6.1. INTRODUCTION

This chapter describes the noise measuring instruments most widely used in the practice of occupational hygiene. The planning, the strategy and the practical aspects of a noise survey are discussed in Chapter 7.

Many types of measuring systems can be used for the measurement of sound depending on the purpose of the study, the characteristics of sound and the extent of information that is desired about the sound. The various elements in a measuring system are:

a. the transducer; that is, the microphone;
b. the electronic amplifier and calibrated attenuator for gain control;
c. the frequency weighting or analyzing possibilities;
d. the data storage facilities;
e. the display.

Not all elements are used in every measuring system. The microphone can, for instance, be connected to a sound level meter or directly to a magnetic tape recorder for data storage and future measurement or reference. An example of the components of the sound level meter is shown in Figure 6.1.

![Figure 6.1. Sound level meter block diagram](image)

The two main characteristics are:

1. The frequency response: that is, the deviation between the measured value and the true value as a function of the frequency. As the ear is capable of hearing sounds between 20 Hz and
20 kHz, the frequency response of the sound level meter should be good, with variations smaller than 1 dB, over that range.

2. The dynamic range: that is, the range in dB over which the measured value is proportional to the true value, at a given frequency (usually 1000 Hz). This range is limited at low levels by the electrical background noise of the instrument and at high levels by the signal distortion caused by overloading the microphone or amplifiers.

6.2. MICROPHONES

6.2.1. The Different Types

The microphone is the interface between the acoustic field and the measuring system. It responds to sound pressure and transforms it into an electric signal which can be interpreted by the measuring instrument (e.g. the sound level meter). The best instrument cannot give a result better than the output from the microphone. Therefore, its selection and use must be carefully carried out to avoid errors. When selecting a microphone, its characteristics must be known so that its technical performance (e.g. frequency response, dynamic range, directivity, stability), in terms of accuracy and precision, meets the requirements of the measurement in question, taking into account the expected conditions of use (e.g. ambient temperature, humidity, wind, pollution).

The microphone can be of the following types: piezoelectric, condenser, electret or dynamic. In a piezoelectric microphone, the membrane is attached to a piezoelectric crystal which generates an electric current when subjected to mechanical tension. The vibrations in the air, resulting from the sound waves, are picked up by the microphone membrane and the resulting pressure on the piezoelectric crystal transforms the vibration into an electric signal. These microphones are stable, mechanically robust and not appreciably influenced by ambient climatic conditions. They are often used in sound survey meters.

In a condenser microphone, the microphone membrane is built parallel to a fixed plate and forms with it a condenser. A potential differential is applied between the two plates using a d.c. voltage supply (the polarisation voltage). The movements, which the sound waves provoke in the membrane, give origin to variations in the electrical capacitance and therefore in a small electric current. These microphones are more accurate than the other types and are mostly used in precision sound level meters. However, they are more prone to being affected by dirt and moisture.

A variation on the condenser microphone which is currently very popular is the electret. In this case the potential difference is provided by a permanent electrostatic charge on the condenser plates and no external polarising voltage. This type of microphone is less sensitive to dirt and moisture than the condenser microphone with a polarisation voltage.

The last type is a microphone where the membrane is connected to a coil, centred in a magnetic field, and whose movements, triggered by the mechanical fluctuations of the membrane, give origin to a potential differential in the poles of the coil. The dynamic microphone is more mechanically resistant but its poor frequency response severely limits its use in the field of acoustics.

6.2.2. The Sensitivity of a Microphone

The sensitivity of a microphone is defined as the amplitude (in mV) of the output signal for an
Sound measuring instruments

Incident sound pressure of amplitude 1 Pa (94 dB) at 1000 Hz. It can also be expressed in decibels by the following expression:

\[
\text{Sensitivity} = 20 \log_{10} \frac{V_p}{V_0 \rho} \text{ dB re } 1 \text{V/Pa}
\]

Thus, a microphone giving an output signal \( V \) of 10 mV for a pressure signal \( p \) of 94 dB has a sensitivity of 10 mV/Pa or -40 dB. Here \( p_0 = 1 \text{Pa} \) and \( V_0 = 1 \text{ volt} \).

