Noise Instrumentation and Measurements

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Noise Limits (OSHA)

- Permissible noise exposures (table)

dBA	Time, hrs
80	32
85	16
90	8
95	4

$$T_{allowed} = \frac{480}{2^{\left(\frac{SPL-90}{5}\right)}}$$

- Fraction of allowed dose for 8 hrs

$$\%ofAllowedDose = 100\% \sum_{i=1}^{n} \frac{T_{exposed\_i}}{T_{allowed,i}} = 100\% \left(\frac{C_1}{T_1} + \frac{C_2}{T_2} + ... + \frac{C_n}{T_n} \right)$$

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Must determine dose from many SPL values

- Need representative survey
- Need accurate measurements

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Overview of Measurements

- Standards
- Instruments
  - Sound level meter
  - Octave band analyzer
  - Dosimeter
  - Types of microphones
- Issues in taking measurements
  - Angle of microphone to noise source
  - Near and far fields
  - Directionality
  - Effects of body and obstructions

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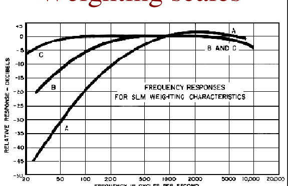
Weighting scales

- Definition: adjustments to measured values
  - All scales ignore very high and very low frequencies
  - 1000Hz unweighted on all scales
- A scale
  - Fletcher-Munsen Curves
  - dBA
  - Approximation of responses of human ear (equal loudness at 40dB), which discounts low freq.
  - Required by OSHA and EPA
- B scale is rarely used (dBB)
- C scale
  - dBC
  - Weights frequencies nearly equally
  - Sometimes used in noise control
  - Used for environmental noise (EPA)



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Basic Sound Level Meter- Weighting Networks

- The "A" weighting network weights a signal to inverted equal loudness contour at low SPLs, the "B" network for medium SPLs and the "C" network is for high SPLs.
- Linear or "Lin." network. This does not weight the signal but enables the signal to pass through unmodified.
- Nowadays the "A" weighting network is the most widely used since the "B" and "C" weightings do not correlate well with subjective tests. "A" network, noted as dBA, is required by the OSHA noise standard.

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Range of Frequencies/Impact Noise

- Impulse/impact noise
  - PEL → based on loudness and impacts per day
- Infrasonic – anything under 20Hz
- Ultrasonic – anything over 20,000Hz

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Sound Level Measurement Devices

- Types of measurement instruments
- Types of microphones
- Calibration
- Sound level meter
- Octave band analyzer
- Dosimeter

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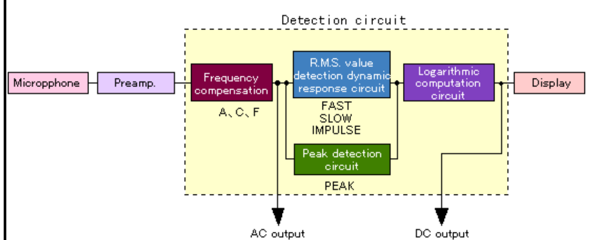
Logic of Sound Instrument



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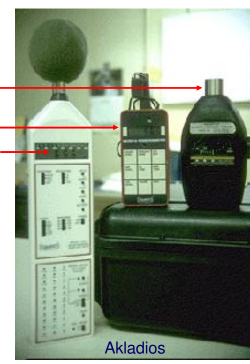
Types of Sound instruments:

- Sound Level Meter
- Noise Dosimeter
- Octave Band Analyzer



Make sure instrumentation is calibrated . . . !!

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Types of microphones

- Capacitor (also called "condenser")
  - Thin-stretched diaphragm forms one plate of a capacitor.
  - Diaphragm is displaced by acoustic energy, causing distance between capacitor plates to vary.
  - Has high electric field strength
  - Dust between plates and condensation of water vapor a problem
- Electret (e.g., Quest 1900 Type I)
  - Similar to capacitor
  - Electrical discharge equivalent of a permanent magnet
  - More affected by temperature, less by moisture than capacitor type
- Piezoelectric
  - Quartz or tourmaline crystals which generate an output potential when strained by a force
  - Highly linear with superior dynamic ranges without distortion
  - Very rugged; not affected by moisture but sensitive to vibration
- Ceramic
  - Similar to piezoelectric, except use barium titanate
  - Very rugged, but not the precision of others (so typically used in Type 2, such as dosimeters)

