Topic 1

Evolution of the Occupational Safety and Health Movement

LEARNING OUTCOMES

By the end of this topic, you should be able to:

1. Describe the two main phases in the evolution of the occupational safety and health movement;

2. Discuss the factors which contributed to the development of occupational safety and health;

3. Examine the history behind the development of occupational safety and health management in Malaysia; and

4. Assess the current developments in the field of occupational safety and health management.

INTRODUCTION

Occupational safety and health management is a function in the field of human resource management. Besides looking after the welfare of their employees, it is also important for companies to create a safe and comfortable workplace for them. In the last two decades, the field of occupational safety and health management has experienced rapid development due to several factors,
such as the emergence of sophisticated technologies and work processes (which could bring new risks), legislative amendments which emphasised more on enforcement, increasing costs of production due to accidents, and the like.

To help you gain a better understanding of the various aspects of workplace safety and health management, this topic will give you an overview of the development of the occupational safety and health movement from its beginnings in the Babylonian era to the present day. This topic will also discuss other influences and factors that contributed to the growth of this field.

1.1 HISTORY OF OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT

It is important to first study the history of the development of occupational safety and health management in order to understand how this field came to existence and became a very significant part of our working lives today. The history of its development can be divided into two main parts, namely:

(a) The evolution of the occupational safety and health movement in general; and

(b) The development of the occupational safety and health movement in Malaysia.

The evolution of occupational safety and health management can be divided into two phases, i.e. before the Industrial Revolution and after the Industrial Revolution. The Industrial Revolution started in some Western countries at the end of the 18th century and early 19th century. It marked the rise of machinery to replace manual labour; a phenomenon that not only affected the way people worked, but changed the workplace entirely.

After the Industrial Revolution era (i.e. from the early 19th century), the field of occupational safety and health management developed rapidly until today.
(a) Occupational Safety and Health Management Before the Industrial Revolution

The beginnings of occupational safety and health management can be traced back to the era of the Babylonian Empire, i.e. around 2000 BC during the reign of Hammurabi. Hammurabi, the king, ruled his country based on a code he created. The Hammurabi Code encompassed all of the laws of the land at that time. Figure 1.1 illustrates the Babylonian era.

The code was engraved on a 2.4-metre high black stone monument (Figure 1.2) that was erected in a public place for all to see. It contained clauses on safety and health laws, as well as those dealing with injuries and monetary damages assessed against those who injured others. For example, if a man caused the loss of someone else’s eye, his own eye should be caused to be lost. If a person caused damage to the properties of others, he must pay compensation for the damage caused.
The heaviest penalty or punishment prescribed in the code for those proven guilty was the death penalty. The existence of the Hammurabi Code indirectly made the community of that time realise how important it was that they should look after not only the safety of their own families, but also the safety of others – a concept known as self-regulation.

The movement continued to evolve in later Egyptian civilisations. Well known for their temples and pyramids, the Egyptian kings or pharaohs used slaves as labour for the construction of those mammoth structures. Large bricks and rocks were manually transported and laid in place under hot weather, thereby exposing the slave labourers to harsh work conditions that eventually led to various health problems. Figure 1.3 illustrates a pyramid that was built using thousands of labourers at that time.
Figure 1.3: The construction of the Giza Pyramid involved thousands of slaves who were exposed to harsh work conditions

King Rameses II (1200 BC), one of the great pharaohs, provided health and medical services to his workers to ensure that they remained fit to complete the construction of many temples, including the Ramesseum Temple.

Similarly, during the Roman era, the Roman rulers were fairly concerned about the safety and health of their living environments. They built sewerage and irrigation systems as well as well-ventilated houses in order to provide better living and work conditions.

The period between the fall of the Western Roman Empire in the fifth century AD and the beginning of the Renaissance in the 15th century AD was known historically as the Middle Ages. It was a period of great changes in culture, politics, science, society, agriculture and economics. Urbanisation – the rise of towns and cities – in Northern and Western Europe raised awareness of workplace safety and health management further.

In 1567, Philippus Aureolus (also known as Paracelsus) wrote a treatise on pulmonary diseases of miners, titled *On the Miners’ Sickness and Other Diseases of Miners.*
Around the same time, Georgius Agricola published his treatise titled *De Re Metallica*, emphasising the need for ventilation in mines.

The 18th century saw the contribution of Bernardino Ramazzini, who wrote *Discourse on the Diseases of Workers*, drawing parallels between diseases suffered by workers and their occupations. His discussion focused on diseases related to the handling of harmful materials and unnatural bodily movements.

<table>
<thead>
<tr>
<th>Writer</th>
<th>Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippus Aureolus</td>
<td><em>On the Miners’ Sickness and Other Diseases of Miners</em></td>
</tr>
<tr>
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</tr>
<tr>
<td>Bernardino Ramazzini</td>
<td><em>Discourse on the Diseases of Workers</em></td>
</tr>
</tbody>
</table>

(b) **Occupational Safety and Health Management During and After the Industrial Revolution**

The Industrial Revolution introduced changes to work operations and workplace conditions. Steam power and machines brought new methods for converting raw materials into finished products, and along came new organisation and specialisation of work (division of labour).

These changes indirectly increased accident risks at the workplace. Furthermore, the relationship at the workplace back then could be described as a master-worker relationship. Workers were considered as “slaves” who must obey the commands of their employers or masters. Liabilities due to accidents were borne by the workers themselves. That meant in the event of any accident, the worker would have to shoulder the blame while the employer did not have to bear any liability.
The development of occupational safety and health management after the Industrial Revolution began in England and later spread to the United States of America (USA). Most factories at that time exploited unskilled children and women to reduce production costs. The involvement of children (Figure 1.4) and women inadvertently increased the risks of workplace accidents.

![Figure 1.4: Child labour in the manufacturing sector](image)

The existence of trade or labour unions probably began in the 18th century, when Europe was transforming from an agriculture-based economy to an industrialised, craft-based economy. Some of the changes brought on by the transformation, such as new methods of production that required unskilled and cheaply available labour, enabled employers to exploit workers extensively. The unions, most of them considered illegal initially, were then formed to protect the interests of the workers and to wield political power so that the workers were not unjustly exploited.

Due to the pressure from the workers and the public, the English government gazetted the Health and Morals of Apprentices Act in 1802. The Act reflected the government’s official involvement in dealing with issues related to safety and health at the workplace.
Table 1.2 summarises the significant milestones in the development of occupational safety and health management in the USA. The development in the USA had a great influence on similar development in other countries, as the USA was the economic superpower at that time.

**Table 1.2: Summary of the History of the Development of Occupational Safety and Health Management**

<table>
<thead>
<tr>
<th>Year</th>
<th>Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1867</td>
<td>Factory inspection introduced in Massachusetts.</td>
</tr>
<tr>
<td>1868</td>
<td>Patent awarded for first barrier safeguard.</td>
</tr>
<tr>
<td>1877</td>
<td>Law on safeguards for hazardous machines passed in Massachusetts; Employers’ Liability Act passed.</td>
</tr>
<tr>
<td>1892</td>
<td>First recorded safety programme was established.</td>
</tr>
<tr>
<td>1900</td>
<td>Studies on efficiency in manufacturing carried out by Fredrick Taylor.</td>
</tr>
<tr>
<td>1908</td>
<td>The compensation law was introduced in the USA.</td>
</tr>
<tr>
<td>1913</td>
<td>The first National Council for Industrial Safety was established.</td>
</tr>
<tr>
<td>1915</td>
<td>The name of the National Council for Industrial Safety was changed to the National Safety Council.</td>
</tr>
<tr>
<td>1916</td>
<td>The concept of negligent manufacture was established.</td>
</tr>
<tr>
<td>1970</td>
<td>Occupational Safety and Health Act passed in the USA.</td>
</tr>
<tr>
<td>1990</td>
<td>Amended Clean Air Act of 1970 passed.</td>
</tr>
<tr>
<td>1996</td>
<td>The Total Safety Management concept was introduced.</td>
</tr>
<tr>
<td>2000</td>
<td>Companies in the USA began to pursue ISO 14000 certification for environmental safety management.</td>
</tr>
<tr>
<td>2003</td>
<td>Violence at the workplace received the attention of occupational safety and health experts in the West.</td>
</tr>
</tbody>
</table>

Labour unions also played an important role in the development of occupational safety and health management. Beginning with the Industrial Revolution, labour unions in the USA fought for safer work conditions and reasonable compensations for work-related injuries. Among the major contributions were their efforts in opposing anti-labour laws and securing a safe and healthy environment at the workplace.
Among the laws that were opposed and successfully abolished was the Fellow Servant Rule (1830-1930). This rule stated that the employer should not be liable for any injury sustained by his workers due to workplace accidents caused by the negligence of other workers.

Furthermore, this rule adopted the Doctrine of Contributory Negligence, which did not hold the employer liable for any injury sustained by any of his workers due to any accident caused by the weaknesses of the workers themselves.

The Concept of Assumption of Risk, which was also part of the doctrine, stated that if a worker accepted a job voluntarily, he must accept the consequences of his actions.

The abolishment of this rule indirectly protected the interest of workers who were involved in accidents and lessened their burden.

### 1.2 MAJOR TRAGEDIES WHICH CONTRIBUTED TO THE DEVELOPMENT OF OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT

There were three major tragedies that had a great impact on the development of occupational safety and health management worldwide. These were:

(a) The silica poisoning at Hawk’s Nest Tunnel, in Virginia, USA;
(b) The Bhopal gas leak, in India; and
(c) The asbestos menace.

#### 1.2.1 The Hawk’s Nest Tragedy

This tragedy took place in 1934 when a group of workers, mostly black, were assigned to dig a tunnel known as the Hawk’s Nest Tunnel, under the Gauley Mountain in West Virginia, USA. The tunnel was to divert a nearby river so that a hydroelectric station could be built. Almost 2,000 workers, most of whom did not wear any form of protective gear, died from silicosis, a disease that affected the proper functioning of the human lungs. The disease was caused by overexposure to silica particles that filled the air as a result of rock drilling activities during the construction of the tunnel.
Generally, a person struck with silicosis would only show symptoms of the disease after 20 to 30 years. However, in the case of the Hawk’s Nest Tunnel project, the stricken workers showed the symptoms rapidly. News of the deaths began to receive public attention. Family members of the deceased became suspicious and began to investigate the cause of the deaths. Investigations carried out by the government revealed that those deaths were not accidental; the employer had neglected the safety and health of the workers, and that led to the tragic deaths of the unfortunate tunnel workers.

