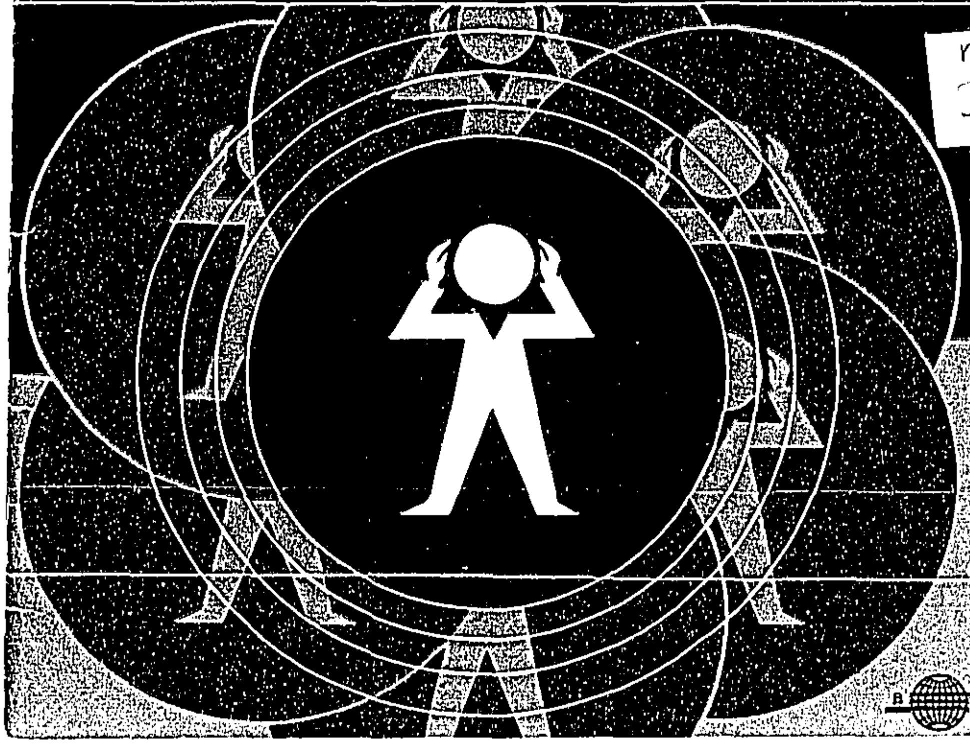
# Measuring Sound





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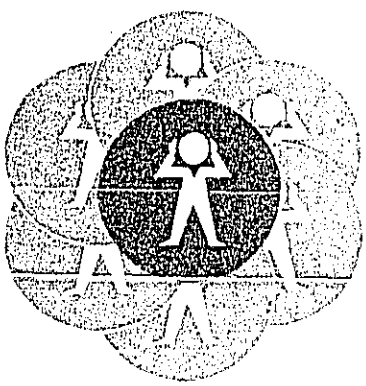
# Introduction



This booklet gives answers to some of the basic questions asked by the newcomer to a noise measuring programme. It gives a brief explanation to questions like:

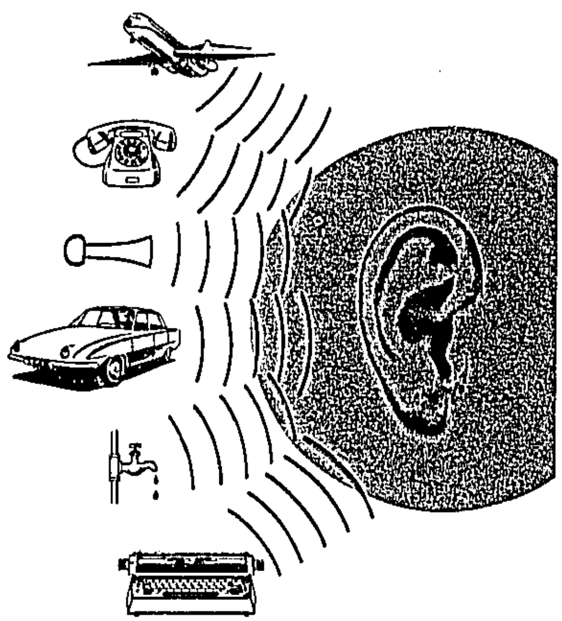
**What do we measure sound?**
**What is sound?**
**What units do we use for measurement?**
**What do we hear?**
**What instruments do we use for measurement?**
**What is a weighting network?**
**What is the meaning of meter response characteristics?**
**What is frequency analysis?**
**How does sound propagate?**
**Where should we measure?**
**How should the microphone be positioned in the sound field?**
**How much do reflections influence our measurement?**
**What about background noise?**
**How does the environment influence our measurement?**
**How do we make a measurement report?**
**Which standards should be used?**
**What is noise mapping?**
**What is noise rating?**
**What is noise dose?**
**What do we do when levels are too high?**

## Sound and the Human Being

Sound is such a common part of everyday life that we rarely appreciate all of its functions. It permits us enjoyable experiences in listening to music or to the singing of birds. It permits spoken communication with family and friends. It alerts us or warns us — with the ringing of a telephone, a knock on the door, or a wailing siren. And sound permits us to make quality evaluations and diagnoses — the chattering valves of a car, a squeaking wheel, or a heart murmur.

Yet, too often in modern society, sound annoys us. Many sounds are unpleasant or unwanted — hence we call them noise. However, how much a noise annoys depends not only on its quality, but our attitude to it. To the design engineer, the sound of his new jet aircraft taking off may be music to his ears, but will be earsplitting agony for the people living near the end of the runway. But sound doesn't need to be loud to annoy. A creaking floor, a scratch in a record, or a dripping faucet may annoy as much as loud thunder.

Worst of all, sound can damage and destroy. A sonic boom may shatter windows and break plaster off the walls. But the most unfortunate case is when sound damages the delicate instrument designed to receive it — the human ear.



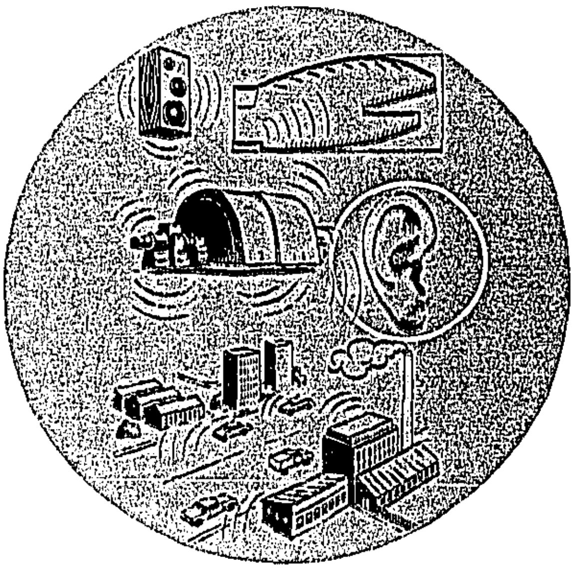
# Why Measure Sound?

The benefits of sound measurements are many. Sound measurements have resulted in improved building acoustics and loudspeakers thus enhancing our enjoyment of music, both in the concert hall and at home.

Sound measurements permit precise, scientific analysis of annoying sounds. However, we must remember that due to the physiological and psychological differences between individuals, the degree of annoyance cannot be scientifically measured for a given person. But the measurements do give us an objective means of comparing annoying sounds under different conditions.

Sound measurements also give a clear indication of when a sound may cause hearing damage and permit corrective measures to be taken. And audiometric testing permits evaluation of an individual's hearing sensitivity. Thus, sound measurements are vital in hearing conservation programs.

Finally, measurement and analysis of sound is a powerful diagnostic tool in noise reduction programs — from airports, to factories, highways, homes and recording studios. It is a tool that permits the improvement of the quality of our lives.

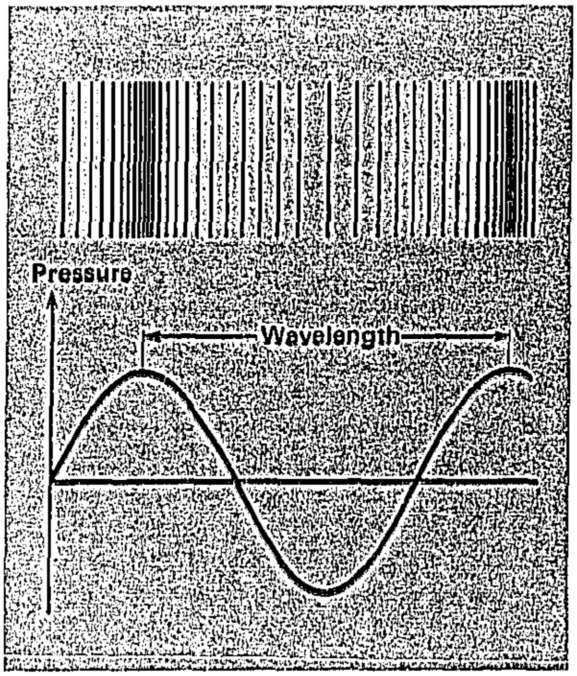


# Just What is Sound?

Sound is defined as any pressure variation (in air, water or some other medium) that the human ear can detect. The most familiar instrument for measuring pressure variations in air is the barometer. However, these pressure variations which occur with changing weather patterns are much too slow for the human ear to detect — and hence don't meet our definition of sound. But if these variations in atmospheric pressure occur more rapidly — at least 20 times per second — they can be heard and hence are called sound. (However, a barometer can't respond fast enough and therefore can't be used to measure sound). The number of pressure variations per second is called the frequency of the sound, which is measured in cycles per second — or Hertz (Hz) as it is now called by international agreement. The range of human hearing extends from approximately 20 Hz to 20000 Hz (or 20 kHz) while the range from the lowest to the highest note of a piano is 27,5 Hz to 4186 Hz.

