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**Introduction to Ergonomics and  
Industrial Safety**  
**Section Five**

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# Work Environment Design

- Methods analysts should provide good, safe, comfortable working conditions for the operator.
- The economic return from investment in an improved working environment is usually significant.
- Ideal working conditions:
  - Improve the safety record,
  - Reduce absenteeism, tardiness, and labor turnover,
  - Raise employee morale, and
  - Improve public relations.
- Additionally, there is always the "threat" of an OSHA inspection, citation, and fine.

# Work Environment Design

1. Noise,
2. Illumination,
3. Temperature
4. Ventilation,
5. Vibration,
6. Radiation
7. Shiftwork

# Noise

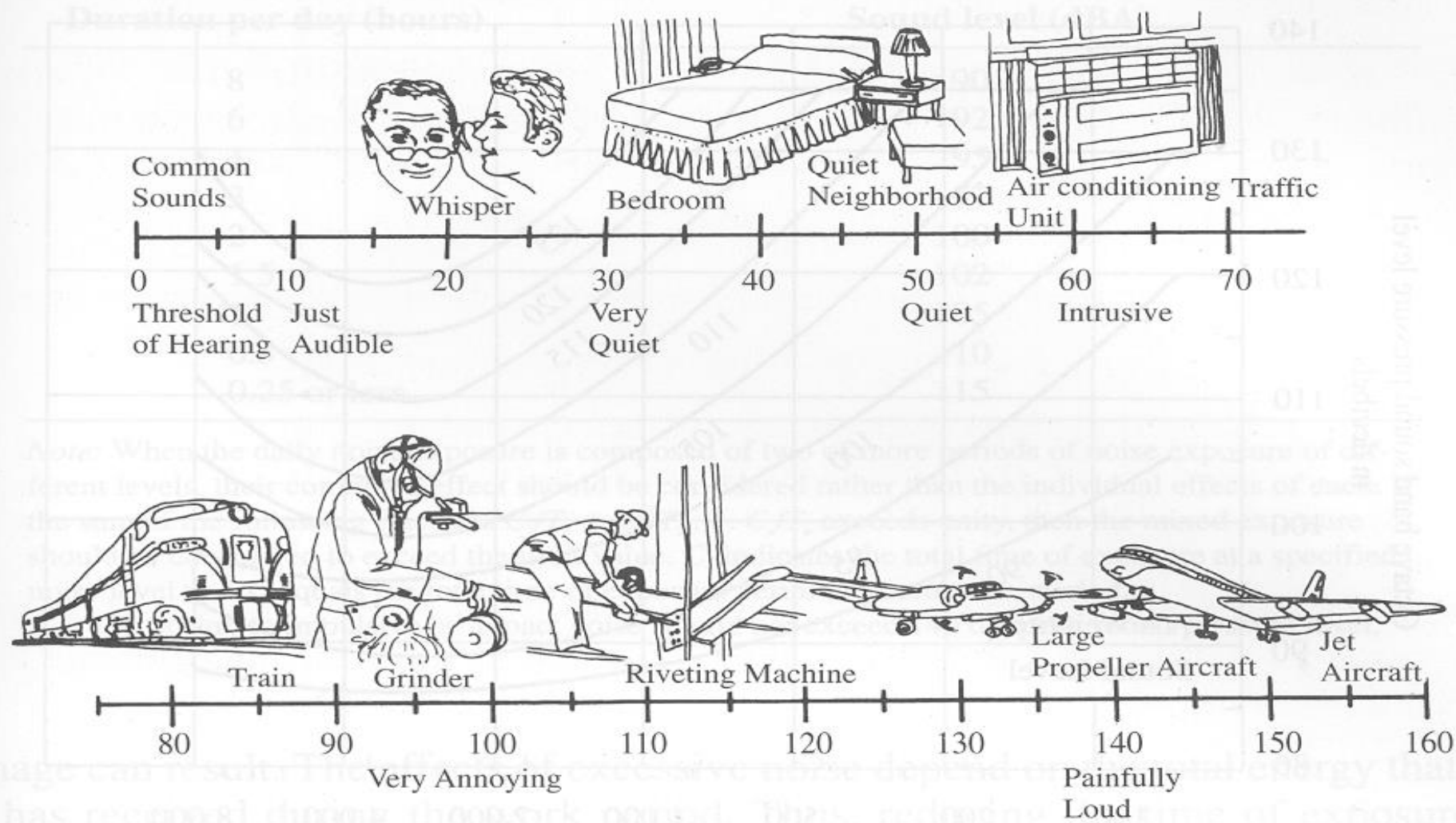
- Noise is any unwanted sound. Sound waves originate from the vibration of some object, which in turn sets up a succession of compression and expansion waves through the transporting medium (air, water, and so on).
- Frequencies audible to the human ear range from approximately 20 to 20,000 cycles per second, Hertz. The equation of wave propagation is:

$$c = f\lambda;$$

where:  $c$  = Sound velocity (1,100 ft/sec),  $f$  = Frequency in Hz,  
 $\lambda$  = Wave length in ft

- Sound intensity is measured in *decibel* (dB).
- The greater the amplitude, the greater the pressure.

**FIGURE 6-7**  
Decibel values of typical sounds (dBA).



# Effects of Noise

- From both psychological and physiological points of view, the low frequencies (50-500 Hz) are far less annoying and harmful than sounds in the critical frequency range of 1,000-4,000 Hz. Above of 10,000 Hz, hearing acuity again drops off
- Noise is classified as *broadband* noise - either continuous (textile industry) or intermittent (drop forge plant).
- In long-term situations, *broadband noise can result in deafness*; in day-to-day operations, it can result in *reduced worker efficiency and ineffective communication*.

Con...

### ***Physiological***

- Startle response - due to sudden loud noise
  - Causes spontaneous muscle contractions, blinking eyes

### **Hearing Loss**

- The chances of damage to the ear, increase as the frequency approaches *the 2,400 to 4,800 Hz range and also*, as the *exposure time increases*.

### ***Hearing loss (three categories):***

1. Temporary threshold shift - hearing impairment of short duration
2. Noise-induced permanent threshold shift - results from long term exposure to noise levels above 90 dB
3. Acoustic trauma - single exposure to high intensity noise can cause temporary or permanent hearing loss

## Meaningful Noise

- Meaningful noise represents distracting information that impacts the worker's efficiency.
- When a person is exposed to noise that exceeds the damage level, initially result a temporary hearing loss (complete) or recoverable after leaving the work environment. If repeated exposure continues over a long period, irreversible hearing damage can result.



## Permissible Noise Levels

- Established by Occupational Safety and Health Administration (OSHA) to avoid hearing loss
- Standards specify permissible duration of exposures for various dB levels

Sound Level	Duration	Sound Level	Duration
80 dBA	32 hr	95 dBA	4 hr
85 dBA	16 hr	100 dBA	2 hr
90 dBA	8 hr	105 dBA	1 hr
92 dBA	6 hr	110 dBA	30 min

# Noise Dose

- OSHA uses the concept of noise dose, with the exposure to *any sound level above 80 dB*. The several partial exposures to different noise are added to obtain a combined exposure:
- Although noise levels below 85 dB may not cause hearing loss, they contribute to *distraction and annoyance*,

## Performance Effects

- Performance decrements are observed in difficult *tasks that demand on perceptual, information processing, and short-term memory capacities*.
- Surprisingly, noise may have no effect, or improve performance, on simple routine tasks

# Noise Control

- ❑ Management can use three ways of noise control:
  1. *Reduce the noise level at its source* using rubber mounts and better alignment and maintenance of the equipment.
  2. *Isolate equipment by housing* all or a substantial portion of the facility in an insulating enclosure.
  3. *Acoustic absorption* can be provided on walls, ceilings, and floors to reduce reverberation.
- Wearing **Hearing Protection**: though OSHA accepts this as only a *temporary solution*, The equipment can include earplugs, some of which are able to attenuate noises up to 110 dB or more, (*noise reduction rating* (NRR), marked on the packaging). muff-type devices.