Following the incident, the US Department of Labour made it compulsory for each state to have a provision on silicosis-related compensation. In addition, employers are required to provide a safe and healthy workplace for their employees through administrative control, engineering control and the provision of personal protection equipment.

1.2.2 The Bhopal Tragedy

To know more about the Hawk’s Nest Tunnel tragedy, visit the following websites: http://en.wikipedia.org/wiki/Hawks_Nest_Tunnel_Disaster and http://www.youtube.com/watch?v=oUL6nnJO-6Q. Then, discuss the impact of the tragedy on industrial safety with your coursemates or on myVLE.

**ACTIVITY 1.1**

To know more about the Hawk’s Nest Tunnel tragedy, visit the following websites: http://en.wikipedia.org/wiki/Hawks_Nest_Tunnel_Disaster and http://www.youtube.com/watch?v=oUL6nnJO-6Q. Then, discuss the impact of the tragedy on industrial safety with your coursemates or on myVLE.

**Figure 1.5:** Demonstrators commemorating the Bhopal tragedy on its 19th anniversary

This tragedy occurred in 1984 in the northern region of Bhopal, India. Some 40 tonnes of methyl isocyanate (MIC) and other dangerous gases including hydrogen cyanide were accidentally released into the air from a Union Carbide chemical plant, killing 3,000 people who were living around the area. This tragedy occurred because the safety devices installed at the plant failed to operate and prevent the gas leaks. Besides that, the failure of the employer, i.e. Union Carbide, to adhere to regulations laid down by the authorities contributed to the tragedy.

In 1989, the High Court of India ordered the company to pay US$470 million in compensation to the families of the victims. Following this tragedy, the government of India and other countries tightened the laws related to workplace safety.

ACTIVITY 1.2

Do you want to know more about the Bhopal tragedy? You may visit the following website: http://www.bhopal.com/

The Bhopal Information Centre is a website dedicated to listing various past discussions on the Bhopal tragedy, from the historical as well the legal points of view.

1.2.3 The Asbestos Menace

In 1964, Dr Irving J. Selikoff, a co-discoverer of a cure for tuberculosis, presented his findings on the effects of asbestos on human beings. The result of his research showed that asbestos could cause lung cancer and other respiratory diseases.

Between 1967 and 1986, he continued his research on the death of 17,800 workers who were exposed to asbestos. His research confirmed that not only did asbestos cause lung cancer, but it also caused cancer to the gastrointestinal tract, larynx, kidneys, pancreas and gallbladder. Consequently, in the 1980s, the usage of asbestos was banned in the US.
ROLE OF SPECIFIC HEALTH PROBLEMS IN THE DEVELOPMENT OF OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT

Several work-related diseases had great impact on the development of modern occupational safety and health management. In the 1800s, coalminers in Britain were found to suffer from a form of lung cancer known as “black spit” due to exposure to dust and the absence of good ventilation systems in the mines.

It was in 1875 that this disease was contained after good ventilation systems were installed in the coalmines and work hours were reduced. In the early 1940s, the name of this disease was changed to coalworkers’ pneumoconiosis (CWP) by a group of British scientists.

The British government designated CWP a separate and compensable disease in 1943. Besides CWP, silicosis, caused by inhaling silica dust, was also feared by miners around the world. The worst tragedy involving silicosis occurred during the drilling of Hawk’s Nest Tunnel, which was discussed earlier in Subtopic 1.2.1.

Mercury poisoning was also another occupational disease. The first mercury poisoning was discovered in a fishing village in Minamata, Japan, in the 1930s. The poisoning was caused by the irresponsible act of a chemical factory located near the village. The factory was discharging methyl mercury as a waste product into the sea. The toxic waste contaminated the aquatic ecosystem, affecting...
particularly the fish, which was the main source of food for the locals. The contamination eventually resulted in the deaths of many inhabitants as well as deformities in babies due to their parents’ exposure to the toxic waste.

Mercury poisoning was also discovered in the hat-making industry in the US in the 1940s. The use of mercury nitrate in hat making caused the workers involved to show symptoms similar to those demonstrated by victims of mercury poisoning in Minamata. One research managed to prove the ill effects of mercury nitrate on human beings. The research proposed that mercury nitrate be replaced by hydrogen peroxide to eliminate the danger of mercury poisoning.

### 1.4 OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT MOVEMENT IN MALAYSIA

The development of occupational safety and health management in Malaysia has been much influenced by developments outside the country. To a large extent, the changes in this area were the result of Malaysia’s shift from an agriculture-based economy to a manufacturing-based economy, which had increased the rate of workplace accidents due to hazardous conditions and work processes.

Prior to 1994, Malaysia had various Acts and regulations governing workplace safety according to types of occupation and hazard. These Acts were enforced by government agencies. Table 1.3 shows the list of Acts and regulations enacted by the Government to ensure the safety and health of workers at the workplace.

**Table 1.3: Summary of Occupational Safety and Health Acts and Regulations Prior to 1994**

<table>
<thead>
<tr>
<th>Act and Regulation</th>
<th>Enforcement Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factories and Machinery Act 1967</td>
<td>Department of Occupational Safety and Health, Ministry of Human Resources</td>
</tr>
<tr>
<td>Environmental Quality Act 1974 and regulations enacted thereunder</td>
<td>Department of Environment, Ministry of Natural Resources and Environment</td>
</tr>
<tr>
<td>Atomic Energy Licensing Act 1984 and regulations enacted thereunder</td>
<td>Atomic Energy Licensing Board, Ministry of Science, Technology and Innovation</td>
</tr>
<tr>
<td>Petroleum (Safety Measures) Act 1984</td>
<td>Department of Occupational Safety and Health, Ministry of Human Resources</td>
</tr>
<tr>
<td>Electricity Supply Act 1990</td>
<td>Department of Electricity and Gas Supply, Ministry of Energy, Communication and Multimedia</td>
</tr>
</tbody>
</table>
Based on Table 1.3, we can see that each Act has its own jurisdictions that are in accordance with a specific type of hazard and occupation. However, the various Acts and regulations overlapped in their area of jurisdiction, which in turn caused difficulties in the implementation processes, particularly in enforcement. To prevent such confusion, the Department of Occupational Safety and Health, under the Ministry of Human Resources, enacted the Occupational Safety and Health Act (Act 514) on 24 February 1994. Figure 1.7 explains the rationale behind this Act.

**Figure 1.7: Occupational Safety and Health Act (Act 514)**

In order to ensure that this Act is properly enforced, the Government has established the National Institute of Occupational Safety and Health (NIOSH) to provide training courses on occupational safety and health practices. In addition, some public and private institutions of higher learning are entrusted to offer courses on occupational safety and health.

**ACTIVITY 1.4**

You may visit the following websites to get more information on the legal aspect of occupational safety and health management in our country:

http://www.niosh.com.my
http://www.dosh.gov.my
http://www.jas.sains.my
http://www.doe.gov.my
1.5 OCCUPATIONAL SAFETY AND HEALTH MOVEMENT TODAY

The international community today sees occupational safety and health management as an important field that must be managed efficiently to ensure a safe and healthy workplace. This field does not focus merely on the safety, health and welfare of workers, but also takes into account the safety and health of the public and the work environment.

Therefore, all parties, particularly employers and various government departments, must play their role to ensure effective implementation of occupational safety and health management. Failure of employers, employees and the authorities to ensure the safety and health of the workplace can result in accidents. Accidents will lead to losses in terms of time, human resources and finance, not to mention the negative impact such incidents will have on the affected organisations. Such losses can also affect the productivity of workers and the quality of products and services.

Adopting new technologies such as computers and robots at work has in some ways facilitated the production process, saved time and ensured product quality. However, these new production methods still pose dangers to workers, as they require new skills and training to operate the machinery and need to be constantly mindful of safety rules on the production floor. Without close human monitoring, the new technologies and machinery will potentially be accident risks. This, in a way, is a new challenge in the field of occupational safety and health management. The traditional approach to reducing accident risks through enforcement and engineering (i.e. reducing risk exposure by using machinery to take over dangerous jobs) is no longer effective without the participation of workers. Today, occupational safety and health management focuses on inculcating safe and healthy work methods at the workplace by involving workers and encouraging them to change their attitude at the workplace.

This development has brought about changes in the demand for occupational safety and health management experts in the labour market. Nowadays, companies are more willing to hire experts from among engineers, doctors and occupational safety and health management officers to help reduce accident risks at the workplace. Companies are now prepared to invest heavily in developing safety and health programmes in order to ensure that the workplace is safe, healthy and comfortable.
A good safety and health management practice will not only reduce the risk of potential accidents, but also bring profit to the company in the long run. In addition, providing a safe and healthy work environment is seen as a competitive tool to win over good employees. Today, this field is seen as a total quality management approach through the implementation of OSH 1800 and ISO 14000 standards in an effort to create a safe and healthy work environment.

**SUMMARY**

- Occupational safety and health management has been practised since the Babylonian era. The Hammurabi Code, written by a Babylonian king, featured the first set of rules in this field.

- Work safety and health gained rapid recognition during the Industrial Revolution in Europe when machines and steam power were introduced.

- The unscrupulous exploitation of child and women labour at that time had also caused an increase in workplace accidents.

- Developments in Europe had an impact on other countries including Malaysia.

- In Malaysia, the development in this field can be seen through the enactment of specific Acts to overcome workplace accidents such as the Factories and Machinery Act 1967, the Environmental Quality Act 1974 and the Occupational Safety and Health Act 1994.

- Today, the provision of a safe and healthy workplace has become part of the business strategy of most companies.

- Through effective occupational safety and health management, not only can employers reduce costs due to accidents, but they will also be able to increase the satisfaction of their employees, enhance their organisations’ image in the eyes of their clients and the public, and contribute to the community.
**Essay Questions**

1. Explain briefly how the Hammurabi Code influenced the development of occupational safety and health management worldwide.