6.2.3. Frequency Response

Good quality piezoelectric or condenser microphones have usually flat frequency response characteristics from 2 Hz to an upper limit which depends on their size. This limit is about 2 kHz for a 1” diameter microphone, 4 kHz for a 1/2” and 8 kHz for a 1/4” microphone. Below this limit, the frequency response is independent of the orientation of the microphone with respect to the noise source, and therefore the microphone can be held in any orientation. Above this limit, the frequency response will depend upon the direction of the sound wave on the microphone membrane.

Some microphones have been designed in order for the response characteristics to be flat when the sound direction of propagation is perpendicular to the membrane. These microphones are called free field microphones and should be oriented toward the most significant sound source. Figure 6.2. illustrates the frequency response characteristics of this type of microphone.

![Figure 6.2. Frequency response of a free field (0°) microphone](image-url)
The numbers on the curves represent the angle of incidence (in degrees) of the incoming sound wave with respect to the normal to the membrane. The quantity, “R”, represents the response to a diffuse sound field (sound incident equally from all possible directions).

Other microphones have been designed for the response characteristics to be flat when the sound comes in all directions at the same time as in a diffuse field. They are called diffuse field microphones. Their frequency response characteristic is very near the response characteristic under an incidence of 70° and these microphones should therefore be oriented at 70° toward the predominant sound source.

Figure 6.3. illustrates the frequency response characteristics of this type of microphone.

![Figure 6.3. Frequency response of a diffuse field (R) microphone](image)

6.2.4. Dynamic Range

The output of a microphone is limited on the one hand by the internal noise of the transducer and on the other hand by the distortion resulting from high noise levels. In addition, the instrument to which the output signal of the microphone is fed will saturate if the signal is too high and will also give a false result (that is, its background noise level) if the signal is too low. Therefore, high sensitivity microphones are needed to measure very low noise levels (lower than 30 dB), and low sensitivity ones have to be used for high noise levels such as for impact noise (above 130 dB).
6.2.5. Selection and Use of a Microphone

The selection of the microphone is based on:
- the levels to be measured,
- the frequencies to be measured - low or high,
- the type of acoustic field - free or diffuse,
- the purpose and the type of measurement - overall level or frequency analysis.

As stated previously, the measurement of low noise levels requires high sensitivity microphones and for high levels, low sensitivity ones are needed. The problem arises outside the range 50 to 120 dB usually: the characteristics indicated by the manufacturer for both the microphone and the indicating instrument should be checked.

If the noise is predominantly at frequencies below 1 kHz and overall levels are to be determined, any type of microphone may be used. On the contrary, if the noise is suspected or known to include a high frequency content, or that a frequency analysis is going to be made, the frequency characteristics of the microphone must be checked. As stated earlier, the smaller the physical dimensions of the microphone, the wider the frequency range and the lesser the effects of directivity since they occur at higher frequencies. Microphones of small diameter would then be preferable. However, they are more fragile and, with the exception of certain special ones, less sensitive.

The user must then choose between free field or diffuse field microphones. When it is necessary to measure the ambient noise level at a given point regardless of the localisation of the sources or in presence of a diffuse field, a diffuse field microphone must be used: this is generally the case in occupational hygiene for the evaluation of exposure to noise.

On the contrary, for control purposes, the aim is usually to characterize the noise emitted by a particular machine. The machine should ideally be placed in a free field environment or at least in a very absorbing room and a free field microphone should be selected. If this is not possible, there exist ISO standards to assist with making the measurements “on-site” (ISO 3740, ISO11200).

Where possible, a diffuse field microphone should be directed at about 70° from the direction of the "predominant" noise source, so that the frequency responses for direct and reflected waves are the same. It should always be remembered that this concerns only high frequencies; therefore the "predominant" source is, in this regard, the one emitting the most at these frequencies, regardless of what is emitted at frequencies below 1 kHz.

