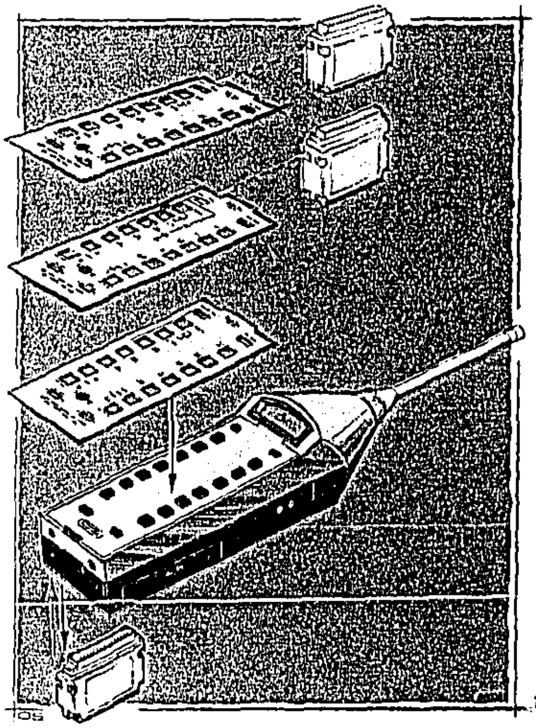
Modular Sound Level Meter

The Sound Level Meters discussed on the previous page can be considered as dedicated instruments with unchangeable capabilities. A Modular Sound Level Meter, on the other hand, can undergo electronic "firmware" changes to suit different measurement requirements. This is done by selecting an appropiate application module having a particular set of instructions which can be loaded into the firmware of the instrument. A corresponding change of front panel is also made possible.

Three appropiate application modules, designated 1, 2, and 3, provide capabilities which convert the instrument to the following:

1. Precision Integrating Sound Level Meter capable of measuring $L_{Aeq,T}$ and *SEL*
2. Statistical Analyzer capable of measuring $L_{AN,T}$ ($1 \leqslant N \leqslant 99$) and probability distribution
3. "Taktmaximal" Precision Integrating Sound Level Meter capable of measuring $L_{Aeq,T}$ and *SEL* according to German standards

In addition the application modules also provide the instrument with other useful capabilities usually found on elaborate dedicated Sound Level Meters.

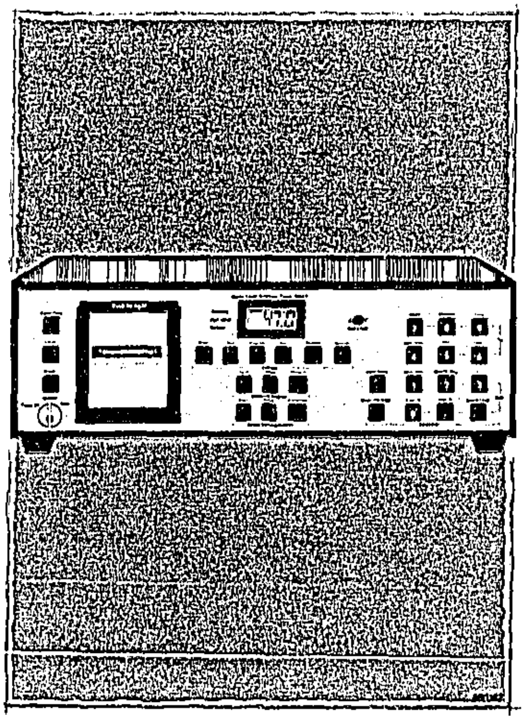


Noise Level Analyzer

It is widely recognised that the annoying element of noise depends not only on frequency content (A-weighting) and energy content ($L_{Aeq,T}$, *SEL*) but also on its fluctuating nature. Statistical analyses are therefore necessary to determine noise levels which are exceeded for given percentages of the measurement duration, i.e. percentile levels $L_{AN,T}$.

The Noise Level Analyzer is a portable instrument designed for the measurement and analysis of environmental noise, airport noise, traffic noise and any other noise where statistical analysis is useful. The instrument is also capable of measuring Equivalent Continuous Level ($L_{Aeq,T}$), Sound Exposure Level (*SEL*), Noise Pollution Level (*NPL*), Traffic Noise Index (*TNI*), Day-Night Average Sound Level (*DNL*) and Community Noise Equivalent Level (*CNEL*) over required intervals and produce print-outs containing all results and plots of statistical data.

The instrument performs noise measurements according to IEC 651, ANSI 1.4 and German *"Taktmaximal"* standards.



Glossary of terms

The following terms are used for describing environmental noise.

A-weighted Sound Pressure Level, L_{pA}: A measure of noise levels, in dB(A), using the A-(frequency) weighted network. A-weighted sound pressure levels correlate well with subjective loudness.

Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq,T}$: That constant level in dB(A) which, lasting for as long as a given A-weighted noise event, i.e. for a period of time T, has the same amount of acoustic energy as the given event.

Sound Exposure Level (*SEL*), L_{AE}: That constant level in dB(A) which, lasting for one second, has the same amount of acoustic energy as a given A-weighted noise event.

Day-Night Average Sound Level (*DNL*), L_{dn}: A 24-hour equivalent continuous level in dB(A) where 10 dB is added to nighttime noise levels from 2200 hours to 0700 hours.

Community Noise Equivalent Level (*CNEL*), L_{den}: A 24-hour equivalent continuous level in dB(A) where 5 dB is added to evening noise levels from 1900 hours to 2200 hours and 10 dB is added to nighttime noise levels from 2200 hours to 0700 hours.

Percentile Level, $L_{AN,T}$: That noise level in dB(A) exceeded for N% of the measurement time T.

Noise Pollution Level (*NPL*), L_{NP}: A variation on $L_{Aeq,T}$ which accounts for short term variability in noise level. L_{NP} is defined as:

$$L_{NP} = L_{Aeq,T} + 2{,}56\,\sigma$$

Where σ is the standard deviation of the dB(A) levels. For a gaussian distribution of dB(A) levels the term $2{,}56\,\sigma$ can be replaced by $(L_{A10,T} - L_{A90,T})$

Traffic Noise Index, *TNI*: Introduced as a descriptor of road traffic noise, it is defined as follows:

$$TNI = 4\,(L_{A10,T} - L_{A90,T}) + L_{A90,T} - 30$$

Perceived Noise Level, L_{PN}: A complex rating based on one-third octave band data used to certify aircraft types for flyover noise. An approximation is given by adding 13($\pm$ 3) dB to the measured A-weighted noise level.

Effective Perceived Noise Level, L_{EPN}: This is the result of applying tone and duration corections to the Perceived Noise Level based on one-third octave band data.

Noise Exposure Forecast, *NEF*: A complex criteria for predicting future noise impact of airports. The computation considers the effective perceived noise level of each type of aircraft, flight profile, number of flights, time of day, etc. Generally used in plots of equal NEF contours around airports for zoning control.

We hope this booklet has served as an informative introduction to environmental noise measurements. If you have other questions about measurement techniques, instrumentation or standards used in your own country, contact your local Brüel & Kjær representative or contact us directly.

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