You probably already have a good idea of the speed of sound from the familiar rule for determining how far away a lightning strike is: count 3 seconds per kilometer or 5 seconds per mile from the time you see the lightning until you hear the thunder. That corresponds to a speed of 1224 km/hour or 765 miles per hour. For acoustics and sound measurement purposes, this speed is expressed as 340 meters per second.

Knowing the speed and frequency of a sound, we can find its wavelength — that is, the physical distance in air from one wave top to the next. Wavelength = Speed/Frequency. At 20 Hz this gives 17 meters, while at 20 kHz, one wavelength is only 1,7 cm.

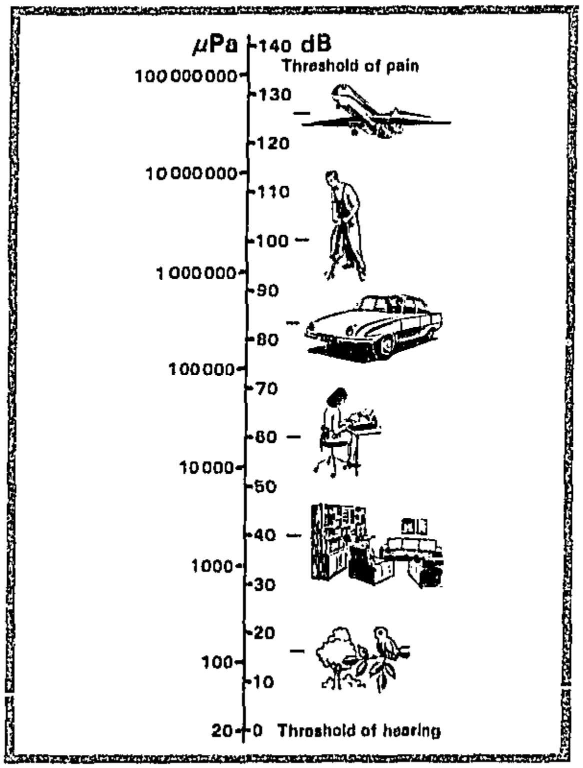


# The dB

The weakest sound that a healthy human ear can detect is 20 millionth of a pascal (or 20$\mu$Pa... 20 micropascals) which is a factor of 5000000000 less than normal atmospheric pressure (One atmosphere is equivalent to 1 kg per square cm or 10 tons per square meter.) This pressure change of 20$\mu$Pa is so small that it causes the membrane in the human ear to deflect a distance less than the diameter of a single atom. Amazingly, the ear can tolerate sound pressures up to more than one million times higher. Thus, if we had to measure sound in Pa, we would end up with some quite large and unmanagable numbers. To avoid this, another scale has been devised — the decibel (dB) scale.

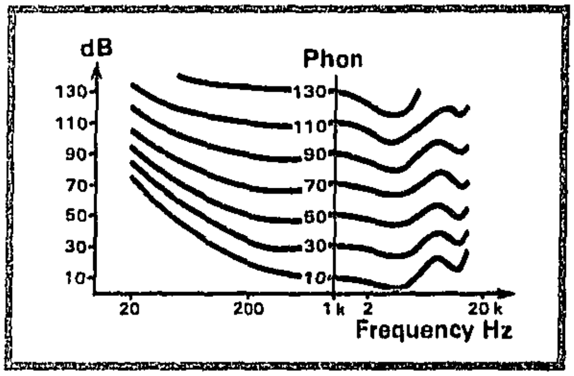
The decibel scale uses the hearing threshold of 20$\mu$Pa as its starting point or reference pressure. This is defined to be 0dB. Each time we then multiply the sound pressure in Pa by 10, we add 20dB to the dB level, thus 200$\mu$Pa corresponds to 20dB (re 20$\mu$Pa), 2000$\mu$Pa to 40dB, and so on. Thus the dB scale compresses the million to one range into a 120dB range.

In the figure, you can see the sound pressure levels (SPL) of various familiar sounds in both dB and Pa.
Another useful aspect of the dB scale is that it gives a much better approximation to the human perception of relative loudness than the pascal scale since the ear reacts to the percentage change in level, which corresponds to the decibel scale where 1 dB is the same relative change everywhere on the scale. 1 dB is the smallest change we can hear. A 6dB increase is a doubling of the SPL, although a 10dB increase is required to make it sound twice as loud.

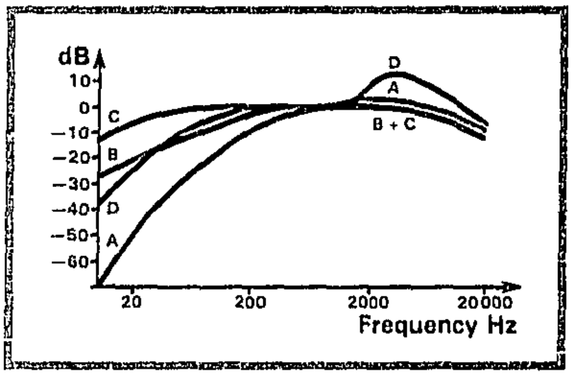


# What do we Hear?

The factors that determine the subjective loudness of a sound are so complex that much research is still continuing on the subject. One such factor is that the human ear is not equally sensitive at all frequencies, but it is most sensitive in the 2 kHz to 5 kHz range, and least sensitive at extremely high and low frequencies. To complicate things even more, this phenomenon is more pronounced at low SPLs than at high SPLs. This can be seen in the figure which shows a family of curves indicating the sound pressure level required at any frequency to give the same apparent loudness as a 1000 Hz tone. For example, a 50 Hz tone must have a 15 dB higher level to give the same subjective loudness as a 1000 Hz tone at a level of 70 dB.



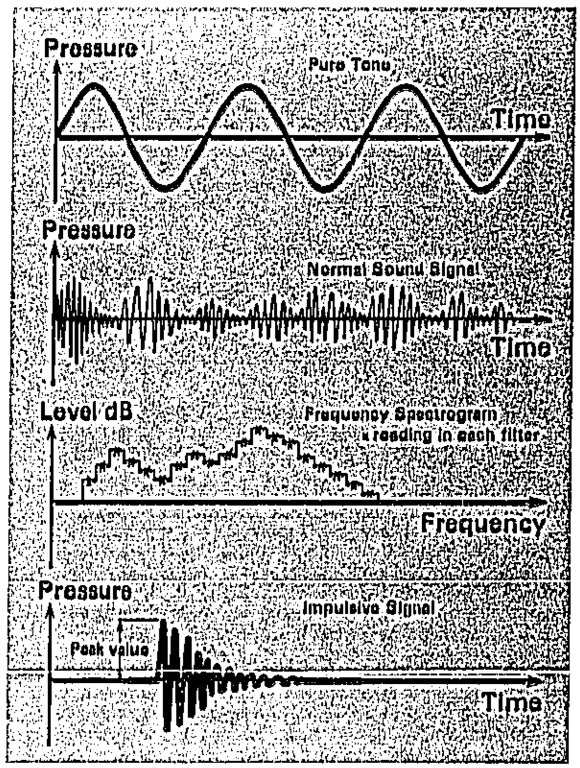

It would seem relatively simple to build an electronic circuit whose sensitivity varied with frequency the same way as the human ear. This has in fact been done and has resulted in three different internationally standardized characteristics termed the "A", "B" and "C" weighting networks. The "A" network approximates the equal loudness curves at low SPLs, the "B" network at medium SPLs and the "C" network at high levels. However, today only the "A" network is widely used since the "B" and "C" networks did not give good correlation to subjective tests. A specialized characteristic, the "D" weighting, has recently been standardized for aircraft noise measurements.