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More on Condenser (Capacitance) Microphones

from Noise and vibration measurement procedures M.P. Norton

- Most commonly used type of microphone because
  - very wide frequency range
  - Insensitive to vibrations
  - Very stable
  - Can be used for extreme temperatures
- Drawbacks
  - Very expensive
  - Relatively large

- Sensing element is a capacitor with a diaphragm
  - deflects with variations in the pressure difference across it.
  - change in capacitance converted into an electrical signal for recording or analysis.
- Size of diaphragm
  - the smaller the diameter of the diaphragm, the higher is the frequency response of the microphone.
  - Range as low as 0.01 Hz and as high as 140 kHz. Dynamic up to 140 dB
  - smaller microphones have a lower sensitivity
- Available with three different types of response characteristics:
  - free-field; pressure; and, random incidence.

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Condenser microphones

from Noise and vibration measurement procedures M.P. Norton

- Free-field
  - Compensate for the disturbance due to their presence in the sound field
  - Uniform frequency response for the sound pressure that existed prior to their insertion in the sound field.
  - Free-field microphones can thus be pointed directly at the sound source.
- Pressure microphones
  - Specifically designed to have a uniform frequency response to the actual sound pressure.
  - Diaphragms should thus be perpendicular to the sound source to achieve grazing incidence.
  - Pressure microphones are often flush-mounted on surfaces for the measurement of flow noise.
  - Can be used as random incidence microphones by fitting them with suitable correctors (provided by manufacturers)
- Random incidence microphones
  - Omni-directional microphones: respond uniformly to sound pressures in diffuse fields.

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Fast/Slow

- Historical artifact due to limitations of early technology, especially meter movements
- Fast: 1/8 sec.
  - Used to estimate the variability in the observed sound where only the limits (upper and lower) are desired.
- Slow: Integrates over longer time (1.0 s)
  - Takes the average to simulate human exposure rather than following a sudden increase or drop
  - Mandated for use by OSHA

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Other issues

- Integrating/Averaging SLM
  - dBA
  - Eliminates slow/fast
  - Defined only for 3 dB doubling
  - Not applicable to OSHA enforcement
- True Peak SLM
  - Fast as electronics allows
  - May be A-weighted or not
- Community Noise Analyzer
  - May selectively use each weighting scheme
  - Computed measures based on integration, averaging and statistical processing
  - Typically enclosed in weatherproof containers and use all-weather microphones

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Calibration

- Sound level meters can be calibrated with a portable acoustic calibrator, such as a sound level calibrator, or a piston phone.
- Calibrators provide a precisely defined sound pressure level to which the sound level meter can be adjusted
  - 114 dB at 1,000 Hz
  - Accuracy: ±0.3 for Type 0 and I, ±0.4 for Type II
- Calibrate sound level meters immediately before and after each measurement session.

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The Basic Sound Level Meter

- Sound level meter is an instrument designed to respond to sound in approximately the same way as the human ear.
- System consists of a microphone, a processing section and a read-out unit.
- The microphone converts the sound signal to an equivalent electrical signal.
- In computing overall value, levels at different frequencies may be “weighted” differently

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Types of SLMs

- Type 0
  - Laboratory standard; high precision
- Type 1
  - Precision (errors < 1 dB)
  - Field and lab
- Type 2
  - Errors < 2 dB
  - General purpose
  - Most used for field surveys
- Type S
  - Special purpose
  - Errors not regulated
- Unregulated
  - Cheap
  - Used by lay people
  - No standing in OSHA compliance

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Impulse and True Peak SLM

- Impulse
  - used in community noise, not OSHA
- True Peak
  - Not well defined
  - OSHA requires less than 140 dB for any length of time
  - Type 0: Actually measures for 50µ second
  - Type 1, 2: Actually measures for 100µ second

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Types of Sound instruments:

- Sound Level Meter
- Octave Band Analyzer
- Noise Dosimeter

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Octave Band Sound Level Meter