**TABLE 25.7** Possible Engineering Controls at Source of Noise

Machine or Process	Engineering Control at Source
Fans and blowers	Increase the size of the fan or blower so that it moves the same amount of fluid (e.g., air) at lower rotational speed. This generally reduces noise output.
Pneumatic tools	Substitute hydraulic or electric drive motors that operate more quietly.
Vibrating machinery	Provide better balancing of the components. Such noise often results from an imbalance of rotating members.
Vibrating machinery	Use resilient couplings and mountings for vibrating mechanisms to dampen the vibrations and isolate them from surrounding machine components.
Impact equipment such as stamping presses and forge hammers	Move the equipment onto rubber mounts to reduce the transmission, if possible. The impact noise of this kind of equipment is often partially transmitted through the floor of the plant.

*Source:* Compiled from [3, 7].

# Lighting and Illumination

- For most, the majority of our work depends on our visual senses. Operating machines, working on an assembly line, reading documents, and typing on a computer all require visual information to some extent. Therefore, appropriate lightning becomes important in work settings.
- Proper lightning is not about turning on the lights as bright as possible so that everything becomes easier to see. Rather, it is about finding optimum levels of lighting for comfortable work.

## Con...

- The source of lightning in a work environment can be daylight from the sun, artificial light via light bulbs or both. Artificial light can be general lightning or localized lightning. It can also be direct or indirect.
- Selecting the type of artificial lightning depends on the task and the properties of work environment such as how reflective objects are, and people's individual characteristics

## Con...

- ❑ Poor lighting may result in difficulty seeing and detecting objects, but also health complaints such as eyestrain and headaches. More importantly however, it can also lead to accidents. Not being able to see the position, location or movement of objects may lead to incorrect judgments and can create risky situations.

Common problems with lighting are:

- Insufficient illumination and poor lit areas
- Contrast
- Glare
- Light flicker

## Con...

- Insufficient light not only can be dangerous but also may decrease productivity
- The general idea is that the more a task requires high visual acuity and is visually complex, the more illumination is needed. Also, the harder the objects are to see due to factors such as low contrast and small object sizes, the more illumination is needed.
- The light in the environment should be distributed uniformly, not leaving dim or dark areas. Having both bright and dark areas in the environment results in the eye constantly trying to adjust to different illumination levels.