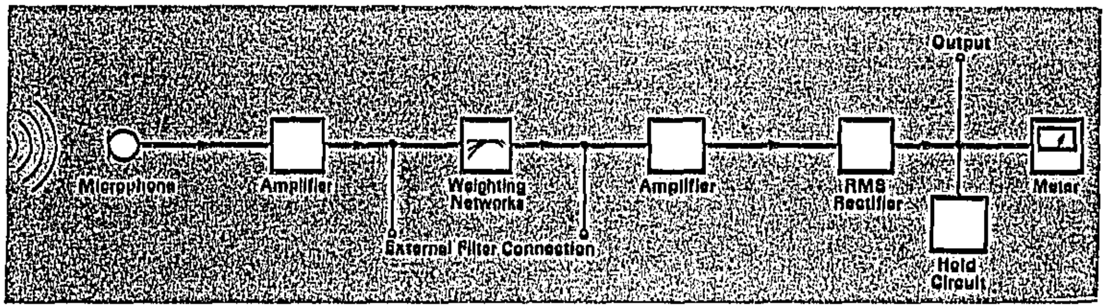
One reason that the "B" and "C" weighting networks did not give the expected results is that the equal loudness contours were based on experiments with pure tones — and most common sounds are not pure tones, but very complex signals.

When more detailed information about a complex signal is required, the frequency range from 20 Hz to 20 kHz can be broken up into sections either one octave or one third octave wide. This is done by electronic filters which reject all signals of frequencies outside the selected band. For example, an octave filter with a center frequency of 1 kHz permits sounds in the 707 to 1410 Hz range to be measured, but rejects all others. This process where a signal is analyzed in many frequency bands is termed frequency analysis. The results are presented on a chart called a spectrogram.

If a sound is of short duration, that is, less than one second, it is termed an impulsive sound. Practical examples are typewriter and hammering noise. This presents another problem in loudness evaluation because the shorter the sound, the less sensitive the ear will be in perceiving it. Researchers generally agree that for sounds shorter than 70 milliseconds (70 thousandths of one second), the perceived loudness decreases. This has resulted in agreement on a standardized electrical circuit whose sensitivity decreases with short duration sounds. This circuit is called the "Impulse" characteristic. However, the damage risk is not necessarily reduced although the loudness decreases with short signals. For this reason, some sound level meters include a circuit for measuring the peak value of the signal, independent of the signal's duration.



# The Sound Level Meter




A sound level meter is an instrument which responds to sound in approximately the same way as the human ear and which gives objective, reproduceable measurements of sound level.

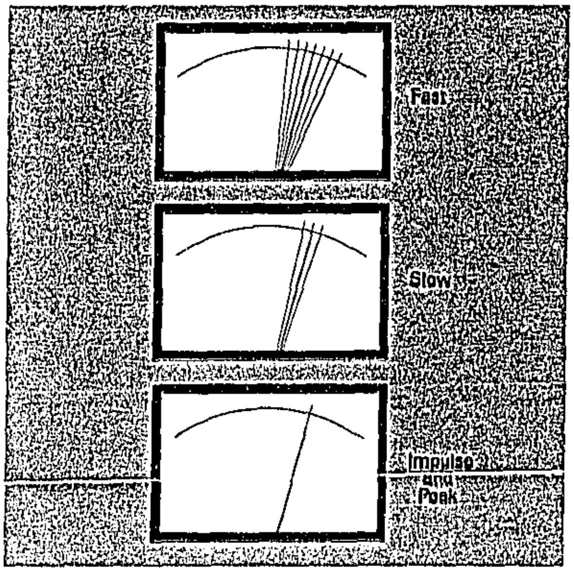
The sound signal is converted to an identical electrical signal by a high quality microphone. Since the signal is quite small, it must be amplified before it can be read on a meter. After the first amplifier the signal may pass through a weighting network (A, B, C or D). An alternative to the network is an octave or third octave filter which may be attached externally. After additional amplification, the signal will now be of a high enough level to drive the meter — after its RMS value has been determined in the RMS detector. The value read on the meter is the sound level in dB. The sound signal is also available at an output socket so that it may be fed to external instruments such as recorders or noise dose meters.

RMS means root mean square — which is a special kind of mathematical average value. It is of importance in sound measurements because the RMS value is directly related to the amount of energy in the sound signal. A peak rectifier may be included for determination of the peak value of impulsive signals and a Hold Circuit will hold the maximum meter deflection, either of the peak value or of the RMS value measured with the Impulse Characteristic.

Since the sound level meter is a precision instrument, provision is made to calibrate it for accurate results. This is best done by placing a portable acoustic calibrator directly over the microphone. This calibrator is basically a miniature loudspeaker giving a precisely defined sound pressure level to which the sound level meter can be adjusted.

# Meter Response

When the sound level varies, we want the meter needle to follow these variations. However, if the level fluctuates too rapidly, the meter needle may move so erratically that it will be impossible to get a meaningful reading. For this reason, two meter response characteristics are used: "Fast" — which gives a fast reacting meter response enabling us to follow and measure not too rapidly fluctuating noise levels and "Slow" — which gives a more sluggish response and helps average out meter fluctuations which would otherwise be impossible to read.




If the meter needle fluctuates like this when using "Fast", switch to "Slow".

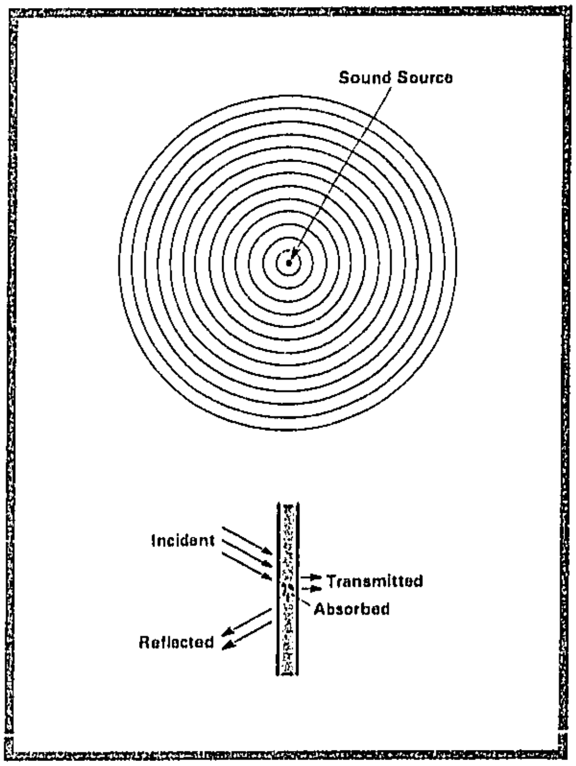
If the fluctuations are still large using "Slow", estimate an average and also note the maximum and minimum readings in your report.

If you measure Impulses, then you need an impulse sound level meter. Some standards require the peak value to be measured while others ask for a measurement with the "Impulse" time constant. In any case the Hold function makes reading easy.

# Sound Propagation

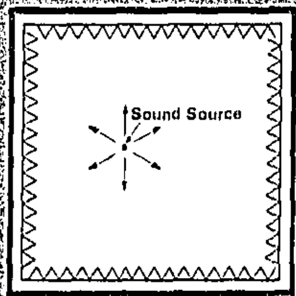
Sound propagation in air can be compared to waves in water. The waves spread uniformly in all directions, decreasing in amplitude as they move from the source. In air, when the distance doubles, the amplitude drops by half — which is a drop of 6 dB. Thus, if you move from one meter from the source to two meters from the source, the sound pressure level will drop by 6 dB. If you move to 4 meters, it will drop by 12 dB, 8 meters by 18 dB, and so on.

However, this is only true when there are no reflecting or blocking objects in the sound path. Such ideal conditions are termed free-field conditions. With an obstacle in the sound path, part of the sound will be reflected, part absorbed and the remainder will be transmitted through the object. How much sound is reflected, absorbed or transmitted depends on the absorbing properties of the object, its size and the wavelength of the sound. In general, the object must be larger than one wavelength in order to significantly disturb the sound. For example, at 10 kHz, the wavelength is 3,4 cm — and even a small object such as a measuring microphone will disturb the sound field — hence sound absorption and isolation is readily achieved. But, at 100 Hz, the wavelength is 3,4 meters and sound isolation becomes much more difficult. You've probably noticed this with music playing in the room next door. The bass is very difficult to block out.



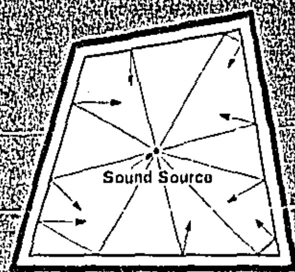
# Anechoic Chambers (Sound Absorbing Rooms)

If it is desired to make measurements in a free-field, totally without reflecting objects, the measurements must be made outdoors at the top of a flagpole (or equivalent) or in an anechoic room. In an anechoic chamber, all walls, ceiling and floor are covered by a highly absorptive material, to eliminate reflections. Thus the sound pressure level in any given direction from the noise source may be measured without the presence of interfering reflections.