Similarly, a free field 0° microphone must always be pointed toward the "predominant" source.

6.3. SOUND LEVEL METERS

6.3.1. Description

The electrical signal from the transducer is fed to the pre-amplifier of the sound level meter and, if needed, a weighted filter over a specified range of frequencies. Further amplification prepares the signal either for output to other instruments such as a tape recorder or for rectification and direct reading on the meter.
The rectifier gives the RMS value of the signal. The RMS signal is then exponentially averaged using a time constant of 0.1 s ("FAST") or 1 s ("SLOW") and the result is displayed digitally or on an analog meter.

In some cases, the sound level meter does not include a logarithmic converter. The scale on the indicating device is then exponential so that the linear signal may be read in dB. In this case, the dynamic range of the display is usually restricted to 10 to 16 dB and the precision of the reading is rather poor. In the case of intermittent noise, the user must constantly adjust the amplifier to adapt the output signal to the dynamic range of the display.

When a log converter is used, the display scale is linear in dB and its dynamic range is usually much greater. This type of display has the advantage of providing the same precision at any level and permitting a much better appreciation of the range of fluctuations of the noise to be measured. In this regard, digital displays are less useful.

The specifications of sound level meters are given in IEC 60651 for four types 0, 1, 2, 3 differing by the measurement precision. The measurement precision is reduced as the type number increases, affecting manufacturing costs significantly. The IEC 60651 standard specifies the following characteristics:
- directional characteristics
- frequency weighting characteristics
- time weighting, detector and indicator characteristics
- sensitivity to various environments.

The type 0 sound level meter is intended as a laboratory reference standard. Type 1 is intended especially for laboratory use, and for field use where the acoustical environment has to be closely specified and controlled. The type 2 sound level meter is suitable for general field applications. Type 3 is intended primarily for field noise survey applications. The frequency response for all types is defined from 10 Hz to 20000 Hz with a higher accuracy at frequencies from 100 Hz to 8000 Hz.

Type 2 and type 3 sound level meters usually include only the A-weighting network and the FAST and SLOW response. Models with AC outlets should be chosen as they make it possible to record the noise on a magnetic tape recorder for further analysis. They are usually equipped with a diffuse field piezoelectric or electret microphone.

Type 0 and 1 sound level meters are often much more versatile with the possibility of measuring vibrations or inserting octave or one third octave band filters. They usually make it possible to measure a non-weighted signal (FLAT response) as well as an A-weighted and a C-weighted signal. They come with a choice from a variety of condenser microphones of different sensitivities and characteristics.

As previously seen, the evaluation of impulses involves the determination of the peak level and the duration of the impulse. Some precision sound level meters are equipped with a circuit that makes it possible to measure the peak level: the time constant used in this case is about 50ms and a circuit is included to hold the instantaneous level. After recording the peak value, the meter must be reset in order to read another value.

Some sound level meters offer the possibility to measure the equivalent A-weighted level \( L_{A_{eq,T}} \) according to the equal energy principle. This can be done in two ways. In the first, the integrating period is prefixed (in some cases, 60 seconds) and the instrument computes the \( L_{A_{eq,T}} \) level progressively: intermediary readings are then irrelevant and the user may only record the final value. In the second type, the integrating period is not fixed and the instrument actually gives the \( L_{A_{eq,T}} \) level computed during the time elapsed since it was started. This type is of more
use than the first one as the user does not have to define beforehand the integrating time to be used. A different type of integrating sound level meter will be more thoroughly discussed in section 6.5.

(Editors’ note: The International Standards IEC 60651 and 60804 define classes of instruments instead of types. The ongoing revision of these standards will result in one single standard which will define only classes 1 and 2 for normal and integrating sound level meters as well.)