- In "frequency analysis", evaluate sound divided into bands of wavelengths
- Frequency range from 20 Hz to 20 kHz can be divided up into sections or bands with electronic filters. Bandwidth either one octave or 1/3 octave.
- An octave is a frequency band where the highest frequency is twice the lowest frequency ($f_2 = 2f_1$).
  - For example, an octave filter with a center frequency of 1 kHz admits frequencies between 707 and 1414 Hz
  - For 1/3 Octave: ($f_2 = 2^{1/3} f_1$)
- Noises with high energy in the middle and high frequency regions (600-1200 Hz and higher) damage hearing
- Noise reduction treatment procedures are quite effective in suppressing the more damaging high frequency sound. They are least effective in attenuating the less harmful (but annoying) low frequencies.
- Hearing loss may occur faster if spectra has sharp peaks

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Octave Band Analyzer Frequencies

Centers of Octaves:

31.5
63
125
250
500
1,000
2,000
4,000
8,000
16,000

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Octave Band Analyzer

- Used to:
  - Select adequate damping material with appropriate α
  - Select adequate isolation material with appropriate Transmission Loss (TL)

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Types of Sound instruments:

- Sound Level Meter
- Octave Band Analyzer
- Noise Dosimeter

Make sure instrumentation is calibrated . . . !!

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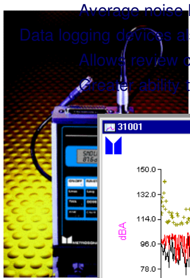
Dosimeters

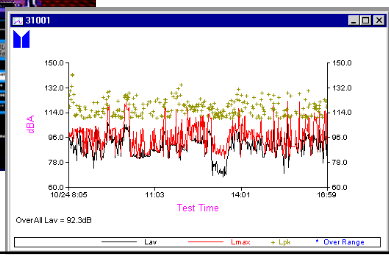
Integration of noise over time. Computes:

- Dose in percent
- Average noise level

Data logging devices also store minute-by-minute data

- Allows review of exposures, giving more confidence in results
- Greater ability to relate exposures to sources and tasks





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Dosimeter Settings

- Weighting:
  - A weight
- Threshold cutoff*
  - 90 dBA: MSHA and OSHA for evaluation of need for controls
  - 80 dBA: OSHA, ACGIH
  - 0 dBA: NIOSH ?? and others

  * Note: will show 0 dBA if below threshold for equivalent average of sampling time
- Doubling rate
  - 5 dBA: OSHA
  - 3 dBA: NIOSH, ACGIH, and others
- Peak
  - 114 dBA

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Using a Dosimeter

- Before starting:
  - Check battery
  - Check settings and set to zero dose
  - Check calibration
- Attaching to worker
  - Identify yourself
  - Explain what you are doing and answer questions
  - Attach dosimeter near clavicle
  - Put windscreen over microphone
  - Record worker's name, job title, and when will stop work for lunch or day
  - Start dosimeter and record start time
- After starting:
  - Check on worker(s)
  - Sketch layout
    - identify where worker stands
    - Identify location and info about sources

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Dosimeter

- After measurement, record:
  - Make, model, and serial number of dosimeter
  - Serial number and last annual calibration date
  - Pre- and post-calibration levels and date
- Ask subject, supervisor, etc. if abnormal events during the time sampled and what happens during the unsampled time.

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Dosimeter . . . 5

- After measurement, record:
  - Start and finish time of measurement (duration)
  - Settings of dosimeter
  - TWA measurement
  - Dose measurement
  - LEQ (Sound Level Equivalent) on dosimeter is the average sound Level received over entire shift
- Review data (does it make sense?)

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Taking Measurements

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Issues in taking measurements

- Angle of microphone to noise source
- Hardness of the room
- Near and far fields
- Directionality
- Effects of body and obstructions

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Directionality

- Noise in near-field often directional
- Noise can be reflected
- Consider in directing the microphone

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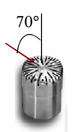
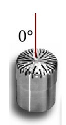
Angle of incidence

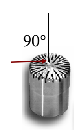
- Angle of microphone to source important if:
  - dimension of microphone greater than ¼ of the wavelength (i.e., about 6k).
  - sound is highly directional and high frequency
- Angle of microphone to source varies by type:



Random incidence microphone (designed to be independent of direction in diffuse field)



Direct incidence (free field) microphone



Pressure microphone

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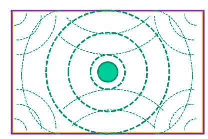
Hardness of the room

Free-field: totally without reflecting objects
- sound pressure level in any given direction from the noise source may be measured without the presence of interfering reflection.
- e.g., measurements made outdoors at the top of a flagpole
- e.g., anechoic chamber. In an anechoic chamber the ceiling, floor and all the walls are covered by a highly absorptive material which eliminates reflections.