2. Explain briefly the Doctrine of Contributory Negligence.

3. State the main effect of coal on human health.

4. Explain briefly why the usage of asbestos is banned.

5. In brief, explain how workers’ health issues and problems contributed to the development of occupational safety and health management.

**True (T) or False (F) Statements**

1. The Hammurabi Code is a code dealing with work-related injuries and negligence.

2. In 1974, the Occupational Safety and Health Act was passed in the US.

3. The provisions of the Occupational Safety and Health Act 1994 are used in all employment sectors.

4. “Black spit” is a type of disease caused by exposure to silica dust.

5. Dr Irving J. Selikoff was an author who explained the parallels between the diseases suffered by workers and their occupations.

6. The National Institute of Safety and Health (NIOSH) plays an important role in enforcing safety and health at the workplace.
INTRODUCTION

When an accident occurs at the workplace, employers tend to claim that it is due to the negligence of workers. But is the negligence of workers the only cause of workplace accidents? What are the effects of workplace accidents?

Accidents do not only cause damage to properties, but can also lead to serious injuries and even deaths. Therefore, in order to prevent accidents, we must identify their causes.

Years ago, several theories of accident causation were been established to explain why accidents occur. Models based on these theories were then used to predict and prevent accidents from occurring. This topic will discuss several theories that can be used by managers to predict and prevent workplace accidents.
2.1 DOMINO THEORY

The Domino Theory was introduced by Herbert W. Heinrich (Figure 2.1) after studying the reports of 75,000 industrial accidents. From the study, he concluded that 88 percent of industrial accidents were caused by unsafe acts committed by fellow workers, 10 percent were caused by unsafe conditions, and only 2 percent were unavoidable.

Examples of unsafe acts committed by fellow workers included being negligent and not observing safety procedures.

Examples of unsafe working conditions were working in high-rise buildings without proper safety gear and equipment, and the use of faulty or improperly insulated electrical appliances. On the other hand, unavoidable accidents included floods, storms and accidents caused by other individuals.

Figure 2.1: Herbert W. Heinrich

Figure 2.2: Using unsuitable footwear is one of the causes of accidents

2.1.1 Heinrich’s Industrial Safety Principles

Heinrich outlined 10 axioms known as the Axioms of Industrial Safety which must be adhered to by managers when managing occupational safety and health aspects at the workplace. Table 2.1 lists these axioms.
Table 2.1: Heinrich’s Axioms of Industrial Safety

<table>
<thead>
<tr>
<th>No.</th>
<th>Axiom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The occurrence of an injury invariably results from a completed sequence of factors, the last one of these being the accident itself.</td>
</tr>
<tr>
<td>2.</td>
<td>The accident in turn is invariably caused or permitted directly by the unsafe act of a person and/or a mechanical or physical hazard.</td>
</tr>
<tr>
<td>3.</td>
<td>Most industrial accidents are caused by unsafe acts committed by humans.</td>
</tr>
<tr>
<td>4.</td>
<td>An unsafe act or condition will not necessarily cause an accident or injury.</td>
</tr>
<tr>
<td>5.</td>
<td>The excuse given for committing an unsafe act can be an indicator or lesson to do the right act.</td>
</tr>
<tr>
<td>6.</td>
<td>The seriousness of an accident cannot be planned or anticipated but what is for sure is that the accident can be avoided.</td>
</tr>
<tr>
<td>7.</td>
<td>The best accident prevention techniques are analogous to the best quality and productivity techniques.</td>
</tr>
<tr>
<td>8.</td>
<td>The management should assume responsibility for safety due to its high position in the organisational hierarchy and because it is in the best position to get results.</td>
</tr>
<tr>
<td>9.</td>
<td>The supervisor is the key person in the prevention of industrial accidents.</td>
</tr>
<tr>
<td>10.</td>
<td>In addition to the direct costs of an accident (e.g. compensation, liability claims, medical costs and hospital expenses), there are hidden and indirect costs.</td>
</tr>
</tbody>
</table>

2.1.2 Heinrich’s Accident Factors

Are you familiar with the domino game? If you are, you will be able to easily understand the domino concept presented by Heinrich.
According to Heinrich, there are five factors in the sequence of events leading up to an accident.

Heinrich proposed a “five-factor accident sequence” in his theory. The sequence of accident factors are summarised in Table 2.2:

Table 2.2: Heinrich’s “Five-factor Accident Sequence”

<table>
<thead>
<tr>
<th>No.</th>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Family Genetics and Social Environment</td>
<td>The negative character traits that may lead people to behave in an unsafe manner may be inherited (genetics) or acquired as a result of the social environment.</td>
</tr>
<tr>
<td>2.</td>
<td>Fault of Person</td>
<td>Negative character traits, whether inherited or acquired, are the reasons why people behave in an unsafe manner and why hazardous conditions exist (e.g. smoking in an area which contains flammable materials).</td>
</tr>
<tr>
<td>3.</td>
<td>Unsafe Acts/Mechanical and Physical Hazards</td>
<td>Unsafe acts committed by a person and mechanical or physical hazards are the direct causes of accidents (e.g. negligence).</td>
</tr>
<tr>
<td>4.</td>
<td>Accidents</td>
<td>Typically, accidents lead to injuries and will have a negative effect on the performance and image of organisations.</td>
</tr>
<tr>
<td>5.</td>
<td>Injury</td>
<td>Accident injuries may range from minor cuts and scratches to serious ones such as loss of a limb and other disabilities. Injuries such as lacerations and fractures have a negative effect on workers’ performance.</td>
</tr>
</tbody>
</table>
Heinrich’s theory has two central points:

(a) Injuries are caused by the actions of preceding factors; and

(b) Removal of the central factor negates the actions of preceding factors and in doing so, prevents accidents and injuries.

However, the weakness of this theory is that not all accident factors are inherited. Accidents may occur due to negligence and mechanical failure.

**ACTIVITY 2.1**

According to Heinrich, genetics and the social environment factor are the main causes of accidents. What is your view on this?

**2.2 HUMAN FACTOR THEORY**

**SELF-CHECK 2.1**

What is the Human Factor Theory? What are the human factors that lead to workplace accidents?

The Human Factor Theory attributes accidents to a chain of incidents ultimately caused by human errors. The following are the three broad factors that lead to human error:

1. Overload;
2. Inappropriate response; and
3. Inappropriate activities.

These factors are explained in detail in the following.
2.2.1 Overload

Overload amounts to an imbalance between a person’s capacity at any given time and the load being carried by the person in a given state. Refer to Figure 2.4 to see how work stress can be a human factor in workplace accidents. The figure illustrates how a worker who is experiencing chronic work stress has a greater chance of suffering from illnesses such as mental stress which, in turn, may cause an undesirable incident to occur.

![Figure 2.4: Chronic work stress](image)

A person’s capacity is the combination of qualities such as his natural ability, training, state of mind, stress and physical condition.

The load that a person is carrying consists of tasks for which he is responsible, and other added burdens resulting from factors such as:

(a) Environmental factors (noise, distractions and so on);
(b) Internal factors (personal problems, emotional stress and worry); and
(c) Situational factors (level of risk, unclear instructions and so on).

The state in which a person is acting is the product of his motivational and arousal levels.
2.2.2 Inappropriate Response/Unsuitable Response

How a person responds in a given situation can cause or prevent an accident. If a person detected a hazardous condition but did nothing to rectify it, he has responded inappropriately. For example, workers at a construction site must wear hard hats and observe all other safety measures laid down by the management. Not following these rules constitutes an inappropriate response. Refer to Figure 2.5 to see how workers are equipped with safety attire.

![Safety attire](image)

Figure 2.5: Safety attire

If a person removed a safeguard from a machine in an effort to increase output, he has responded inappropriately. Again, if a person disregarded an established safety procedure, he has responded inappropriately. Such responses can lead to accidents. In addition to inappropriate responses, an unsuitable workplace or work environment can contribute to accidents.

The unsuitability of a person’s workplace with regard to the physical size of the facilities available as well as the force, reach, feel, and similar factors can lead to accidents and injuries.
2.2.3 Inappropriate Activities

Human error can be the result of inappropriate activities. An example is the undertaking of a task that a person is not familiar with. Another example is misjudging the degree of risk involved in a given task. Such inappropriate activities can lead to accidents and injuries.

For a better understanding of the Human Factor Theory, please refer to Figure 2.6.

![Diagram of Causes of Human Errors](image)

**Figure 2.6:** Causes of human errors  
*Source: Geotsh, D. L. (2005)*

2.3 ACCIDENT/INCIDENT THEORY

The Accident/Incident Theory is an extension of the Human Factor Theory. It was developed by Dan Petersen and is sometimes referred to as Petersen’s Accident/Incident Theory. Petersen introduced such new elements as ergonomic traps, the decision to err, and systems failure.
To help you understand better, please refer to the model in Figure 2.7.

Figure 2.7: Petersen’s accident/incident model  

Based on this model, overload, ergonomic traps, and a decision to err may lead to human error. The decision to err may be conscious and based on logic, or it may be unconscious.

Various pressures such as tight deadlines, peer pressure and budget factors can lead to unsafe behaviours. Another factor that can influence such a decision is the “it won’t happen to me” attitude.

The systems failure component is an important contribution of Petersen’s theory. First, it shows the potential for a causal relationship between management decisions or management behaviour, and safety. Second, it establishes the management’s role in accident prevention as well as the broader concepts of safety and health in the workplace.
Systems failure is normally caused by several acts or approaches which do not fulfil the requirements of occupational safety and health such as the following:

(a) The management does not establish a comprehensive safety policy;
(b) Responsibility and authority with regard to safety are not clearly defined;
(c) Safety procedures such as measurement, inspection, correction and investigation are ignored or given insufficient attention;
(d) Employees do not receive proper orientation; and
(e) Employees are not given sufficient safety training.

2.4 EPIDEMIOLOGICAL THEORY

Traditionally, safety theories and programmes have focused on accidents and the resulting injuries. However, the current trend is towards a broader perspective that encompasses the issue of industrial hygiene. Industrial hygiene concerns environmental factors that, if not addressed properly, can lead to sickness, disease and other forms of health impairment. This trend has, in turn, led to the development of an epidemiological theory of accident causation. Do you know what the Epidemiological Theory is?