6.3.2. Use of Sound Level Meters

This section describes how to use physically the instrument in order to correctly measure the noise level existing at the point where the microphone is placed. The following steps must be taken successively:

1. Batteries must be checked before use (see Section 6.9) and during long measuring sessions.
2. A wind shield must be used if the air velocity is noticeable. It should anyway be used all the time as a dust shield (see Section 6.9).
3. The microphone should be oriented as described previously.
4. All intruding objects such as the body of the sound level meter (SLM) or the operator itself will degrade the frequency response of the microphone at high frequencies and directivity effects will appear at much smaller frequencies. Therefore, the SLM should be, whenever possible, installed on a stable and sturdy tripod equipped with resilient blocks to isolate the sound level meter from vibration and consequent spurious readings. The operator should be at a reasonable distance (2-3 m) behind the sound level meter. Extension cables should be used if possible when measurements are to be made in a restricted area (see section 6.9). When the instrument makes it possible, an extension rod should be used for the microphone. For walk-through surveys, the SLM should be held well away from the body.
5. The SLM must be calibrated before any measuring session using a calibrator described in Section 6.8. If the temperature of the instrument is significantly different from the ambient temperature where it will be used, it should be first warmed up (see Section 6.9) before calibration and use. The calibration must be checked at the end of the session. If the instrument is not calibrated anymore, the data might have to be discarded and the reasons for this calibration change should be investigated as this might indicate an important malfunctioning of the instrument.
6. Nowadays, it is much more advantageous to use an integrating sound level meter to determine the $L_{A_{eq},T}$ over a representative period of time $T$ than to use a simple SLM on fast or slow giving an instantaneous value.

6.4. FREQUENCY ANALYZERS

6.4.1. Description

The objective of frequency analysis is to determine how the overall level is distributed over a range of frequencies. The most usual analysis for occupational hygiene noise studies is octave band analysis. For more detailed information, narrower bands can be used such as one-third octave analysis or constant bandwidth analysis.

A number of analyzers are available for use with the sound level meter. The simplest models are sets of passive filters (octave or one third octave) that can be inserted between the two
amplifiers of the SLM. Other analyzers are specific instruments making it possible to automatically scan the whole range of frequency bands. These are sequential instruments making measurements in one band at a time. This strongly restricts their use as the noise must be constant both in amplitude and in frequency during the 5 to 10 minutes of the analysis.

More sophisticated analyzers have the possibility to make the frequency analysis in all desired bands at the same time. These are analyzers using a set of parallel filters or using the fast fourier transform of the input signal before recombining the data into the desired bands.

One important aspect to be considered about the filters is their frequency characteristics. Ideally, the filter should provide an attenuation of infinity outside the band. In practice, this is never the case. For most common filters, the attenuation at the cut off frequencies is usually around 3 dB and is some 24 dB per doubling of frequency outside that range. Figure 6.4. gives the typical frequency characteristic of an octave band filter. The practical implication of this is that a signal of 100 dB at 1000 Hz for instance will give a reading of 76 dB in the octave bands centred at 500 Hz and 2000 Hz, although no energy is present at frequencies covered by these two octave bands.

The user must then be very careful when interpreting the results of the frequency analysis of a noise that includes a strong pure tone.

Figure 6.4. Typical 500Hz octave band filter characteristic
As an example, consider the octave band spectrum of figure 6.5, presenting a predominant value for the 1000 Hz octave band (106 dB). A pure tone of 106 dB at 1000 Hz would give a reading of $106 - 24 = 82$ dB both for the 500 Hz and the 2000 Hz octave bands. The levels of 90 and 91 dB respectively would not be very much influenced by this and therefore would reflect the total intensity at frequencies inside these bands.

However the frequency of the pure tone might be 1175 Hz: the attenuation provided by the 2000 Hz octave band filter would then be 15 dB and the level in this band 91 dB. Similarly for a 860 Hz tone, the attenuation for the 500 Hz octave band would be 16 dB and the level wrongly estimated at 90 dB.

![Figure 6.5. Example of the octave spectrum of a noise including a pure tone in the octave centred at 1000 Hz](image)

It is clear that, unless more sophisticated frequency analyses are performed, it is impossible to know precisely the frequency of the tone and therefore to determine whether the levels in the side bands are correct or not. Faced with cases like this, the user must proceed with more sophisticated analyses.