# Reverberation Chambers (Sound Reflecting Rooms)

The opposite of an anechoic room is the reverberation chamber where all surfaces are made as hard and reflective as possible and where no parallel surfaces exist. This creates a so-called diffuse field because the sound energy is uniformly distributed in the room. In this type of room, it is possible to measure the total acoustic power output from the noise source, but the sound pressure level in any given direction is practically meaningless due to the reflections. As such rooms are cheaper to construct than anechoic chambers, they find widespread use for machinery noise investigations.



# The Practical Room

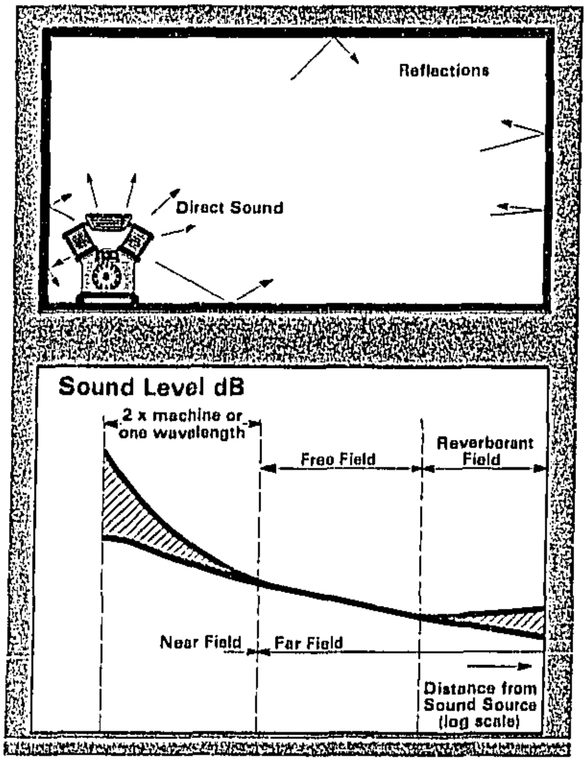
In practice, the majority of sound measurements are made in rooms that are neither anechoic nor reverberant — but somewhat in-between. This will make it difficult to find the correct measuring position when it is desired to measure the noise emission from a given source.

When determining emission from a single source, several errors are possible. First, if you measure too close to the machine, the SPL may vary significantly with a small change in position. This situation occurs at a distance less than the wavelength of the lowest frequency emitted from the machine or at less than twice the greatest dimension of the machine, whichever distance is the greatest. This is termed the near field of the machine, and measurements in this region should be avoided if possible.

Other errors may arise if you measure too far away from the machine. Here, reflections from walls and other objects may be just as strong as the direct sound and correct measurements will not be possible. This is termed the reverberant field. Between the reverberant and near field is the free field which can be found by noting that the level drops 6 dB for a doubling in distance from the source. It is here the measurements should be made. It is quite possible, however, that the conditions are so reverberant or the room is so small that no free field exists.

When making the measurement, state the distance, direction and height of the microphone. For example, 74 dB(A), 3 meters directly in front of the air condition, at a height of 1 meter.



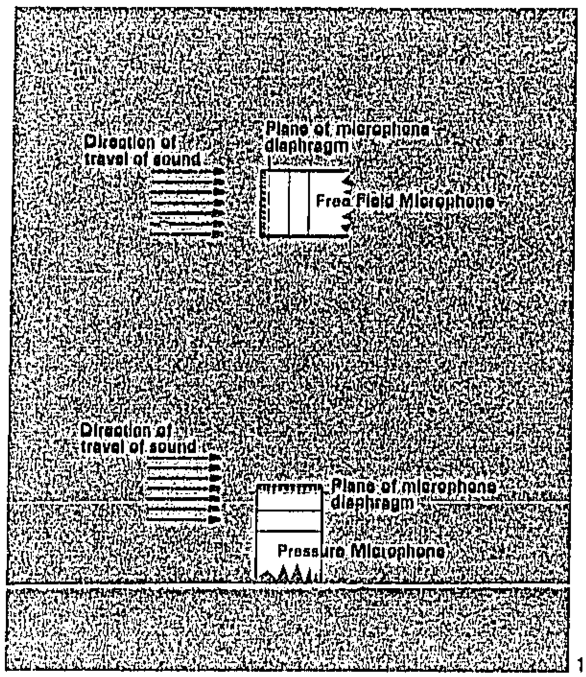


# The Microphone in the Sound Field

The quality of the measuring microphone must meet many high standards. First, it must have uniform frequency response. By this we mean that the microphone must be equally sensitive at all frequencies. Secondly, the microphone should be equally sensitive to sounds coming from all angles. This is termed an omnidirectional characteristic and is especially important when measuring in a diffuse field.

Brüel & Kjær make microphones with three types of characteristics, free-field, pressure, and random incidence response. Free field microphones have uniform frequency response for the sound pressure that existed before the microphone was introduced into the sound field. It is important to note that any microphone will disturb the sound field, but the free field microphone is designed to compensate for its own disturbing presence. However, the pressure microphone is designed to have uniform frequency response to the actual sound pressure level present, which of course includes the microphones' own disturbing presence. Finally, the random incidence microphone is designed to respond uniformly to signals arriving simultaneously from all angles, such as is the case in highly reverberent or diffuse sound fields.

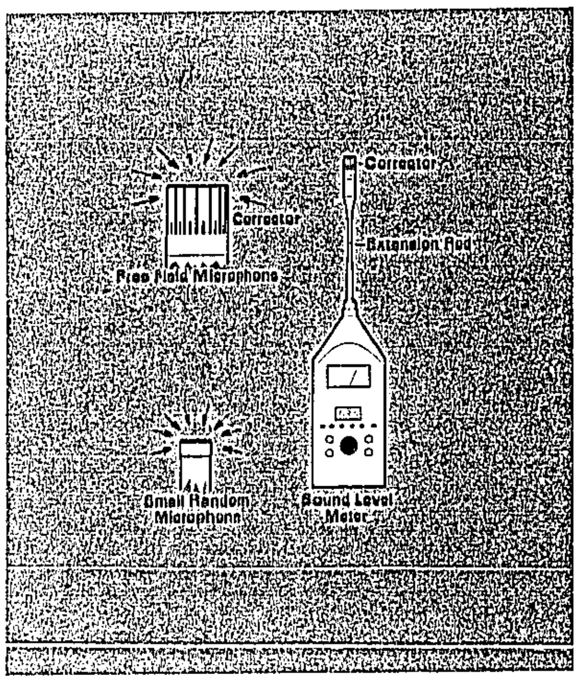
When making measurements in a free field, a free-field microphone should be pointed directly at the sound source while a pressure microphone should be oriented at a 90° angle to the sound source so that the sound grazes the front of the microphone.



# The Microphone in the Sound Field

In a diffuse or random sound field, the microphone should be as omnidirectional as possible. In general, the smaller a microphone is, the better its omnidirectional characteristic will be. However, smaller microphones are also less sensitive which may not be acceptable if measuring under relatively quiet conditions. To overcome this, the most sensitive free-field microphone, which is also the largest (one inch diameter), may be fitted with a special device, called a Random Incidence Corrector — which makes it much more omnidirectional. However, if the high sensitivity of the one-inch microphone is not required, the best solution is to use the half-inch, or smaller, random microphones.

However, when measuring in diffuse fields, it is important to remember that the instrument case and operator presence may block the sound from certain directions and ruin the otherwise excellent omnidirectional characteristics of the microphone. Therefore, the microphone should be mounted on an extension rod, or, better still, on an extension cable to get it away from the sound level meter and operator.



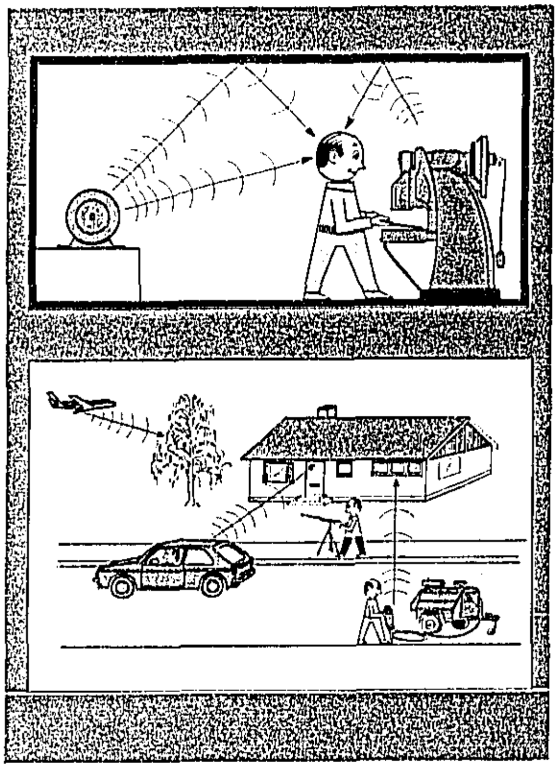
# Environmental Noise

So far we have described the measurement of noise emitted by a single machine in order to rate the machine or to predict its noise at greater distances. This is one kind of measurement. Another kind is the measurement of total noise at a location due to one or more sources and their reflections from walls, ceilings and other machines.