Figure 2.8 illustrates the epidemiological theory of accident causation. The key components are predisposition characteristics and situational characteristics. These characteristics, taken together, can either result in or prevent conditions that may lead to an accident.
For example, an employee who is particularly susceptible to peer pressure (predisposition characteristic) is pressured by his co-workers (situational characteristic) to speed up his operation. Any decision that might lead to carelessness will increase the probability of a workplace accident.

### 2.5 SYSTEMS THEORY

Are systems components interrelated? Can these elements, combined as a unified whole, cause accidents?

The systems model is a model developed by R. J. Firenze. A system is a group of regularly interacting and interrelated components that together form a unified whole. This definition is the basis for the systems theory of accident causation. This theory views a situation in which an accident may occur as a system comprising the components shown in Figure 2.9.
The likelihood of an accident occurring is determined by how these components interact in performing a task. For example, a numerically controlled five-axis machining centre in a shop is usually operated by an experienced employee. When she goes on a two-week vacation, her temporary replacement may be someone less experienced. This situation may lead to accidents.

This change in one component of the system (person/host) increases the probability of an accident. Such a simple example is easily understood. However, not all changes in patterns of interaction are this simple. Some are so subtle that their analysis may require a team of people, each with a different type of expertise, to scrutinise the situation and learn where the problems lie.

The primary components of the systems model are the person/machine/environment, information, decisions, risks, and the task to be performed. Each of the components has a bearing on the probability that an accident will occur. This model is shown in Figure 2.10.

![Feedback Loop](Image)

**Figure 2.10: The Systems Theory model**

*Source: Geotsh, D. L. (2002)*

As this model shows, even as a person interacts with a machine within an environment, three activities take place between the system and the task to be performed. Every time a task is performed, there is the risk that an accident may occur. Sometimes, the risks are great; at other times, they are small. This is where information collection and decision making come in.

Based on the information that has been collected by observing and mentally noting the current circumstances, the person weighs the risks and decides whether to perform the task under existing circumstances.

For example, a machine operator is trying to fulfil a rush order that is behind schedule. An important safety device in his machine has malfunctioned, hampering normal operations. Simply taking it off will interrupt work for only five minutes, but doing so will increase the probability of an accident, as there is now less safeguarding.
On the other hand, replacing the faulty safety device can take up to an hour. Should the operator remove the safety guard and proceed with the task or take the time to replace it? The operator and his supervisor may assess the situation (collect information), weigh the risks, and make a decision to proceed. If their information was right and their assessment of the risks accurate, the task would probably be accomplished without an accident.

However, the environment in which the machine operator is working is unusually hectic, and the pressure to complete an order that is already behind schedule is intense.

These factors are stressors that can cloud the judgement of those collecting information, weighing risks, and making the decision. When stressors are introduced between points 1 and 3 in Figure 2.10, the likelihood of an accident increases.

For this reason, Firenzie recommended that five factors be considered before beginning the process of collecting information, weighing risks and making a decision.

These factors are:

(a) Job requirements;
(b) The workers’ abilities and limitations;
(c) The gain if the task is successfully accomplished;
(d) The loss if the task is attempted but fails; and
(e) The loss if the task is not attempted.

These factors can help a person achieve the proper perspective before collecting information, weighing risks and making a decision. It is particularly important to consider these factors when stressors such as noise, time constraints and pressure from a supervisor may tend to cloud one’s judgement.

2.6 BEHAVIOURAL THEORY

The behavioural theory of accident causation and prevention, often referred to as behaviour-based safety was introduced by E. Scott Geller (2001) (Figure 2.11). Behaviour-based safety is the application of behavioural theories from the field of psychology to the field of occupational safety.
The following is the definition of the Behavioural Theory.

The **Behavioural Theory** reinforces incentives and rewards to promote the desired safe behaviours. This concept uses the ABC model where A stands for activators or antecedent events, B stands for behaviour and C refers to the consequences following the behaviour or produced by it.

According to Geller, there are seven basic principles of the Behavioural Theory. These principles are explained in Table 2.3.

**Table 2.3: Seven Basic Principles of the Behavioural Theory**

<table>
<thead>
<tr>
<th>No.</th>
<th>Seven Basic Principles of the Behavioural Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Intervention that is focused on employee behaviour;</td>
</tr>
<tr>
<td>2.</td>
<td>Identification of external factors that will help understand and improve employee behaviour (from the perspective of safety in the workplace);</td>
</tr>
<tr>
<td>3.</td>
<td>Direct behaviour with activators or events antecedent to the desired behaviour, and motivation of the employee to behave as desired with incentives and rewards that will follow the desired behaviour;</td>
</tr>
<tr>
<td>4.</td>
<td>Focus on the positive consequences that will result from the desired behaviour as a way to motivate employees;</td>
</tr>
<tr>
<td>5.</td>
<td>Application of the scientific method to improve attempts at behavioural interventions;</td>
</tr>
<tr>
<td>6.</td>
<td>Use of theory to integrate information rather than to limit possibilities; and</td>
</tr>
<tr>
<td>7.</td>
<td>Planned interventions with the feelings and attitudes of the individual employee in mind.</td>
</tr>
</tbody>
</table>
For example, workers are shown a video on positive and negative attitudes towards wearing safety hard hats (refer to Figure 2.12). If a worker did not wear the safety hat, he has made a mistake and may get injured due to falling objects. The consequences of the behaviour is C, while wearing the hat or failure to wear the hat is B, and the video shown is A (i.e. the antecedents to the behaviour).

![Figure 2.12: All construction workers must wear safety hats](image)

There is often a degree of difference between any theory of accident causation and reality. The various models presented with their corresponding theories in this topic attempt to explain why accidents occur. For some accidents, a given model may be very accurate. For others, it may be less so. Often, the cause of an accident cannot be adequately explained by just one model or theory.

Thus, according to the combination theory, the actual cause may combine parts of several different models. Safety personnel should use these theories as appropriate both for accident prevention and accident investigation. However, they should avoid the tendency to try to apply one model to all accidents.

### 2.7 BIRD’S TRIANGLE

Frank Bird, an expert on accident loss control, showed the relationship between major, minor and no-injury accidents. His study is shown in Figure 2.13. He found that all near miss accidents must be investigated and analysed immediately. The necessary actions must be taken as near miss accidents which occurred yesterday could become a serious accident tomorrow (Stranks, 2003).
In fact, according to Bird, near miss accidents tend to lead employers to be careless and be overconfident because there are no injuries or damage to properties. As a result, employers will tend to ignore such near misses. Such an attitude will lead to the next level, i.e. damage to properties, minor injuries, and if still unchecked, then to the next level which involves serious or permanent injuries as shown by the 600:30:10:1 formula in Figure 2.13.

![Figure 2.13: Bird’s triangle](Stranks (2003))

**SUMMARY**

- Based on the discussion earlier, there are several theories which can be used to explain the causes of, or factors leading to, accidents. Among these factors are:
  
  (a) Human error factor;
  
  (b) Unsafe workplace;
  
  (c) Ergonomic factor; and
  
  (d) Systems failure.
• In brief, workplace accidents occur due to a combination of several factors that interact with one another and not merely due to a single factor.

• Managers must be able to identify factors leading to accidents in order to prevent or reduce them.

<table>
<thead>
<tr>
<th>KEY TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident causation</td>
</tr>
<tr>
<td>Accident/Incident Theory</td>
</tr>
<tr>
<td>Axioms of Industrial Safety</td>
</tr>
<tr>
<td>Behavioural Theory</td>
</tr>
<tr>
<td>Bird’s triangle</td>
</tr>
</tbody>
</table>

## SELF-TEST 1

### Essay Questions

1. Give three examples of occupations that may cause overload to workers.

2. By referring to the Epidemiological Theory, explain how the work stress factor can increase the risk of workplace accidents.

3. Based on the Accident/Incident Theory, systems failure is one of the causes of workplace accidents. Explain this in brief.

4. You are a production manager at a factory which produces palm oil-based products. One day, one of your workers suffered injuries to his wrist after it was trapped in a machine. Based on the investigations carried out, you discovered that among the causes of the accident were the machine’s failure to operate properly, workers who were not serious, and negligence.

   With the help of a figure, explain how these factors caused the accident and injury based on Heinrich’s Domino Theory.
True (T) or False (F) Statements

1. Herbert Heinrich used the domino concept in his theory to identify accident causation.

2. E. S. Geller introduced the concept of ABCO in his theory.

3. Systems failure is a major factor in the Human Factor Theory.

4. Low motivation may cause workers to feel that they are experiencing an overload.

5. Ergonomic traps are the main cause in the Accident/Incident Theory.
Workers falling off the roofs of buildings or being electrocuted are examples of workplace accidents. Most workplace accidents are caused by similar factors and these incidents can actually be prevented. Have you ever wondered about the losses incurred by employers, employees and governments when workplace accidents occur?

This topic will discuss workplace accidents including accident costs, causes, types and effects on a given industry. This will help you to understand the role that must be played by managers and workers to ensure safety and health at the workplace.
3.1 COST OF ACCIDENTS

There are two types of costs related to workplace accidents, namely, direct costs (insured costs) and indirect costs (uninsured costs).

Direct costs are costs such as claims and medical expenses paid to workers directly affected by an accident. The rate and method of payment are predetermined.

Indirect costs include all the other unexpected costs related to an accident, such as wages paid to unaffected workers despite stopping work caused by the accident, cost of property damage and raw materials, additional cost for overtime, and so on.

Accident costs can also be divided into six categories as summarised in Table 3.1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage Losses</td>
<td>25</td>
</tr>
<tr>
<td>Medical Expenses</td>
<td>16</td>
</tr>
<tr>
<td>Insurance Administration</td>
<td>19</td>
</tr>
<tr>
<td>Property Damage</td>
<td>18</td>
</tr>
<tr>
<td>Fire Losses</td>
<td>7</td>
</tr>
<tr>
<td>Other Costs</td>
<td>15</td>
</tr>
</tbody>
</table>

In general, direct costs of workplace accidents involve only about one fifth of the total accident costs. The remaining are indirect costs such as productivity loss, lowered output quality of goods, and low morale among workers.