For more sophisticated instruments and especially for digital equipment, the problem is of a lesser importance as the filter attenuation with frequency is usually much higher (typically over 90 dB per octave).

### 6.4.2. Use of Frequency Analyzers

The procedure described here for carrying out a frequency analysis will only be concerned with
the use of sequential octave or one-third octave filters, as with more sophisticated parallel filter
equipment, the procedure might be very instrument specific. Again, only technical aspects will
be presented here: the problem of deciding what type of analysis needs to be done, when and for
what purpose being discussed elsewhere. Basic elements are:

1. Usually frequency analyses are performed on unweighted signals. If it is not the case, the
weighting used must be clearly indicated (e.g. “A-weighted”).

2. It is obvious that the noise must be fairly steady both in frequency and in amplitude during
the time of the sequential analysis. If it is not steady, the noise must be recorded on a
magnetic tape and the sample must be successively analyzed with each filter. Clearly this
problem would not exist in equipment with parallel or FFT filters.

3. As the width of octave or one-third octave bands is smaller for low bands (31.5 and 63 Hz)
than for higher ones, the fluctuations of the noise are usually much greater. Therefore the
sampling time in order to get a reliable evaluation of the band level must be higher: actually,
the sampling time must be inversely proportional to the width of the band (in Hz).

4. The frequency analysis should be carried on only for those bands for which the frequency
characteristic of the microphone and the input amplifier is flat. Corrections may not simply
be added to measured levels.

5. As shown in figure 6.1, the filters are inserted between the input amplifier which receives the
total signal and the output amplifier which must prepare the filtered signal for detection and
display. For a noise such as the one represented in Figure 6.5, the overall level was 113 dB,
while the 8 kHz octave band level was 70 dB. The difference in this case is 43 dB which
means that the output signal of the filter was 140 times (10 to the power 2.15) lower than the
input signal. In such a case, care must be taken for the input signal not to saturate the input
amplifier and/or the output signal not to be covered by the internal electronic noise of the
output amplifier. The instruction manual of the measuring instrument should be consulted
about the procedure to prevent this. Some sound level meters are provided with overload
indicators for each amplifier to check that this is not the case.

6. Data for octave and one third octave analyses must be reported in a bar graph format instead
of by simply joining the different points plotted at centre frequencies (see Figure 6.5).

6.5. NOISE DOSIMETERS

6.5.1. Principles

The need to ascertain the noise exposure of workers during their normal working day, has led to
the development of the noise dosimeter. This is a small, light and compact instrument to be worn
by the worker. It measures the total A-weighted sound energy received and expresses it as a
proportion of the maximum A-weighted energy that can be received per day. This instrument is
particularly useful whenever the exposure varies appreciably during the working day.

The maximum A-weighted energy that is permitted to be received per day is defined in
standards or regulations: it is absolutely necessary that the dosimeter be calibrated on the basis
of the adopted standard (e.g. 85 dB(A) or 90 dB(A) for an 8-hour exposure), including the
accepted trading rule, which is 3 dB(A) in accordance with the ISO 1999 - 1990 standard (and
for most European countries) and 5 dB(A) for the OSHA Standard (USA). The 3 dB(A) trading
rule is consistent with the equal energy principle: 96 dB(A) during 2 hr providing the same
energy as 93 dB(A) during 4 hours or 90 dB(A) during 8 hours. The 5 dB halving rate assumes
that 90 dB(A) during 8 hours is equivalent to 95 dB(A) for 4 hours or 100 dB(A) for 2 hours.
(Editors’ note: NIOSH recommended in 1998 a 3-dB exchange rate, see Chapter 4)

Dosimeters are actually sound level meters having a DC output signal converted into a series of impulses which are counted to provide the dose. The technical characteristics of dosimeters must then be the same as for type II sound level meters.