Noise at an employee's work station is an example of environmental noise. The measurement is made where the person works, without regard to whether he is in the near or far field of his machine or whether other machines are operating in the vicinity. These conditions may be considered in efforts to reduce the noise level, but not when measuring the employee's exposure.

Because environmental sounds come from various directions, the sound level meter must be omnidirectional. It must have a uniform response irrespective of where the various sound sources are located.

Other examples of environmental noise are found in the community, at plant boundaries, in offices and in theatres.

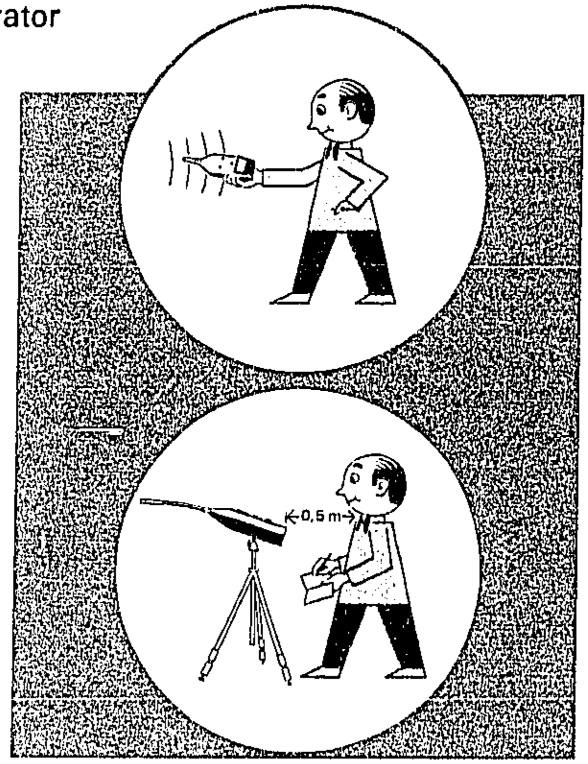


# Influence of Instrument and Operator

When measuring noise, precautions should be taken to keep the sound level meter and operator from interfering with the measurement. Not only can the instrument case and operator presence block sound coming from a given direction, but they can cause reflections that may cause measuring errors. You may never have thought of your body as a sound reflector, but experiments have shown that at frequencies of around 400 Hz, reflections from the body may cause errors of up to 6 dB when measuring less than one meter from the body.

To minimize the reflections from the instrument case, all Brüel & Kjær sound level meters are specially designed with a conically shaped front end. For even more precise measurements, some instruments are provided with an extension rod for mounting the microphone away from the case. And extension cables are available to prevent the meter body from blocking any sound waves.

To minimize reflections from the operator it is usually sufficient that the sound level meter be held at arms length or mounted on a tripod, possibly fitted with its extension rod. For further reduction of operator reflections the microphone should be mounted away from the sound level meter by means of an extension cable. In any case you can check whether your presence is influencing the reading by letting the sound level meter remain fixed while you step to the side.



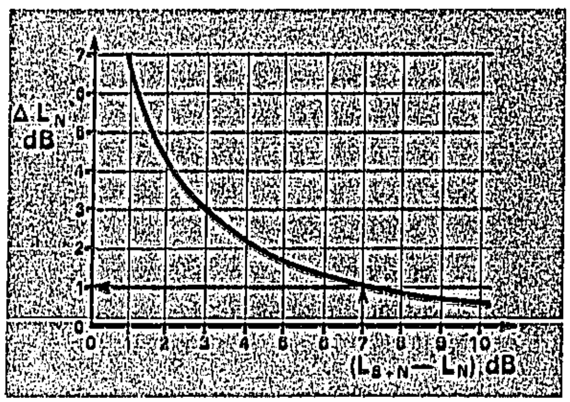
# Background Noise (Subtracting sound levels)

Another factor that may influence the accuracy of measurements is the level of the background noise compared to the level of the noise signal to be measured . Obviously, the background noise must not drown out the signal of interest. In practice this means that the level of the signal must be at least 3 dB higher than the background noise, but a correction may still be necessary to get the correct result. The procedure for measuring the sound level from a machine under conditions of high background noise is as follows:

1. Measure the total noise level ($L_{S+N}$ ) with the machine running.
2. Measure the background noise level ($L_N$) with the machine turned off.
3. Find the difference between the two readings. If less than 3 dB, the background noise level is too high for an accurate measurement. If between 3 and 10 dB, a correction will be necessary. No correction is necessary if the difference is greater than 10 dB.
4. To make the correction, enter the bottom of the chart with the difference value from step 3, go up until you intersect the curve and then go to the left to the vertical axis.
5. Subtract the value on the vertical axis ($\Delta L_N$) from the total noise level in step 1. This gives the noise level of the machine.

Example:

1. Total Noise = 60 dB
2. Background Noise = 53 dB
3. Difference = 7 dB
4. Correction (from chart) = 1 dB
5. Noise of Machine = 60 — 1 = 59 dB



# Addition of Sound Levels

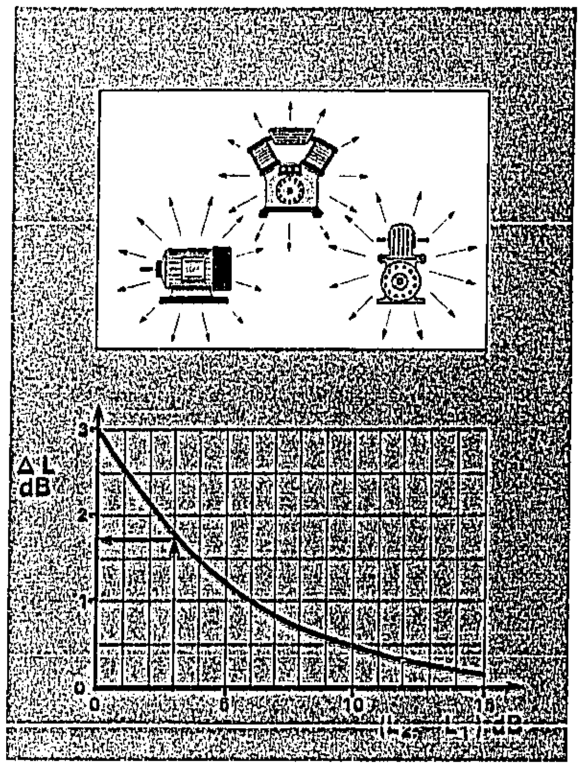
If the noise levels of two machines have been measured individually and you want to know how much noise the machines will make when operating together, the two sound levels must be added. However, when using dB, you can't add the sound levels directly, but must make a correction for instance by use of a chart as shown below.

The procedure is as follows:

1. Measure the levels of machine 1 and machine 2.
2. Find the difference between these levels.
3. Enter the bottom of the chart with this difference. Go up until you intersect the curve, then go to the left to the vertical axis.
4. Add the value indicated at the vertical axis to the level of the noisiest machine. This gives the sum of the noise levels of the two machines.

Example:

1. Machine 1 = 85 dB
   Machine 2 = 82 dB
2. Difference = 3 dB
3. Correction (from chart) = 1,7 dB
4. Total Noise = 85 + 1,7 = 86,7 dB

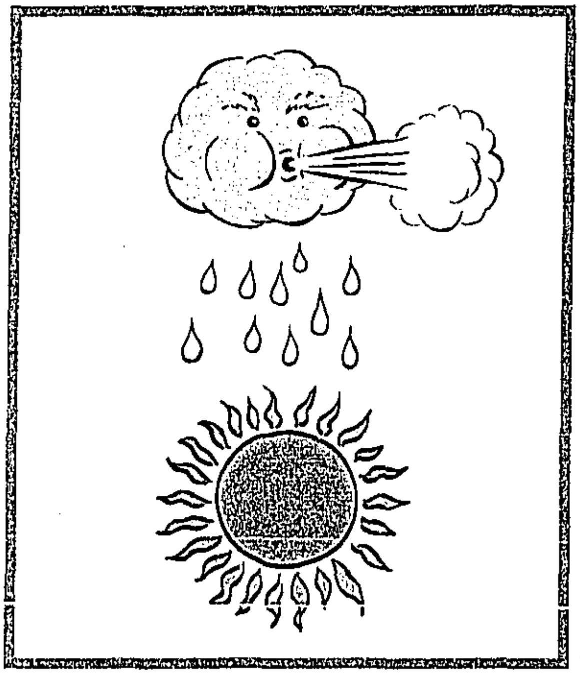


# The Influence of Environment

**Wind**
Wind blowing across the microphone makes a lot of extraneous noise similar to the noise you can hear with the wind blowing in your ear. To minimize this, a special windscreen consisting of a ball of porous polyurethane sponge should always be used over the microphone when working outdoors. It also shields the microphone from dust, dirt and precipitation.