ACTIVITY 3.1

Assuming that you are a manager and you are required to list the costs which have to be taken into consideration and controlled so that your company will not incur losses in the event of an accident. Using your logic and knowledge, provide your suggestions and discuss them with your coursemates.
ACCIDENT CAUSES

3.2.1 Work Environment Factor

How would you feel if you had to work in an untidy, noisy and disorganised environment such as the one shown in Figure 3.1? Would you be able to give your full commitment to your work?

3.2.1 Work Environment Factor
The environmental factor includes the problem of disorderly placement of equipment and tools, which might hinder human movement around the workplace, hence increasing the likelihood of an accident.

Insufficient lighting and poor ventilation may cause visual impairment and breathing problems, respectively, in the long run. In addition, unhygienic and untidy surroundings will reduce one’s ability to perform his duties efficiently due to environmental discomfort.

The use of hazardous substances without adequate protection and proper handling, whether they are used as raw materials or intermediate products, not only will harm the workers, but also cause pollution to the entire vicinity, including the public.

Besides that, how the handling of hazardous work processes is identified, managed and controlled may also be a factor leading to workplace accidents, particularly in the manufacturing industry where a wide range of chemical substances are used. Figure 3.2 illustrates air pollution at the workplace. Such pollution will no doubt cause health problems to workers, which will in turn cause production downtime and other losses.
3.2.2 Equipment Factor

In the manufacturing sector today, sophisticated equipment such as robots and automated machines are used to produce goods. These machines are cost-effective and efficient. However, they may potentially become a cause of accidents, as they still require human assistance to ensure that they operate properly. Human error in this case may introduce new risks, despite all the necessary precautions taken to ensure smooth operation. On the other hand, obsolete machines and machines subjected to continuous use (Figure 3.3) may also lead to breakdown caused by overuse, resulting in accidents.

![Figure 3.3: Continuous usage of machines increases the risks of accidents](image)

Operating machines and equipment in an unsafe and inappropriate manner will only lead to accidents. Sometimes, the machines themselves are left in an unsafe condition when they are not fitted with adequate safety devices, such as a proper guard, thereby increasing the potential for accidents to occur.

3.2.3 Worker Factor

Each work system involves three elements, namely, human, machine and environment. The human (or worker) element is the most important element, as without it, work cannot be completed. It is therefore not surprising, that the main cause of accidents is the worker factor. Table 3.2 explains how the human factor may cause workplace accidents.
Table 3.2: Workplace Accidents Caused by the Human Factor

<table>
<thead>
<tr>
<th>No.</th>
<th>Cause</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Worker Negligence</td>
<td>Workers are the closest people to the task being performed. They know the work process, the substances used and the accident risks associated with the task performed. Accidents often occur when a worker is negligent during the course of his work, such as not using safety boots while working at a construction site where foot injuries caused by falling objects are highly probable.</td>
</tr>
<tr>
<td>2.</td>
<td>Insufficient Training and Work Information</td>
<td>The failure of the employer to provide training and information on how the work is to be performed may lead to accidents. For example, workers who are not trained in electrical wiring may cause electric shock to himself or his co-workers during the wiring process.</td>
</tr>
<tr>
<td>3.</td>
<td>Age and Current Health Conditions</td>
<td>When a worker is recruited, there are several things which must be taken into consideration, among which are his age and health. Failure of the employer to detect an existing disease suffered by the worker (such as heart disease and hypertension) may contribute to accidents. For example, if a worker has a heart problem and continues to work in a strenuous environment, then he is prone to getting a heart attack compared to a healthy person.</td>
</tr>
<tr>
<td>4.</td>
<td>Failure to Follow Employer’s Rules and Instructions</td>
<td>Workers sometimes, whether intentionally or not, fail to follow rules and instructions from their supervisor/employer. For example, a worker might forget to wear safety boots and hard hats in a factory, and face the risk of stepping on a sharp object or being hit by a falling object. His failure to observe safety rules and procedures may cause harm to himself and his co-workers.</td>
</tr>
</tbody>
</table>
3.3 DEATHS AND INJURIES CAUSED BY WORKPLACE ACCIDENTS

Statistically in Malaysia, workplace accidents have been decreased from year to year, based on numbers broken down according to the various economic sectors. However, unfortunate incidents still occur due to several factors.

Table 3.3 shows a few types of accidents that typically lead to injuries and even deaths.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Accident</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Over exertion</td>
<td>The result of employees working beyond their physical limits.</td>
</tr>
<tr>
<td>2.</td>
<td>Impact Accidents</td>
<td>Workers being struck by, or striking against, an object. For example, a worker being struck by a machine.</td>
</tr>
<tr>
<td>3.</td>
<td>Poisoning</td>
<td>Poisoning is caused by chemical substances, whether gases, liquids or solids. Hazardous chemical substances are harmful to humans if they enter the human body through inhalation, injection or skin absorption.</td>
</tr>
<tr>
<td>4.</td>
<td>Falls</td>
<td>Examples include a worker falling from the roof of a building; falling into a drain; stumbling and falling due to a defect in the walking surface.</td>
</tr>
<tr>
<td>5.</td>
<td>Fire</td>
<td>Injuries and deaths caused by fire, toxic fumes, falls, impact from a falling object due to fire at the place of work.</td>
</tr>
<tr>
<td>6.</td>
<td>Motor Vehicle Accidents</td>
<td>Motor vehicle accidents are the main causes of injuries and deaths at the workplace. It may be a work risk if the person works as a driver or it can occur to workers on their way to or from their place of work.</td>
</tr>
<tr>
<td>7.</td>
<td>Suffocation</td>
<td>Suffocation can be work-related or non-work related. Suffocation can occur in the water (drowning) and also on land due to a lack of oxygen.</td>
</tr>
<tr>
<td>8.</td>
<td>Firearms</td>
<td>Injuries and deaths caused by firearms such as armed robbery; negligence while using firearms; and violence.</td>
</tr>
</tbody>
</table>
Based on Table 3.4, the manufacturing sector recorded the highest number of accidents and death cases. Hence, companies must take preventive measures to reduce accident risks in their organisations.

Table 3.4: Industrial Accidents from 2001 to September 2003

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Fishery and Forestry</td>
<td>12,424</td>
<td>75</td>
<td>9,456</td>
<td>69</td>
<td>6,501</td>
<td>52</td>
</tr>
<tr>
<td>Mining and Quarry</td>
<td>573</td>
<td>7</td>
<td>545</td>
<td>12</td>
<td>389</td>
<td>8</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>35,642</td>
<td>243</td>
<td>33,523</td>
<td>214</td>
<td>23,319</td>
<td>164</td>
</tr>
<tr>
<td>Electric, Gas, Water and Cleaning services</td>
<td>442</td>
<td>13</td>
<td>516</td>
<td>14</td>
<td>448</td>
<td>11</td>
</tr>
<tr>
<td>Construction</td>
<td>4,593</td>
<td>89</td>
<td>5,015</td>
<td>88</td>
<td>4,134</td>
<td>72</td>
</tr>
<tr>
<td>Trade</td>
<td>13,774</td>
<td>192</td>
<td>13,685</td>
<td>134</td>
<td>8,826</td>
<td>102</td>
</tr>
<tr>
<td>Transport</td>
<td>4,382</td>
<td>91</td>
<td>4,439</td>
<td>90</td>
<td>3,218</td>
<td>62</td>
</tr>
<tr>
<td>Financial and Insurance Institutions</td>
<td>602</td>
<td>6</td>
<td>567</td>
<td>9</td>
<td>388</td>
<td>7</td>
</tr>
<tr>
<td>Services</td>
<td>5,950</td>
<td>106</td>
<td>5,924</td>
<td>87</td>
<td>3,952</td>
<td>65</td>
</tr>
<tr>
<td>Civil Services</td>
<td>7,487</td>
<td>136</td>
<td>8,140</td>
<td>141</td>
<td>4,334</td>
<td>92</td>
</tr>
<tr>
<td>TOTAL</td>
<td>85,869</td>
<td>958</td>
<td>81810</td>
<td>858</td>
<td>55,509</td>
<td>635</td>
</tr>
</tbody>
</table>

Source: Industrial Accident Reports from 1999 to 2003, SOCSO

3.4 ACCIDENT COST ESTIMATION

Prevention is better than cure. This saying has never been more true than in the field of occupational safety and health management. Employers are responsible for implementing a workplace accident control and prevention programme that consists of training courses, seminars and purchase of safety equipment for workers so that they can carry out their work safely without risking their health or lives.
However, some employers think that such programmes are expensive, or that they can do without them. If you were an occupational safety and health officer, you would be responsible for proving that this view is wrong: take a look at the cost estimation method developed by Professor Rollin H. Simonds.

In order to arrive at the actual cost of an accident, Simonds recommends that costs associated with a workplace accident be divided into insured and uninsured costs. Determining the insured costs of accidents is a simple matter of examining accounting records. The next step involves calculating the uninsured costs by using the classification proposed in Table 3.5.

**Table 3.5: Professor Simonds’ Classes of Accidents**

<table>
<thead>
<tr>
<th>Accident Class</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Lost work days, permanent partial disabilities, and temporary total disabilities.</td>
</tr>
<tr>
<td>Class 2</td>
<td>Treatment by a physician outside the company’s facility.</td>
</tr>
<tr>
<td>Class 3</td>
<td>Locally provided first aid, property damage of less than USD$100 (RM340) or the loss of fewer than eight hours of work time.</td>
</tr>
<tr>
<td>Class 4</td>
<td>Injuries that are so minor they do not require the attention of a physician result in property damage of USD$100 (RM340) or more, or cause eight or more work hours to be lost.</td>
</tr>
</tbody>
</table>

In order to determine the average cost of workplace accidents, Simonds recommends that each organisation keep records of the cost of accidents during a specified period not covered by insurance, based on the classes stated in Table 3.5.