6.5.2. Use

The noise dosimeter is clipped to the workers' clothes with the microphone close to the ear, and can be worn without hampering work. The dose provided by the instrument is of course dependent on the duration during which the instrument is used. Therefore, it should first be corrected for an 8 hour period and then converted to the daily noise exposure ($L_{EX,8}$) level according to the relevant formula (ISO or OSHA).

It is important to know that some old dosimeters do not take into account levels below 89 dB(A) or 80 dB(A), as they assume that lower levels do not lead to hearing impairment. The $L_{EX,8}$ is then physically not correct. These dosimeters are obsolete and should be discarded. On certain instruments, a warning marker is activated if the peak level ever exceeds 140 dB.

It is worth noting that the characteristics of the dosimeters have never been standardized. Furthermore, they are extremely limited as they provide one single value at the end. It is strongly recommended to abandon this type of instrument and use the personal sound level meters described in the next section.

6.6. PERSONAL SOUND LEVEL METERS

6.6.1. Principles

Personal sound level meters are in fact integrating sound level meters designed as dosimeters in order to be worn by the worker during his regular work. These instruments make it possible to record on almost any increment of time the equivalent level, the peak level or any statistical parameter. Typically it will record the $L_{Aeq,T}$ (in dB(A)) and $L_{peak}$ (in dB) every second. This is extremely interesting as it makes it possible to analyse the evolution of the noise exposure during the day and to correlate it to the type of work or the location of the worker.

This type of instrument makes use of the equal energy principle and offers generally a much broader dynamic range than dosimeters discussed in section 6.5. They are definitely expected to replace dosimeters in the near future and in fact are already referred to as dosimeters by some manufacturers and users. Personal sound level meters or personal sound exposure meters conform to the IEC 61252 standard.

6.6.2. Use

Their use is identical to the one of dosimeters with the microphone located closer to the ear of the worker.

6.7. RECORDERS

6.7.1. Graphic Level Recorder

If the sound level meter has a logarithmic DC output facility, common graphic recorders can be
used to obtain a permanent record of the evolution of the sound level, providing that their writing speed is compatible with the SLOW or FAST characteristics of the SLM.

If there is no DC output or if this output is not proportional to the dB level but only to the RMS pressure, then a special recorder must be used. Many different types are available and it is not intended to review them. The essential characteristics for this type of equipment are:

- the RMS detection capabilities;
- the frequency response;
- the writing speeds, that should at least correspond to the slow and fast characteristics of the sound level meter. For reverberation time measurements, however, much faster writing speeds are needed;
- the dynamic range of the graph (often 25 or 50 dB) and of the instrument.

It is usually not practical to record graphically the instantaneous noise level at a workplace for extended periods of time: the graph allows only the determination of maximum and minimum levels and cannot be used to define any average level. The use of this technique should be restricted to special cases such as:

- the characterisation of short events of noise;
- the determination of the intermittency of a noise;
- the study of the reverberation time;
- the recording of frequency analysis.

A graphical record of the history of the $L_{Aeq}$ noise level is usually possible with the exposure meters described in Section 6.6.

6.7.2. Magnetic Tape Recorders

Magnetic tape recorders are used to make a permanent recording of the noise for future analysis or reference. Some HIFI audio recorders can be used, providing their frequency response and dynamic range are suitable. For general surveys, small recorders with a frequency response of $\pm 3$ dB in the range 30 Hz to 16 kHz and a dynamic range of 40 dB may be sufficient. For precise measurements and frequency analyses, higher quality instrumentation is needed. The real objectives of the instrument have to be assessed since the relative price of these instruments may vary in the range of 1 to 20.

As the dynamic range of an analog recorder is no more than 40 to 50 dB, usually it is difficult or impossible to record impulse noise as met in industry or as used for measuring the reverberation time. Some digital recorders (referred to as DAC recorders) are now available: they have a much broader dynamic range (around 90 dB) and a good frequency response (20 - 18000 Hz).

Besides analog and digital recorders, there are also frequency modulated (FM) recorders which are of special interest for measuring vibration as their frequency range extends down to DC.