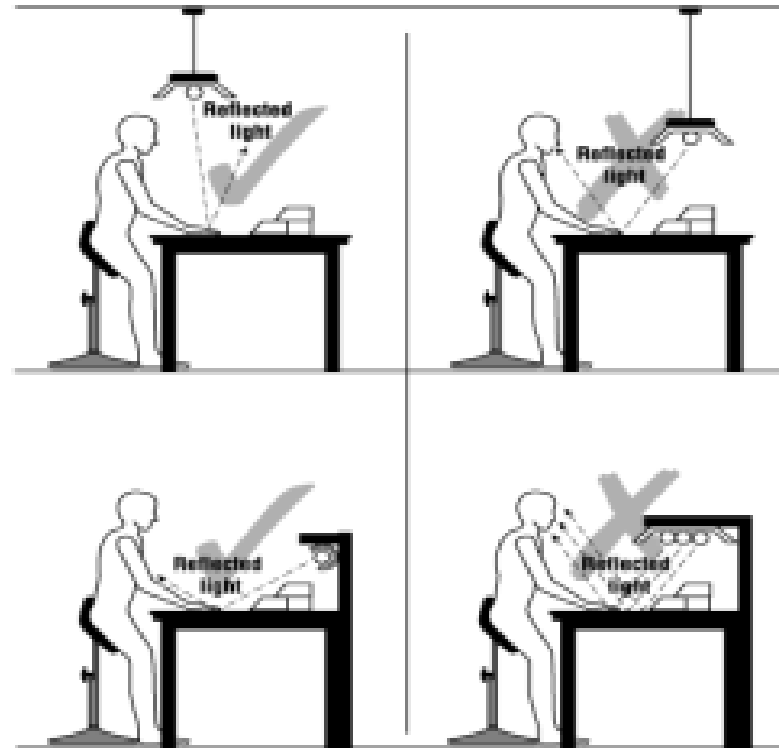


## *Glare*

- It is a common problem which occurs when a bright light source provides lighting that is more than the eye has adapted to.
- Common sources of glare are sun, bright lamps, shiny objects and computer monitors.
- The sun and lamps are examples of direct glare whereas monitors and shiny objects are examples of reflected glare; they reflect the light they receive
- To avoid glare issues, the position of light sources and work equipment can be adjusted so that the light is not reflected directly to the eyes.

## Con...

- Glare can cause discomfort but can also interfere with the task, decreasing performance.
- The brightness around the source of glares and general lightning in the environment can be increased.
- Shiny objects and surfaces can be replaced with less shiny materials



In this example, you can see correct and incorrect positioning of light sources.

# *Contrast*

- It is also another important aspect of lightning. The general principle is the task area should be brighter than its surrounding area.
- Proper levels of contrast help to detect and distinguish objects relevant to task from the background.
- Also, the contrast between objects in the physical environment or on a display should also be appropriate.
- For example, different parts of a machine can be colored to create proper contrast.
- The brightness of text and background on a display can be adjusted to create good contrast (for example, black text on a white background).

# *Light flicker*

- occurs when the intensity of light is unstable. This usually happens when the voltage is fluctuating. People can easily notice if the flicker rate is low
- Flicker can be a hazard where a moving part of the machinery can be perceived as stationary or moving slowly if the flicker rate of the light source and movement frequency of the machine are similar

## Con...

- In the case of fluorescent lights, electronic ballasts that provide very high flicker rates can be used to reduce perceived flicker.
- Very high flicker rates prevent human eye from noticing the flicker. Also, older light bulbs should be replaced with newer ones frequently.



## Con...

- To make sure that the work environment has proper lighting
- There should be no *reflections* on the objects that cause discomfort.
- *Shadows* should be eliminated as much as possible.
- Lights should not *flicker*
- *Glare* should be eliminated
- *Displays* should have appropriate brightness and contrast, glare on screens should be minimized, and the content on displays should be easily read

## Temperature and Ventilation

- Some people have to work in extreme environments such as near a furnace or extremely cold environments.
- The human body regulates its temperature and achieves a thermal balance through producing metabolic heat and losing it.
- The body has to maintain a core temperature around 36-37°C for proper functioning
- There are multiple factors that influence body heat

## Con...

- Hot or cold environments can create **heat and cold stress**, which may lead to uncomfortable work, but extreme temperatures may **pose physical and psychological risk** to people and must be dealt with.
- A **comfortable temperature** range for most people is between 20 and 27°C with a 35-60% humidity.
- **Excessive heat** can be found in environments such as foundries and smelters,





## Con...

- but also outdoor environments such as construction and agricultural sites where the heat comes from the sun.
- In these environments, both heat production and heat gain from the environment are high.
- As a result, the body needs to lose heat. However, if the heat gain is more than **heat loss**, this situation can lead to physiological and psychological problems
- As temperature or humidity increases, people experience irritability, their concentration and mental capabilities decrease, and physical tasks become more difficult to conduct.

## Con...

- ***Heat stroke:*** Core body temperature rises above 41°C. Internal organs stop functioning and the person collapses. Heat stroke can be fatal.
- ***Heat exhaustion:*** The person feels dizzy and weak, and breathing becomes difficult.
- This occurs because of loss of salt and body water due to excessive sweating. Can lead to heat stroke if the heat is not removed.
- ***Other illnesses*** include heat edema, heat rashes, heat cramps, and heat syncope

## Con...

- There are several ways to cope with excessive heat:
- Tasks that demand heavy effort can be *mechanized*.
- Hot surfaces can be *covered* with material that reduces the heat they radiate.
- *Proper ventilation and cooling* of the environment, or dehumidification of the environment
- *Heat-protective clothing* that prevents incoming heat yet allows the sweat to evaporate
- *Acclimatization* to hot environments makes the person more tolerant to heat.