For example, the costs of Class 1 accidents may be recorded for a period of six months. Find the average cost per accident by dividing the total sum with the number of accidents in the specified period. Table 3.6 will help you to understand the estimation of indirect accident costs for Class 1.
Table 3.6: Accident Cost Estimation

<table>
<thead>
<tr>
<th>Cost ($</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost 1</td>
<td>200.00</td>
<td>500.00</td>
<td>97.00</td>
<td>453.00</td>
</tr>
<tr>
<td>Cost 2</td>
<td>150.00</td>
<td>200.00</td>
<td>25.00</td>
<td>58.00</td>
</tr>
<tr>
<td>Cost 3</td>
<td>150.00</td>
<td>375.00</td>
<td>–</td>
<td>97.00</td>
</tr>
<tr>
<td>Cost 4</td>
<td>–</td>
<td>1,500.00</td>
<td>–</td>
<td>2,530.00</td>
</tr>
<tr>
<td>Cost 5</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cost 6</td>
<td>–</td>
<td>–</td>
<td>83.00</td>
<td>15.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>500.00</td>
<td>2,575.00</td>
<td>205.00</td>
<td>3,153.00</td>
</tr>
</tbody>
</table>

Average Cost per Accident = Total cost of accident/number of accidents
= $(500+2,575+205+3,153)/4 = $1,608.25

3.5 EFFECTS OF ACCIDENTS ON ORGANISATIONS

Organisations nowadays take a serious view of workplace accidents. This is because workplace accidents have negative implications on the organisations, which in turn reduce their competitiveness in the market. Among these implications are:

(a) **Operational Costs**
As explained earlier in this topic, accident costs include the medical costs of workers injured in the accident, costs of insurance premiums which must be borne by the organisations, costs of accident investigation, costs due to absence of workers affected by the accidents, costs of productivity loss, and the costs of training workers replacing the workers incapacitated by the accident. When the accident rate increases, accident prevention programmes must be implemented and these programmes may add substantial amounts to the overall costs.
All these costs can be avoided if only accidents can be prevented, and this can be achieved by inculcating a safe work culture. That means education, training and adhering to safety procedures. Ultimately, the management is responsible for creating a safe and healthy work environment.

(b) **Legal Costs**

When an accident occurs at the workplace, enforcement agencies such as the Occupational Safety and Health Department, the Department of Environment and the Fire and Rescue Department will conduct an investigation into why the accident happened and what could be done to prevent a recurrence. If any existing law has been violated, the organisation involved will be sued. The penalty imposed might be in the form of summonses, an order to close the premises, or worse still, an order to cease operations altogether.

According to the Occupational Safety and Health Act 1994, both parties involved – the employer and the employee – are jointly responsible for ensuring that safe work methods are being practised. It is very important for both parties to understand and fulfil their responsibilities stated in the Act in order to reduce the adverse effects of workplace accidents.

(c) **Motivating Workers**

Implementing occupational safety and health aspects at the workplace can be a motivating factor to workers. Workers who work in a safe and conducive environment will feel happy and be motivated to perform their tasks more effectively and efficiently. Such an environment will also encourage workers to be more committed.

(d) **Boosting Organisational Image**

When the rate of workplace accidents is low, workers will feel safe. This in turn will boost the image of the organisation among the public and attract more job seekers. A good corporate image will be a major “selling point” to win over potential employees, thereby cutting down on the tedious process of recruitment and worker selection. Moreover, a reputable organisation will be able to hire more appropriate and more qualified candidates who may come forward on their own to apply for jobs.

In addition, the surrounding community will respect and support the efforts of the organisation to improve its work safety and health standards. In the long run, goods produced or services rendered by the organisation will be of high standards, whether in the local or international market.
Workplace accidents can never be totally eliminated.

The efforts of occupational safety and health practitioners are merely to reduce the number of workplace accidents.

Apart from that, these efforts are also aimed at reducing the number of fatal accidents and incidents that can bring both temporary and permanent disabilities to victims.

Workplace accidents invariably lead to financial and human losses.

The indirect costs due to accidents are higher than their direct costs.

To prevent such losses, accident prevention programmes must be implemented by organisations so as to fulfil their occupational safety and health responsibilities.

### Essay Questions

1. State two causes of workplace accidents due to the equipment/machinery factor.

2. Explain briefly how occupational and safety management programmes and practices can have positive effects on the motivation of workers at the workplace.
3. Explain briefly how the worker factor poses an accident risk at the workplace.

4. MariMai is a company that processes raw rubber. Throughout August until December 2003, there were five accident cases involving indirect costs totalling RM13,582 which must be borne by the company. What was the average cost borne by the company for each accident that occurred?

**SELF-TEST 2**

**True (T) or False (F) Statements**

1. There are two types of accident costs, i.e. direct costs and indirect costs.

2. The worker factor is one of the causes of accidents at the workplace.

3. Damage of property is considered a direct cost.

4. Indirect costs are costs that can be controlled and predetermined easily.
Work stress, whether due to information overload, work pressure or other causes, is an unhealthy factor that lessens a worker’s productivity. Therefore, managers must deal with it wisely.

According to a research, almost 35 percent of workers said that their work caused emotional and health problems, while another 45 percent concluded that work stress affected their personal lives (Nelson & Quick, 2005).

Hence, it is important to understand the factors that lead to workplace stress and its effects on workers’ productivity and quality of life.
Workplace stress has been defined as an undesirable human reaction to social, occupational, or environmental stimuli such as work overload, unstable work, insufficient information, excessive demands and the like, which cause stress known as distress.

There is also a positive type of stress that encourages workers to be more aggressive so as to increase their productivity. This positive pressure is known as eustress. Eustress is experienced moderately and is capable of motivating people to achieve their goals and succeed in completing their task. Figure 4.1 illustrates the stress curve describing eustress and distress.

Figure 4.1: Yerkes-Dodson’s curve

Source: Adapted from Nelson & Quick (2005)
Figure 4.1 shows that workplace stress may improve the performance of workers up to a certain point – the optimum level. After the optimum level, more stress will have a negative effect on the performance of workers. A low level of arousal will also cause workers to experience distress. Therefore, workers must be motivated so that they can achieve the optimum level of arousal or stimulation in order to improve their performance.

Table 4.1 illustrates the benefits of eustress and the effects of distress. The positive effects of eustress can be seen in terms of performance as it motivates workers to work harder, enhances their physical strength and health through better blood circulation due to an effective cardiovascular system, and enables them to fully focus on the task being performed. Figure 4.2 shows a worker experiencing stress at work.

### Table 4.1: The Benefits of Eustress and the Effects of Distress

<table>
<thead>
<tr>
<th>Benefits of Eustress</th>
<th>Health</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance</strong></td>
<td><strong>Health</strong></td>
</tr>
<tr>
<td>• Increased motivation</td>
<td>• Cardiovascular effectiveness</td>
</tr>
<tr>
<td>• Increased physical strength</td>
<td>• Focused during emergency situations</td>
</tr>
<tr>
<td><strong>Effects of Distress</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Individual</strong></td>
<td><strong>Organisation</strong></td>
</tr>
<tr>
<td>• Psychological effects</td>
<td>• Workers’ participation</td>
</tr>
<tr>
<td>• Diseases</td>
<td>• Decline in performance</td>
</tr>
<tr>
<td>• Behavioural effects</td>
<td>• Increasing compensation claims</td>
</tr>
</tbody>
</table>

**Source:** Nelson & Quick (2005)

**Figure 4.2:** Workplace stress may make it difficult for a person to focus
The effects of distress can be perceived in two forms, i.e. on individuals and on organisations as a whole. The burden of excessive arousal on individuals can have the following three negative effects:

(a) Psychological effects such as depression, fatigue and the like;
(b) Diseases such as heart disease, stroke and so on; and
(c) Behavioural effects such as violence, abuse of power and the like.

As for organisations, distress will result in additional costs due to absenteeism, high turnover rate, decline in workers’ performance, decline in quality and productivity, increasing compensation claims due to accidents and work-related stress.

The clinical definition of stress is the total response of a human organ to a situation that threatens or stimulates the worker. Thus, the definition of stress is the unconscious response of a person to a situation he sees as a challenge or a threat to the quality of his life.

Due to the fact that workers always experience stress that increases their mental and health risks, this topic will focus on distress.

### 4.2 SOURCES OF WORKPLACE STRESS

Basically, there are two types of workplace stress, namely, work-related and non-work related stress. Sources of work-related stress include the following:

(a) Physical working conditions;
(b) Role ambiguity and workload;
(c) Interpersonal problems;
(d) Organisational pressure on the physical conditions; and
(e) Emotional feelings towards others.

Examples of non-work related sources of stress are personal lifestyle and family problems. Figure 4.3 illustrates the causes and consequences of stress.
4.2.1 Work Stress

As shown in Figure 4.3, causes of work stress involve:

(a) Physical working conditions;
(b) Workload and the various roles played by a person;
(c) Interpersonal problems; and
(d) Organisational pressure.

The conditions illustrated in Figure 4.3 are explained below.

(a) **Physical Working Conditions**

Poor lighting, loud noises and the presence of various hazards at the workplace may prevent a person from performing his work comfortably.
For example, a work environment that is too hot or too cold will adversely affect a person’s physical condition, possibly causing problems such as dehydration due to excessive heat. A computer-based work environment can also cause stress.

(b) **Role and Workload**

The role played by a worker and the workload he must handle may cause stress. Table 4.2 illustrates the role of the task and workload.

<table>
<thead>
<tr>
<th>No.</th>
<th>Task and Workload</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Workload and task complexity</strong></td>
<td>Excessive workload, task complexity and the various demands imposed on the worker can cause stress. A job perceived as being too complex may cause feelings of inadequacy and result in emotional stress. Repetitive work may lack complexity but it will cause the worker to feel bored and dissatisfied with the job as it is no longer challenging. This situation causes boredom-related stress.</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Control over work</strong></td>
<td>Lack of control over job assignment can also be a source of workplace stress. Workers might feel less stressed if they participate in determining the work routine, including scheduling and selection of tasks. Studies have shown that workers who have more control over their work experience have less work stress compared to those who lack control over their work.</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Role conflict</strong></td>
<td>Role conflict occurs when a person has to play two different roles. For example, a role played at the workplace will have an effect on the role to be played at home and vice versa. When there is a role overload at the workplace, the role at home will be affected, hence creating stress for the person and vice versa. Workers also face intra-role conflicts when they receive instructions from various parties at the workplace.</td>
</tr>
<tr>
<td>4.</td>
<td><strong>Role ambiguity</strong></td>
<td>Role ambiguity occurs when a person feels that the instructions given are not clear. Due to ambiguous instructions, workers will not know how to perform the task given and will feel stressed upon approaching the deadline for the completion of the task.</td>
</tr>
</tbody>
</table>
(c) **Interpersonal Problems**
The sources of interpersonal problems may involve bad supervision, office politics, conflict among workers or with supervisors, sexual harassment, style of leadership and the like.