**Humidity**
The sound level meter and microphone will not be influenced by relative humidity levels up to 90%. However, care should be taken to shield the instrument from rain, snow etc. A windscreen should always be used over the microphone during precipitation. Even if the windscreen becomes very wet, measurements will still be accurate: However, for continuous use in extremely humid environments, special outdoor microphones, rain covers and dehumidifiers are recommended.

**Temperature**
All B & K sound level meters are designed to operate accurately over the −10° to +50°C range. However, care should be taken to avoid sudden temperature changes which may cause condensation in the microphone.

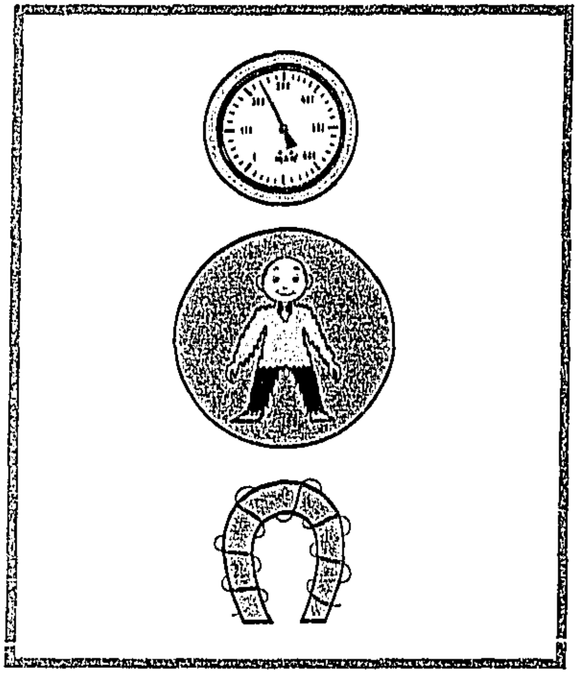


# The Influence of Environment

**Ambient Pressure**
Variations in atmospheric pressure of ± 10% will have a negligible influence (less than ± 0,2 dB) on microphone sensitivity. However, at extremely high altitudes, the sensitivity, especially at high frequencies may be affected more than this and the microphone instruction manual should be consulted. Also, when calibrating the instrument with a Pistonphone, correction must be made for atmospheric pressure.

**Vibration**
Although the microphone and sound level meter are relatively insensitive to vibration, it is always a good practice to isolate them from strong vibrations and shock. Foam rubber pads or similar isolating material may be used if the sound level meter must be used in an environment of high vibration.

**Magnetic Fields**
The influence of electrostatic and magnetic fields on the sound level meter is negligible.



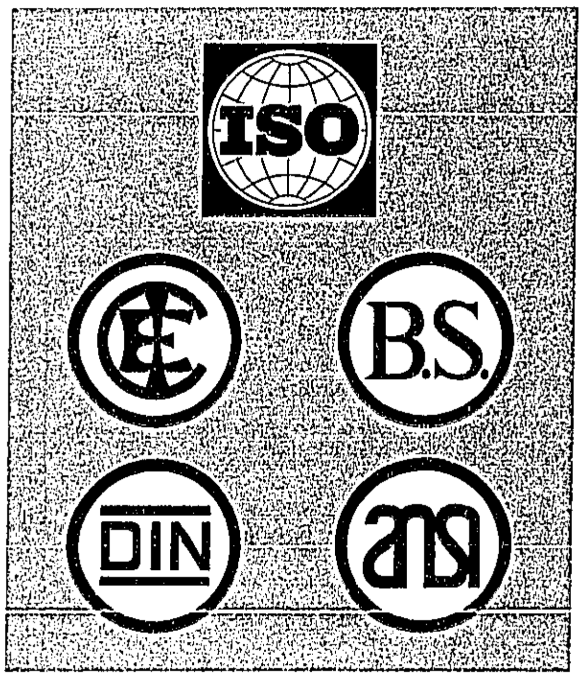
# Standardization of Measurements

Whenever sound measurements are made, the recommendations of the applicable national and international standards should be consulted. These standards discuss both measuring techniques and specifications for the equipment used. The standards give a well defined procedure for making reproduceable and accurate measurements.

"Acoustics — Guide to the Measurement of Acoustical Noise and its Effect on Man" is the title of ISO (International Standards Organization) standard 2204 which should be of particular interest to the newcomer because it defines all basic terms and measuring methods and also gives a reference list of other applicable standards.

IEC 123 and IEC 179 are established by the International Electrotechnical Commission and define the specifications for various grades of sound level meters. All Brüel & Kjær sound level meters are built to conform to these standards. In the United States, the American National Standard (ANSI) is used. B & K sound level meters also conform to the ANSI standards when used with extension rods provided.

For a listing of national and international standards on acoustic noise measurements please contact your local Brüel & Kjær representative.

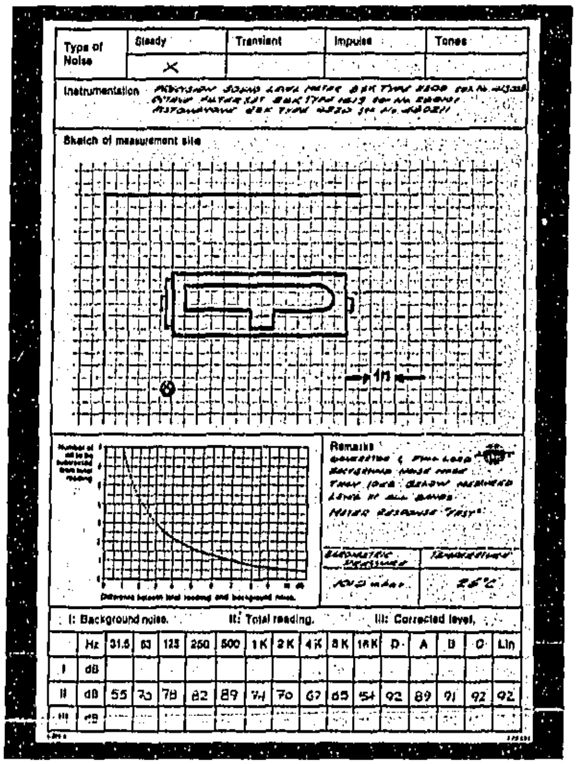


# The Measurement Report

A very important part of sound measurements is careful documentation of the results. A good measurement report should contain at least the following information:

1. A sketch of the measuring site showing applicable dimensions, the location of the microphone and object being measured.
2. Type and serial number of instrument.
3. Method of calibration.
4. Weighting networks and meter responses used.
5. Type of sound signal (impulsive, continuous, tones etc.)
6. Background noise level.
7. Meteorological data and date.
8. Data on object being measured (machine type, load, speed etc.).

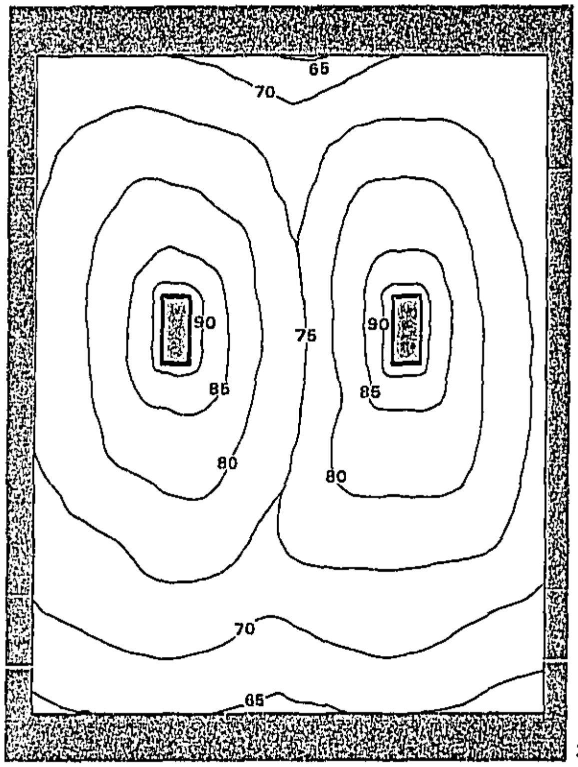
With a carefully written report, future comparisons will be made more accurate and reliable.




| | Hz | 31.5 | 63 | 125 | 250 | 500 | 1K | 2K | 4K | 8K | 16K | D | A | B | C | Lin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | dB | | | | | | | | | | | | | | | |
| II | dB | 55 | 70 | 78 | 82 | 89 | 74 | 70 | 67 | 65 | 54 | 92 | 89 | 91 | 92 | 92 |
| III | dB | | | | | | | | | | | | | | | |