6.7.3. Use of a Tape Recorder

The criteria for the selection of a tape recorder are:

- the frequency response at the different speeds. Usually the limits are directly proportional to the speed;
- the range of speeds;
- the dynamic range;
The procedure for making a recording is as follows:

1. Use preferably as the input signal, the AC output of a sound level meter, making it possible to control the level of this signal in steps of 10 dB. This will be assumed to be the case in the following steps.

2. In presence of the noise, adjust the SLM so that the SLM reading is between mid and full scale. Adjust the input potentiometer of the recorder (on pause) so that the signal does not saturate the amplifier of the recorder (as indicated by the V.U. meter). The meter needle should NEVER go into the red part of the scale. The input attenuation should not be too high, however, or the dynamic range of the recording will be reduced.

3. Once this is done, DO NOT modify any more the setting of the recorder. Record by voice the attenuation used on the SLM (for example 80 dB).

4. Adjust the noise calibrator (for example, 94 dB, 1000 Hz) so that the correct level is read on the SLM. Place the SLM attenuator on the corresponding attenuation (e.g. 90 dB) and record the calibration signal for 1 or 2 minutes, mentioning clearly by voice, on the tape, what will be done and what has been done. The output signal of the SLM is in this case proportional to: attenuation setting (90) + 4 (meter reading) dB. Therefore, the recorded signal will be a reference of 84 dB, if 80 is the attenuation to be used for the real recording.

5. Remove the calibrator, replace the SLM attenuator on its previous setting and after indicating orally the start of the recording and its probable duration, proceed with it. The duration of the recording is dictated by the problem to be investigated. It is well advised to make much longer recordings than at first appears needed.

6. At the end of the recording, again indicate orally the stop and give full information on what was recorded, and on any particular event that might have happened during the recording.

7. Repeat Step 4 of calibration.

If, for any reason, the settings of the recorder have been modified during the recording, the whole procedure must be repeated.

6.8. CALIBRATORS

Microphones are individually calibrated at the factory, and the calibration chart must be delivered with the instrument. In the field, calibration is performed by applying a known sound pressure level at a fixed frequency to the microphone. Calibrators are small, battery driven and operate on different principles. One operates at 250 Hz and produces a sound level of 124 dB, accurate to ± 0.2 dB. To obtain the best results, the microphone should be well sealed in the coupler opening. A change in atmospheric pressure alters the calibration level slightly, but a correction
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can be made using the barometer which is provided as a part of the instrument set. Another example is a pocket unit, which operates at 1000 Hz. The calibration level is 94 dB with an accuracy of ± 0.5 dB.

The use of a calibrator as defined by IEC 60942 is recommended for checking the accuracy of hand-held indicating instruments, and must be used when tape recording data, as explained previously. Accurate calibration of equipment used in the field is essential as it provides for consistency in measurements, allows accurate comparison of measurements made over long time intervals, brings to light any slight changes in the accuracy of instrumentation, and allows a re-analysis of data, if this is required at a later date. This care in the use of calibration for field measurements should be backed up by regular laboratory calibration using more accurate techniques, in order to check the frequency response as well as the amplitude response of the equipment.

6.9. STORAGE, HANDLING AND TRANSPORTATION

It is obvious that great care must be taken of the instruments. They should not be exposed to extremes of temperature or to direct sunshine. The limits that the instruments can stand are usually defined by the manufacturer. The operating range of temperature should also be specified: it is usually narrower.

- Instruments should also not be exposed to extremes of humidity, and any condensation should be carefully avoided. This means in particular that the instrument should not be taken from a cold environment (a cold car in wintertime for instance) directly to a hot and humid place. If the temperature of the instrument is lower than the dew point of this environment, condensation might occur, provoking short-circuits or general malfunctioning that might be unnoticed. The problem is of a greater importance for microphones. Condensation on the membrane might in the short term induce erroneous measurement; in the long term however, oxidation of the membrane develops and small holes might appear: in this case, the microphone must be replaced.

Before going from a cold to a hot environment, the instrument, in its tight box, should be progressively brought to a temperature near that of the new environment and certainly well above its dew point. This means also that the equipment should not be left in the cold overnight or transported in the trunk of a car.