# Con...

- Extreme cold environments reduce the physical and psychological capability of individuals.
- *Mental tasks*, especially those that need being alert, are difficult to carry out in cold environments.
- *Manual tasks* also become more difficult due to loss of dexterity and strength.
- *Extremities* are especially vulnerable to cold because they don't have muscles to produce heat and they lose heat faster.
- *Hypothermia* is the most dangerous condition people can experience under extreme cold.
- If the core body temperature starts to drop below 33°C, the person experiences weakness and dizziness, starts to lose consciousness, and further decrease in core body temperature can be fatal.
- Less dangerous conditions include frostnip and frostbite.

# Vibration

- ***Vibration*** is the oscillation (repetitive motion) of an object about an equilibrium point. Vibration affects the body through contact with the vibrating objects such as a chainsaw (hand-arm vibration) or vibrating floor (whole body vibration).
- Depending on the exposure, vibration can lead to health problems



## Con...

- A common disease, hand-arm vibration syndrome (HAVS), also known as vibration white finger (VWF) or Raynaud's phenomenon, occurs due to damage caused by vibration of hand tools such as grinders where muscles, bones, joints and tendons can be damaged, leading to loss of sensitivity and strength, and pain and numbness in fingers when exposed to cold.
- whole-body vibration which is usually caused by vibrating floor or vibrating environment such as a truck, may cause fatigue, headaches, insomnia and stomach problems in short-term and can increase the risk of developing low back problems in long-term when combined with other factors such as bad posture

**con...**

- The effects of vibration can be reduced in several ways
- *Anti-vibration systems* can be built in hand tools. These are mechanisms by which the vibration on the machine can be reduced.
- *Anti-vibration gloves* can be used. These gloves reduce the effects of vibration coming from the tools.
- Frequent and timely maintenance of work equipment, periodic rests, and monitoring personal health can reduce the negative effects of vibration exposure.

# Radiation

- Although all types of ionizing radiation can damage tissue, attention is given to gamma ray, X ray, and neutron radiation. High-energy electron beams impinging on metal in vacuum equipment can produce very penetrating X rays that may require much more shielding than the electron beam itself.
- The absorbed dose is the amount of energy imparted to a given mass of material. The unit is *rad*, which is equivalent to the absorption of 0.01 joules per kilogram.
- Very large doses -100 rads or more-received over a short time span by the entire body can cause radiation sickness. A dose of about 400 rads to the whole body would be fatal to approximately one-half of adults. Small doses received over a longer period may increase probability of contracting some types of cancers or other diseases.



## Shift work

- Shift work, defined as working other than daytime hours, is becoming an ever increasing problem for industry.
- the need for continuous services from:
  - police, fire, and medical personnel,
  - expensive automated machinery
  - just-in-time production
- The problem is the stress on circadian rhythms, which are roughly 24-hour variations in bodily functions in humans.
- The most marked cyclic changes occur in sleep, core temperature, heart rate, blood pressure, and task performance,

## Con...

- It could be assumed that night workers would adapt to night work because of the change in work patterns.
- Unfortunately, the other social interactions still play a very important role, and the circadian rhythm never truly shifts and may even grow, which some researchers consider to be a worse scenario.
- Thus, night workers also experience health problems, such as appetite loss, digestive problems, ulcers, and increased sickness rates.
- The problems become even worse as the worker becomes older.

## *Recommendations shift work*

1. Avoid shiftwork for workers older than 50.
2. Use rapid rotations as opposed to weekly or monthly cycles.
3. Schedule as few night shifts (three or less) in succession as possible.
4. Limit the total number of working shifts in succession to seven or less.
5. Include some free weekends, with at least two successive days off.
6. Schedule rest days after night shifts.
7. Keep the plans simple, predictable, and equitable for all workers.

Thank You!