For example, organisations that are not sensitive towards sexual harassment will cause the employees involved to experience stress, which might lead to their resignations. Similarly, the performance of those working under supervisors who are too autocratic can be adversely affected.

(d) **Organisational Stress**
There are many forms of stress caused by organisations such as employee retrenchment, job security, organisation restructuring and the like.

For example, employees who feel that their jobs are insecure will be worried. The existence of other job opportunities which provide better perks and professional training will reduce stress related to job security.

### 4.2.2 Non-work Related Stress

Non-work related stress is caused by family and personal lifestyle factors. People also face stress due to non-work related factors.

For example, the feeling of responsibility for the welfare and safety of the family can be a source of stress at the workplace. This feeling of responsibility will make the employees feel that their options to take risks are limited. These employees tend to feel that they are “trapped in the job”. Long working hours tend to make them feel uneasy and stressed as they feel that they have neglected their family responsibilities.

**SELF-CHECK 4.1**

Discuss the sources of stress which exist in an organisation and suggest an ideal way of overcoming them.
4.3 HUMAN REACTION TO WORKPLACE STRESS

Human reactions to workplace stress can be identified through the following aspects:

(a) Physiological effects such as heart disease, ulcer, high blood pressure, headaches, sleep disorders and the like;

(b) Psychological effects such as lack of concentration, difficulty in making decisions, feelings of anxiety, enmity and guilt; and

(c) Behavioural effects such as behaviours which might cause accidents, jitteriness, absenteeism, high turnover rate and low productivity.

Continual or persistent stress has been linked to many physiological problems. Initially, the effects may be psychosomatic, but with continued stress, the symptoms show up as actual organ dysfunction. The most common forms of stress-related diseases are gastrointestinal problems, particularly gastric or duodenal ulcers. The human response to workplace stress can be compared to a rubber band being stretched. As stress continues to be applied, the rubber band stretches until a limit is reached when the rubber band breaks. For humans, various physical and psychological changes are observed with repetitive stimulation of stress. Until the limit is reached, the harmful effects can be reversed. With an increase in intensity or duration of the stress beyond the individual’s limit, the effects on the human become pathological.

Figure 4.4 illustrates the three stages of the human stress response.

![The Three Stages of the Human Stress Response](image)

**Figure 4.4:** The three stages of the human stress response
The alarm reaction occurs when the stress of a threat is sensed. The stage of alarm is characterised by pallor, sweating, and an increased heart rate. This stage is usually short. It prepares the body for whatever action is necessary.

When the stress is maintained, the stage of resistance initiates a greater physical response. The alarm symptoms dissipate, and the body begins to adapt to the stress. The capacity for adaptation during this stage is limited.

Eventually, with sustained stress, the stage of exhaustion is reached. This stage is demonstrated by the body’s failure to adapt to the continued stress. Psychosomatic diseases such as gastric ulcers, colitis, rashes, and autoimmune disorders may appear during this stage. The tendency to develop a specific stress-related disease may be partially predetermined by heredity, personal habits such as smoking, and personality.

![Figure 4.5: Human response towards stress](source: McShane & Van Glinow (2004))

**ACTIVITY 4.1**

4.4 SHIFT WORK AND STRESS

Sometimes, employees are required to work on shifts when the majority of others are resting. Shift work has traditionally been required by the medical community, the transportation industry, utilities, security, and, increasingly, by retail sales. In some cases, shift work requires rotating between two and three different starting times, which may vary by eight hours or more. However, today, there are organisations which practise three-day (or four-day) shifts, i.e. each shift (of, say, three 12-hour cycles) lasts for three days with mandatory rest of four days afterwards, or vice versa. For such a situation, the total number of working hours is 8 hours a day and workers may work overtime up to a maximum of 12 hours a day.

Basic physiological functions are scheduled by the biological clock called the circadian rhythm. Most people grow up on the day shift, going to school during the day and sleeping at night. After a life of being on the day shift, the body perceives a change in work shift as being stressful. If the person takes a job starting at midnight, his body will still expect to be sleeping at night and active during the day.

Many physical and psychological functions are affected by the circadian rhythm. Blood pressure, heart rate, body temperature, and urine production are measurably lower or slower at night. These same functions are normally higher or faster during the day (active time). Behavioural patterns also follow the circadian slower-at-night and active-in-day pattern.

Not working the normal day-shift hours results in an increase in workplace stress, with rotating shifts being the most stressful. From a safety viewpoint, shift workers are subjected to more workplace stress in terms of weariness, irritability, depression, and a lack of interest in work. Shift work increases workplace stress and may cause a worker to become less safe.
4.5 WORKPLACE STRESS MANAGEMENT

Stress can be managed both by organisations and individuals. Figure 4.6 shows several strategies for organisations and individuals to manage workplace stress.

**Figure 4.6:** Strategies to overcome workplace stress  

The following are some strategies for reducing workplace stress:

(a) Eliminate the factors creating the stress;
(b) Social support from employers, co-workers and family members;
(c) Withdraw from the source of stress;
(d) Change perception about the situation causing the stress; and
(e) Control the effects of stress.
Factors which create stress can be eliminated in the following manner:

(a) Redesign tasks so that workers can improve their performance;
(b) Workers and employers agree on the objective to be achieved;
(c) Consult workers before a task is given; and
(d) Establish social relationships which support workers such as creating a family-friendly environment like childcare facilities at the workplace, flexible working hours and the like.

For example, a former task did not require workers to make any decision. However, after redesigning the task, workers are encouraged to be involved in the decision-making process. This will reduce workers’ stress as they are able to complete their task without having to wait for their managers to decide for them.

Support from employers, co-workers and family members includes emotional support for workers who face problems. Withdrawing workers from the factor causing the stress, be it temporarily or permanently, includes assigning suitable tasks to them and transferring them to less stressful departments. Changing perceptions about a situation which causes stress can be done by setting individual goals, strengthening oneself, enhancing effectiveness and so on.

Controlling the effects of stress can be done by leading a healthy lifestyle, controlling physiological effects by means of treatment, and taking a break after work.

Most sources of stress can be changed, eliminated or reduced. However, workers must be aware of and understand their reactions to stress. In Figure 4.7, several tips on reducing workplace stress are listed.

<table>
<thead>
<tr>
<th>Tips which can be practised to reduce workplace stress:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Eating balanced food daily;</td>
</tr>
<tr>
<td>(b) Exercising regularly;</td>
</tr>
<tr>
<td>(c) Taking up a hobby which promotes calmness and peace of mind;</td>
</tr>
<tr>
<td>(d) Setting realistic goals;</td>
</tr>
<tr>
<td>(e) Being positive and focusing on good attributes, accepting one’s advantages and weaknesses.</td>
</tr>
</tbody>
</table>

Figure 4.7: Tips which can be practised to reduce workplace stress

A moderate amount of mental stress may assist in accomplishing a task but extreme mental stress can create social and health problems.
Workplace stress is an epidemic that affects the workplace in the current era of high technology.

Managers must prevent stress from affecting their workers as it is not only very costly to rectify later, but is capable of reducing productivity that leads to a decline in worker performance.

Implementing an effective strategy will prevent organisations from incurring losses and enable workers to enjoy a healthy and harmonious quality of life. Furthermore, it will enhance the productivity of the workers and organisations.

### KEY TERMS

<table>
<thead>
<tr>
<th>Behavioural effects</th>
<th>Psychological effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circadian rhythm</td>
<td>Role conflict</td>
</tr>
<tr>
<td>Distress</td>
<td>Role ambiguity</td>
</tr>
<tr>
<td>Eustress</td>
<td>Workplace stress</td>
</tr>
</tbody>
</table>

### SELF-TEST 1

**Essay Questions**

1. Explain the Yerkes-Dodson’s curve.

2. State the basic physiological function scheduled by the biological clock.


4. Explain three effects of distress experienced by workers and organisations, respectively.

5. Explain three causes of workplace stress.
True (T) or False (F) Statements

1. The degree of stress among workers of similar conditions is the same.
2. The feeling of responsibility for the safety of the public is also a source of stress.
3. Continual stress is often linked to many physiological problems.
4. Changing perceptions about the condition that creates stress is a strategy to reduce workplace stress.
5. Blood pressure, heart rate, body temperature and urine production are measurably lower or slower at night.
This topic discusses the physical conditions of the workplace such as the workstation, work equipment and posture during work. Advanced and sophisticated equipment used at the workplace often pose risks to their users and expose them to bodily injuries in the long run.

Basically, these injuries show their effects only after some time. In fact, people might not be aware that they are actually suffering from injuries due to ergonomic problems.


5.1 ERGONOMICS DEFINED

What is meant by ergonomics and how important is it to workers? The ergonomic principles involve everything from work systems to sports, health and safety. Various industries are now using ergonomics increasingly in order to enhance human productivity, quality of work environment, and occupational safety and health.

Studies have shown that people working at ergonomic workstations or using ergonomic equipment are less likely to experience fatigue, discomfort or stress.

The word “ergonomics” is derived from the Greek language. “Ergon” is Greek for work; and “nomos” means laws.

In other words, ergonomics involves “using a special design to make tasks more compatible with humans and not to force humans to be more compatible with tasks”.

As such, ergonomics deals with various aspects ranging from physical stress on the muscles, nerves, bones, tendons, and ligaments to environmental factors which affect hearing, vision, comfort and health.

Ergonomics is also defined as the “systematic application of knowledge about the physiological, physical, and social attributes of human beings in the design and use of all things which affect a person’s working conditions: equipment and machinery, the work environment and layout, the job itself, training and the organisation of work”.

In other words, ergonomics seeks to adjust tasks to the worker through equipment design and work procedures.