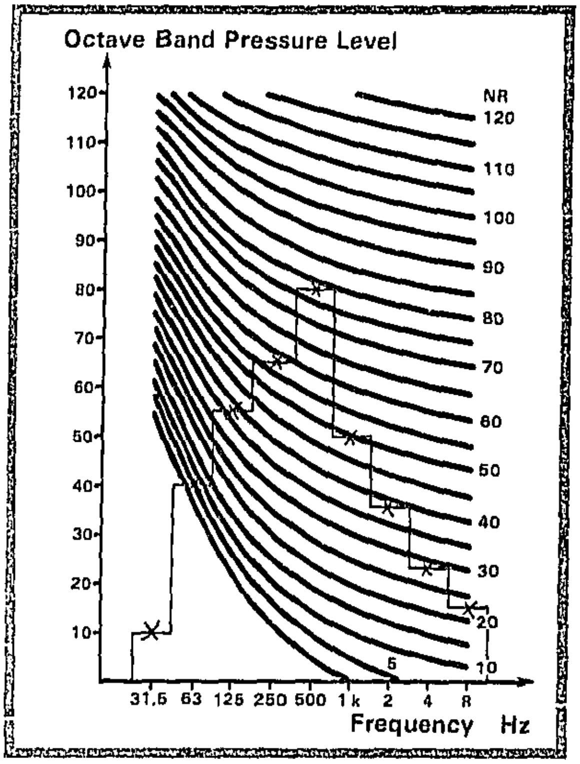
# Noise Mapping

One of the first steps in a noise abatement programme will usually be to make a noise map or topograph: A reasonably accurate sketch showing the relative positions of all machines and other items of interest is drawn. To this sketch is added the measured noise levels taken at a suitable number of positions around the area being investigated; the more measurements, the more accurate the topograph. Connecting lines drawn between the points of equal sound levels will now produce a noise topograph indicating the sound distribution patterns. A topograph of this kind will immediately show the zones of noise danger and is the starting point for planning the steps to be taken to protect the workers. When the necessary steps have been taken, new measurements will give a clear picture as to what extent they have changed the noise patterns. A topograph with red zones could also be used to indicate areas where ear protectors are obligatory.



# Using Noise Rating Curves

In almost any noise abatement programme, in particular when the measured dB(A) values are above the allowable limit, it will be necessary to try to rate the harmfulness of the noise. For this purpose, it will always be necessary to make an octave or third-octave frequency analysis. Several, and some quite complicated methods are recommended in various standards. The simplest method is to use noise rating curves as shown to the right. They are used in the way that the level values for each frequency band are noted in the graph. It can then be seen which NR curve lies just above the spectrogram and the noise is then assigned that particular NR number, in the example, NR 78. From the shape of the curves it can be seen that much more weight is put on the higher frequencies than the lower ones. Such curves can be found in ISO R 1996. In some countries similar curves are used to give the maximum allowable time that the worker may be exposed to the noise, as well as being used to set allowable limits for machinery etc., in this way taking, amongst other things, the frequency response of the human ear into account.



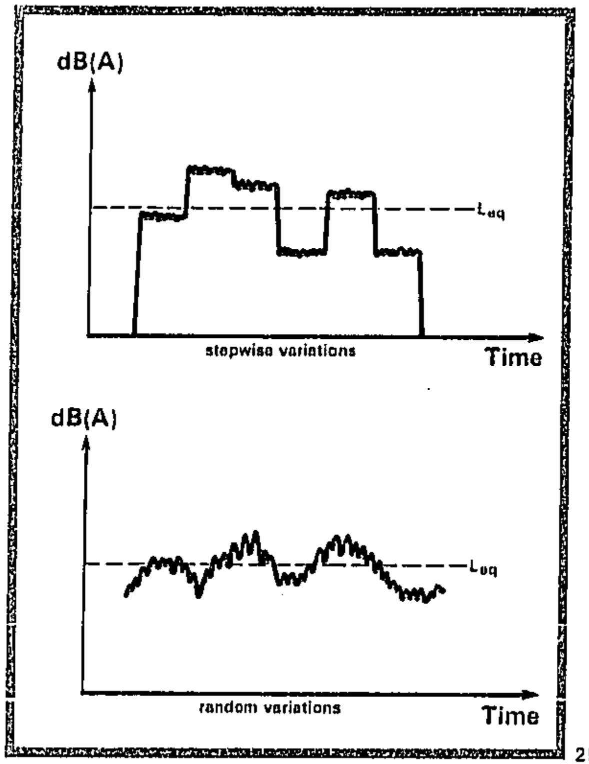
# Noise Dose

The hearing damage potential of a given noise depends not only on its level, but also its duration. For example, a one minute exposure to a noise is nowhere near as harmful as a 60 minute exposure to a noise of the same level. Thus, to assess hearing damage potential, both the level and the duration must be measured. For constant levels, this is easy, but if the level varies, the level must be sampled repeatedly over a well defined sampling period. Based on the level samples, it is possible to calculate a single number (called $L_{eq}$) which represents an equivalent continuous level in dB(A) which has the same hearing damage potential as the varying level. If the level varies stepwise, $L_{eq}$ can be calculated based on measurements with a sound level meter and a stopwatch.

However, if the level varies randomly, manual calculations cannot easily be used to calculate $L_{eq}$, but Noise Dose Meters are available to perform the calculations automatically. These instruments are available either in stationary format, or in portable versions so they can be carried in the pocket of a worker preferably with the microphone mounted close to his ear.

There are two different ways of calculating $L_{eq}$. ISO 1996 and 1999 define one method, while in the United States, the Occupation Safety and Health Act (OSHA) defines another.

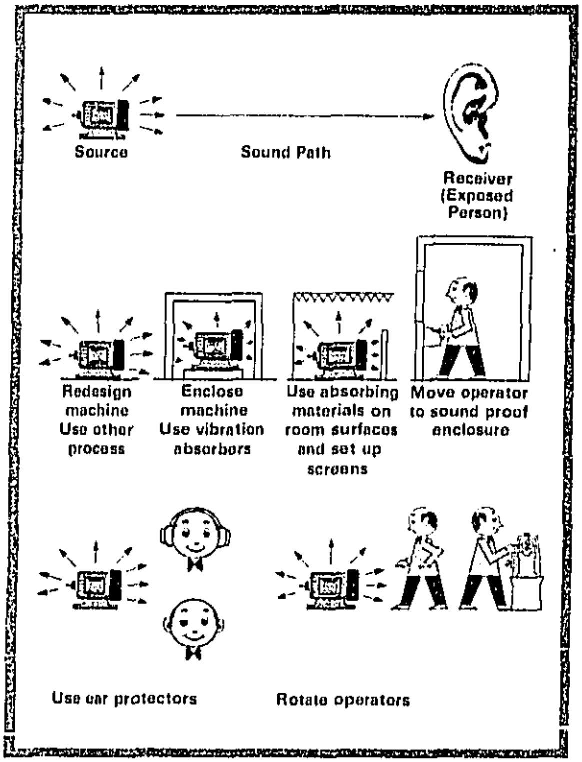
Where more information on the level distribution of the noise is desired, special noise level analyzers can be employed.



# When Levels are too High

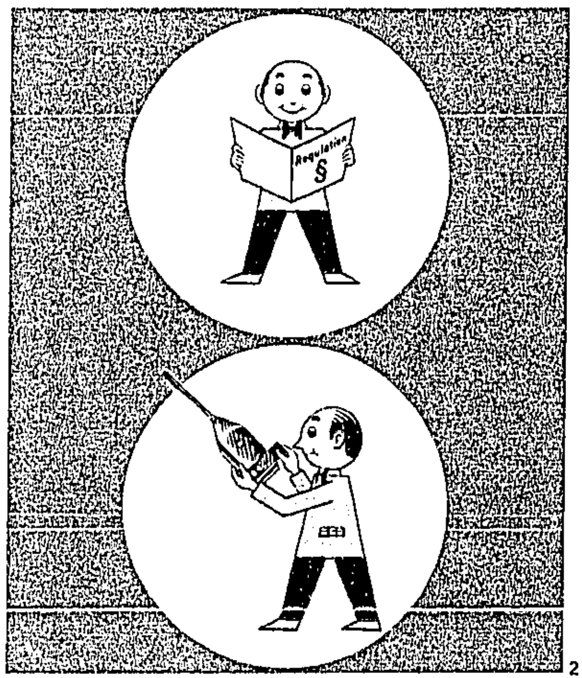
When measurements have ascertained that the sound pressure levels are too high, steps must be taken to reduce them. Although the details of a noise abatement program can easily be quite complex, there are four general guidelines to possible solutions:

1. Reduce the noise at its source. This may be done by acoustic treatment of machine surfaces, design changes or purchasing a new, quieter machine.
2. Block the sound transmission path. This may be done by placing an enclosure or acoustic screens around the machine and mounting it on vibration isolators to prevent transmission through the floor. Noise is further reduced by coating walls, ceiling and floor with absorbing materials to reduce reflections from their surfaces.
3. Equip the exposed person with ear protectors. However, this should not generally be used as a permanent solution.
4. Shut down the offending machinery. In severe cases, this step must be considered. It is also possible to limit the hours of operation, move the offending noise source to another location, or rotate workers so their exposure time is reduced.