- Reverberation chamber
  - all surfaces are made as hard and reflective as possible and where no parallel surfaces exist
  - creates a so-called diffuse field in which the sound energy is uniformly distributed throughout the room
  - Can measure noise anywhere, but is average of reflections



- Majority of rooms are somewhere in-between

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Anechoic Chamber

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Use of C Scale

- If the C-scale on a noise level meter has a higher level than the A-scale, what range of frequencies predominant in your sample?

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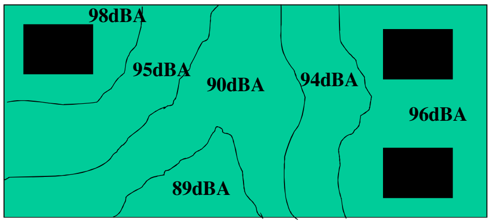
Using Sound Level Meter

- Average exposure using sampling techniques
- Source identification
- Contour mapping



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Vibration Measurements

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Vibration Measurement

Noise and vibration measurement procedures M.P. Norton

- Types of vibration transducers include:
  - Eddy current probes,
  - moving element velocity pick-ups,
  - and accelerometers.
- Accelerometer is the most commonly used vibration transducer
  - Best all-round characteristics
    - very large dynamic range (30 x 106:1)
    - come in all shapes and sizes, are very rugged
    - wide frequency range.
  - measures acceleration and converts the signal into velocity or displacement as required
  - Most widely used
  - Limitation: do not have a D.C. response
- Holds calibration very well for years
- The electrical signal from vibration transducer
  - passed through a preamplifier
  - subsequently sent to processing and display equipment
    - Low-end: simple analog device which yields a root-meansquare value of the signal
    - High-end: instantaneous analysis of the entire vibration frequency spectrum.

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Vibration Measurement

Noise and vibration measurement procedures M.P. Norton

- The most common type is the piezoelectric accelerometer
  - sensing element is a piezoelectric crystal which functions in a manner similar to that of the ceramic microphone. A
  - spring-mounted mass in contact with a piezoelectric element
  - generates an electrical charge across a polarised, ferroelectric ceramic element when it is mechanically stressed either in tension, compression or shear, as illustrated in Figure 8.
- Two types of piezoelectric accelerometers are commercially available.
  - compression type where a compressive force is exerted on the piezoelectric element
    - generally used for measuring high shock levels
  - shear type where a shear force is exerted instead.
    - general purpose applications
- Triaxial (3 directions) accelerometers are available.

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Vibration Measurement

Noise and vibration measurement procedures M.P. Norton

- Trade-off between sensitivity and frequency range.
  - Larger accelerometers have lower resonant frequencies and smaller useful frequency ranges. Manufacturers generally provide a frequency range chart
- The mass of an accelerometer can significantly distort the true vibration level on a structure.
  - "mass loading" is generally a problem on lightweight structures and at higher frequencies
  - One also has to ensure that the
- The mounting of an accelerometer on a vibrating structure is very important to obtaining reliable results
  - Large errors can result if it is not solidly mounted to the vibrating surface.
  - Accelerometers should also always be mounted such that the designed measuring direction coincides with the main sensitivity axis.
- Five common ways of mounting accelerometers are:
  - connecting threaded stud - very good frequency response
  - cementing stud - very good frequency response
  - thin layer of wax - very good frequency response
  - a magnet - limits the frequency response to about 6000 Hz but it provides good electromagnetic isolation
  - hand held probe
    - limits the frequency response to about 1000 Hz

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Vibration Measurement

Noise and vibration measurement procedures M.P. Norton

- Environmental influences that can affect the accuracy of an accelerometer
  - include humidity, temperature (up to about 2500C is okay)
  - ground loops
    - overcome by suitable earthing
    - isolate via a mica washer between the accelerometer and the connecting stud
  - base strains
    - if surface is experiencing large strains
    - Use shear type
  - electromagnetic interferences
  - cable noise.
  - moisture:
    - can only enter an accelerometer through the connector since it is a sealed unit.
    - Silicone rubber sealants are commonly used to overcome this problem

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The End

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