The equipment should also be stored in a normal temperature (10 to 25°C) and dry (30 to 70% relative humidity) environment. Microphones should be taken care of by surrounding them with desiccating capsules or even storing them in a dry 20°C oven when they are not in use.

Measuring instruments should not be exposed to vibration for obvious reasons. This implies that they should always be stored, handled and transported in their original box with damping materials such as plastic foam around them. This is also a further reason for not transporting them in the trunk of a car.

Measuring instruments should be protected against dust. Portable instruments such as sound level meters, and dosimeters, when not used, must be stored in their box. When used, they might be protected by either removing them from the dusty area and using extension cables, or by enveloping them in tight plastic bags. Laboratory instruments, standing on tables, should be covered with a plastic sheet when not used: such a cover is usually provided by the manufacturer. As far as the microphone is concerned, a wind shield should always be used. This shield, consisting generally of a ball of very porous plastic foam, must be cleaned carefully and regularly. The foam shield must be discarded if it shows any sign of crumbling.

Dust on the microphone membrane is however unavoidable. The user should never try to
remove it either with his finger (as this will modify the position of the membrane) or by blowing air on it (as this will induce condensation). If by accident, the membrane has become very dusty, one might try to remove the larger particles carefully with a very soft paint-brush. The membrane may be cleaned with a cotton wool bud soaked in hexane.

The instruments should also be kept away from polluted areas. This is however seldom a problem if condensation is avoided. The same precautions apply here.

Batteries should be removed from the instrument when it is not used for a prolonged period of time. Non rechargeable batteries should be checked regularly and replaced as soon as they are flat, otherwise they might leak which might corrode and completely wreck the instrument. Rechargeable batteries must be kept fully charged as far as possible. The batteries of an instrument make a single set which must be charged together. Individual batteries should not be interchanged between sets and the whole set needs replacement when worn. The manufacturer should be consulted regarding how to charge the set, with what adaptor, at what rate, and how many times this can be done. For instruments powered by mains, the voltage must be kept in the range indicated by the manufacturer. A stabilized supply might be needed if the voltage fluctuates too much.

Great care must be taken of cables, connectors and switches. These are the main reasons for errors or problems. Cables should be wound very loosely when necessary. In the laboratory they should be kept straight, hung by the middle (not by a connector), loosely bent. They should be replaced as soon as the insulating plastic becomes damaged. Connectors should be checked systematically. If by accident, cables have been sharply cut or bent or exposed to high heat or any strong pull has happened on a connector, the cable must be carefully checked and ideally discarded, as short-circuits or open circuits might happen then or later, which could damage the instrument or lead to erroneous measurements. The instrument to which the cable was connected should also be checked for loose plugs, open circuiting or short-circuiting.

Switches are very delicate items, especially on recent smaller instruments. They must be operated softly and without pressure. As soon as they indicate any sign of malfunctioning, switches must be thoroughly cleaned and, if necessary, replaced. The cleaning can best be done using cotton tips soaked with alcohol or hexane. Cleaning products that might leave residue or attack the contacts (sometimes gold-plated) must be definitely rejected. Care must also be taken with microphone threads while screwing to sound level meters.

Magnetic recorders need special attention concerning the cleaning of the heads (as described above) and the choice and handling of the tapes. Tapes should be demagnetized before recording and stored away from iron or steel surfaces (and, of course, magnetic fields). They should be kept in a dry box at all times. When mounted, the recorder cover must be kept closed. Tapes should be discarded after a few uses as the magnetic noise builds up, restricting the dynamic range of recording. Heads might need special care in addition to regular cleaning: the operating manual should be consulted.

Finally, the manual of each instrument might give special instructions concerning its handling, the storage and the maintenance. Needless to say that this must not be overlooked but must be practised during the entire life of the instrument.

REFERENCES

INTERNATIONAL STANDARDS

Titles of the following standards referred to in this chapter one will find together with information on availability in chapter 12:


FURTHER READING