# Some Basic Rules

To conclude this booklet, let us review some basic rules to follow in any noise measurements using a portable sound level meter.

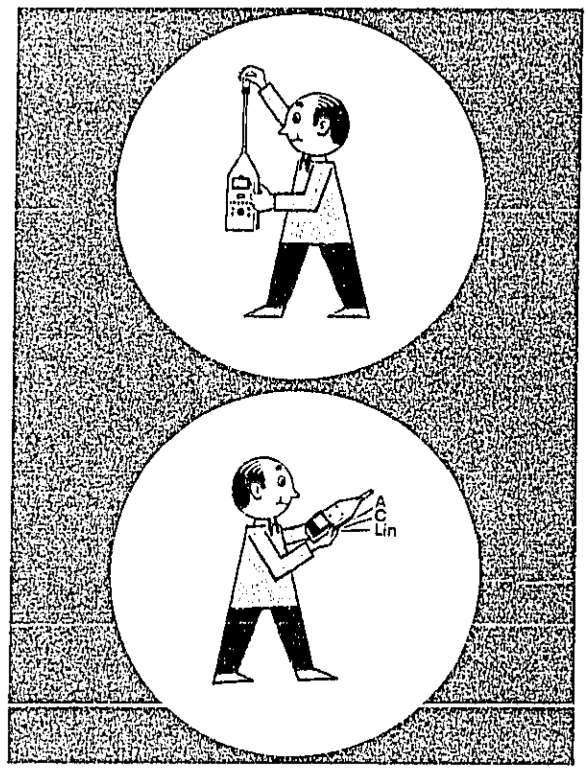



1. Check applicable standards and rules for the proper measuring equipment and techniques (see p. 21).

2. Check that the batteries are OK and take along an extra set of good quality batteries. If the instrument is to be stored for a long time, the batteries should be removed.

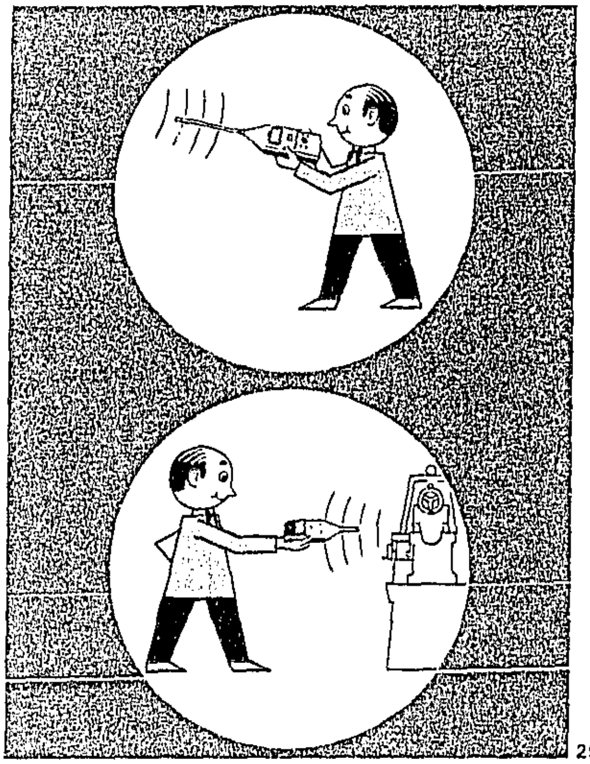
3. Make sure that the instrument is properly calibrated. Periodic use of an acoustic calibrator is recommended.

4. Decide which weighting network you should use. Normally this would be the "A" network.

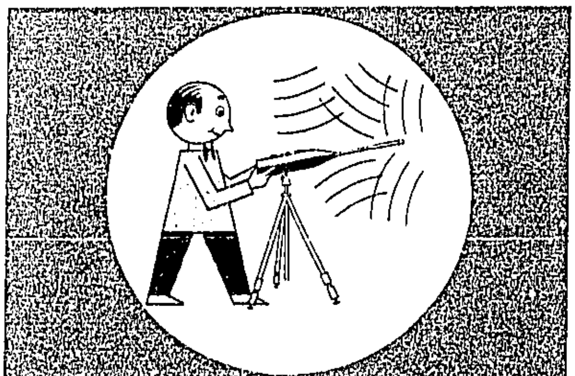


5. Make some orientation measurements before noting actual values. Determine the kind of sound field you are working with (see p. 13 and 14) and find the correct measuring positions (see p. 12).

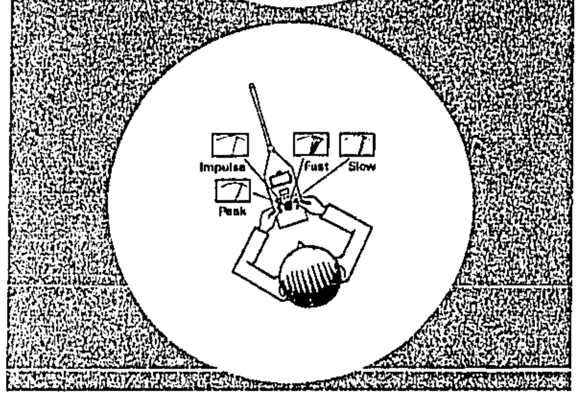
6. When using a sound level meter with a free-field microphone, hold the meter at arms length to avoid reflections and point the microphone at the sound source (see p. 16).



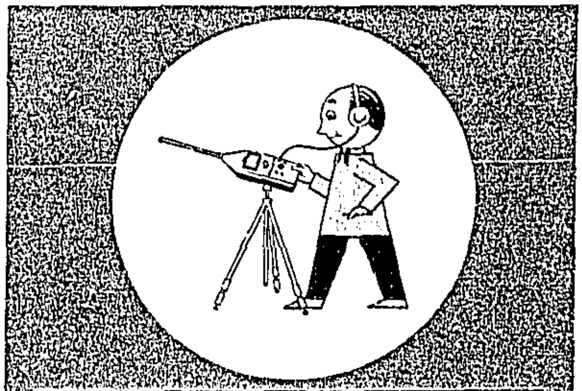
7. If the sound comes from more than one direction, it is important to choose a microphone and mounting which gives the best possible omnidirectional characteristics (see p. 14).



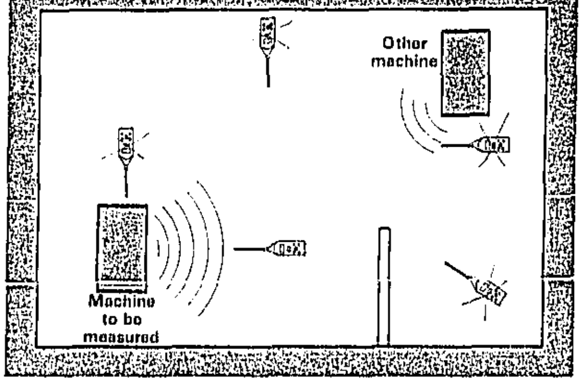
8. Select the correct meter response, "Fast" or "Slow" to get an accurate reading (see p. 9). If the sound is impulsive, an "Impulse Sound Level Meter" should be used (see p. 7 and 9.)



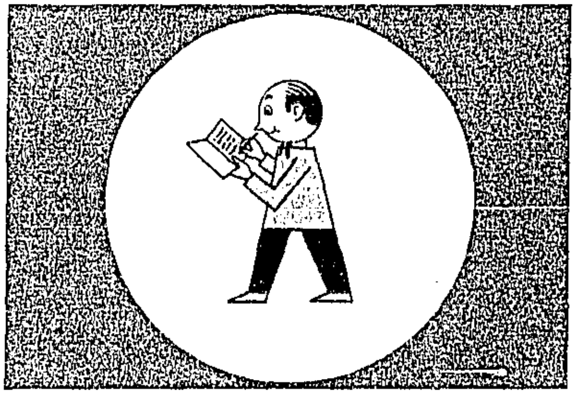
9. If you are not sure which noise is causing the meter to deflect, the use of a set of headphones connected to the output of the sound level meter will help you identify the sound. This is of course only possible if the SLM has an output.



10. During the measurement, remember to:
    a. Keep away from reflecting surfaces.
    b. Measure at a suitable distance from the machine (see p. 12).
    c. Check the background noise level (see p. 17).
    d. Do not measure behind shading objects.
    e. Use a windscreen whenever working outdoors.
    f. Be careful not to accept readings if the meter is overloaded or overdeflected.



11. Keep a well documented measurement report. (see p. 22).



We hope this booklet has served as an informative introduction to the measurement of sound and will continue to serve as a handy reference guide. If you have other questions about measurement techniques or instrumentation, contact one of our local representatives, or write directly to:

**Brüel & Kjær**
**2850 Nærum**
**Denmark**