5.2 LEGAL REQUIREMENTS AND ERGONOMICS APPLICATION

The Occupational Safety and Health Act 1994 is an Act based on the self-regulation concept. In essence, the concept means that employers who create risks for their workers must ensure the safety and health of their workers at the workplace.
One of the objectives of this Act is to create working conditions that meet the physiological and psychological needs of the workers. Thus, employers are responsible for establishing a safe work system which does not pose any health risks to the workers (Section 15 (2)(a), Occupational Safety and Health Act 1994). Refer to Table 5.1 for a list of Acts that oversee the application of ergonomics.

**Table 5.1: List of Acts which Oversee the Application of Ergonomics**

<table>
<thead>
<tr>
<th>Act</th>
<th>Brief Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupational Safety and Health Act 1994</td>
<td>This Act lists the responsibilities of employers to reduce ergonomic problems.</td>
</tr>
<tr>
<td>Regulation 30 of the Factories and Machinery Rules (Safety, Health and Welfare) 1970</td>
<td>This regulation contains provisions pertaining to suitable seating facilities for workers.</td>
</tr>
</tbody>
</table>

The application of ergonomics at the workplace takes into consideration four main elements. These elements are shown in Figure 5.1.

**The four main elements in the application of ergonomics are:**

1. Workstation design such as workstation height, organisation of equipment, accessories and components;
2. Tool designs and handles, taking into consideration vibration, size of handle, type of grip, and usability;
3. Task designs such as manual handling, fatigue and stress (shift job), task requirements and sitting vs standing; and
4. Design of physical work conditions such as lighting, noise level, temperature and level of comfort.

**Figure 5.1: Four main elements in the workplace ergonomic application**
5.3 FACTORS ASSOCIATED WITH PHYSICAL STRESS

The eight variables that can influence the amount of physical stress experienced on the job are listed in Figure 5.2.

**Eight variables that can influence the amount of physical stress:**

(a) Sitting versus standing;
(b) Stationary versus movable/mobile;
(c) Large demand for strength/power versus small demand for strength/power;
(d) Good horizontal work area versus bad horizontal work area;
(e) Good vertical work area versus bad vertical work area;
(f) Non-repetitive motion versus repetitive motion;
(g) Low surface versus high surface; and
(h) No negative environmental factors versus negative environmental factors.

**Figure 5.2:** The eight variables that can influence the amount of physical stress

Try to understand the eight variables that can affect a person’s work efficiency.

(a) **Sitting versus Standing**

Generally speaking, sitting is less stressful than standing. Standing for extended periods, particularly in one place, can produce unsafe levels of stress on the back, legs and feet as shown in Figure 5.3. Although less stressful than standing, sitting can be stressful too, unless appropriate precautions are taken.

**Figure 5.3:** Avoid standing for a long period because it creates stress on the back, legs and feet
These precautions include proper posture, a supportive backrest, and frequent standing/stretching movements.

(b) **Stationary versus Mobile**

Stationary jobs are those done primarily at one workstation. Of course, even these jobs involve movement at the primary workstation and occasional movement to other areas. Mobile jobs, on the other hand, require continual movement from one station to another.

The potential for physical stress increases with stationary jobs when workers fail to take such precautions as periodically standing, stretching or moving. The potential for physical stress increases with mobile jobs when workers carry materials as they move from station to station. Figure 5.4 illustrates a production operator who normally does stationary jobs.

![Figure 5.4: Example of a stationary job: a production operator](image)

(c) **Large versus Small Demand for Strength/Power**

Regardless of whether the stress results from lifting a few heavy objects or repeated lifting of lighter objects, jobs that demand larger amounts of strength/power are generally more stressful than those requiring less.

In classifying jobs by these two criteria, it is important to understand that repeatedly moving small amounts of weight over a period of time can have a cumulative effect equal to the amount of stress generated by moving a few heavy weights. Figure 5.5 illustrates a construction worker whose job has a large demand for strength/power.
Good versus Bad Horizontal Work Area
A good horizontal work area is one that is designed and positioned so that it does not require the worker to bend forward or twist the body from side to side. Horizontal work areas that require these movements are bad. Bad horizontal work surfaces increase the likelihood of physical stress.

Good versus Bad Vertical Work Area
Good vertical work areas are designed and positioned so that workers are not required to lift their hands above their shoulders or bend down in order to perform any task. Vertical work areas that require these movements are bad. Bad vertical work areas increase the likelihood of physical stress.

Non-repetitive versus Repetitive Motion
Repetitive motion jobs involve short-cycle motion that is repeated continually. Non-repetitive jobs involve a variety of tasks that are not, or only infrequently, repeated. Repetition can lead to monotony and boredom. When this happens, the potential for physical stress increases.

Low versus High Surface Contact
Surface stress can result from contact with hard surfaces such as tools, machines and equipment. High surface contact jobs tend to be more stressful in the physical sense than low surface contact jobs.

Presence versus Absence of Environmental Factors
Generally, the more environmental factors a worker has to contend with on the job, the more stressful will the job be. For example, personal protective equipment, although conducive to reducing environmental hazards, can increase the amount of physical stress associated with the job.

Figures 5.6, 5.7 and 5.8 illustrate the proper and improper sitting postures when doing work.
Figure 5.6: Improper sitting posture

Figure 5.7: Proper sitting posture

Figure 5.8: The proper sitting posture when taking a rest
There are seven indicators that can be considered as signals showing that an ergonomic problem exists in an organisation. The seven common indicators are listed in Figure 5.9.

**ACTIVITY 5.1**

To enhance your understanding of work postures, explain briefly the influence of the three variables as shown in Figures 5.7 and 5.8 on the productivity of workers.

### 5.4 COMMON INDICATORS OF ERGONOMIC PROBLEMS

There are seven indicators that can be considered as signals showing that an ergonomic problem exists in an organisation. The seven common indicators are listed in Figure 5.9.

**Common Indicators of Ergonomic Problems**

(a) Apparent trends in accidents and injuries  
(b) Incidence of cumulative trauma disorders  
(c) Absenteeism and high turnover rates  
(d) Employee complaints  
(e) Employee-generated changes  
(f) Poor quality  
(g) Manual material handling

*Figure 5.9: Common indicators of ergonomic problems*
The seven common indicators of ergonomic problems are explained in the following.

(a) **Apparent Trends in Accidents and Injuries**
By examining accident reports, record-keeping documents, first-aid logs, insurance forms, and other available records of illnesses or injuries, safety and health professionals can identify trends if they exist. A pattern or a high incidence rate of a specific type of injury typically indicates that an ergonomic problem exists.

For example, a production operator who always lifts heavy boxes to the store needs frequent medical treatment for his back. In the end, the operator may be referred to a chiropractor who may confirm that he is suffering from a serious back injury. This is an example of an injury trend based on the medical records of the operator.

(b) **Incidence of Cumulative Trauma Disorders (CTDs)**
Factors associated with CTDs include a high level of repetitive work, greater-than-normal levels of hand force, awkward posture, high levels of vibration, high levels of mechanical stress, extreme temperatures, and repeated hand-grasping or pinch-gripping. By observing the workplace and people at work, employers can determine the amount of exposure that employees have to these factors and the potential for ergonomics-related problems.

For example, a worker who uses a concrete/asphalt breaker frequently is exposed to white finger syndrome due to high vibrations.

(c) **Absenteeism and High Turnover Rates**
High absentee rates and high turnover rates can be indicators of ergonomic problems. People who are uncomfortable on the job to the point of physical stress are more likely to miss work or leave for less stressful conditions.

Take, for instance, a production operator whose work involves continuous standing. Standing for extended periods, particularly in one place, can produce unsafe levels of stress on the back, legs and foot soles. Such conditions might cause the operator to take medical leave or stay away from work due to physical stress.
(d) **Employee Complaints**
A high incidence of employee complaints about physical stress or poor workplace design can indicate the presence of ergonomic problems.

For example, a typist might complain that her chair is too high, causing physical stress to her legs and back. She might complain persistently to her supervisor about her uncomfortable chair, but no action is taken to rectify the situation.

(e) **Employee-generated Changes**
Employees tend to adapt the workplace to their needs. The presence of many workplace adaptations, particularly those intended to decrease physical stress, can indicate the presence of ergonomic problems.

For example, workers may place additional padding on their chairs, modify protective equipment, install additional lights, and others. Such employee-generated changes may be evidence of ergonomic problems.

(f) **Poor Quality**
Poor quality, although not necessarily caused by ergonomic problems, may be the result of ergonomics. Poor quality is at least an indicator. Certainly, poor quality implies there is a need for closer inspection.

(g) **Manual Material Handling**
The incidence of musculoskeletal injuries is typically higher in situations that involve a lot of manual material handling. Musculoskeletal injuries increase significantly when the job involves one or more of the following:

(i) Lifting large objects;

(ii) Lifting bulky objects;

(iii) Lifting objects from the floor; and

(iv) Lifting frequently.

Lifting heavy objects inappropriately and not receiving proper training can lead to musculoskeletal injuries which might result in the worker not being able to perform his task properly. When such conditions exist, the company has ergonomic problems.
Common indicators sometimes are not strong enough proof that ergonomic problems exist in organisations. Thus, employers must try to identify specific ergonomic problems through task analysis. Problems that can be pinpointed by a task analysis are as follows:

(a) Hazardous movements;
(b) Frequent manual lifting;
(c) Excessive wasted motion or energy;
(d) Poor operation flow;
(e) Unnatural or uncomfortable posture;
(f) High psychological stress;
(g) High fatigue;
(h) Quality control problems; and
(i) Automated equipment.

After identifying the tasks that need to be analysed in detail, employers may carry out the task analysis shown in Figure 5.10.

Figure 5.10: The six techniques of task analysis
(a) **General Observation**
General observation of a worker or workers performing the task(s) in question can be an effective task analysis technique. The effectiveness is usually enhanced if the workers are not aware that they are being observed. When observing employees at work, be especially attentive to tasks requiring manual material handling and repetitive movements.

(b) **Questionnaires and Interviews**
Questionnaires and interviews can be used for identifying ergonomic problems. Questionnaires are easier to distribute, tabulate and analyse, but interviews generally provide more in-depth information.

(c) **Videotaping and Photography**
Videotaping technology has simplified the process of task analysis considerably. Videotaping records the work being observed as it is done, is silent so it is not intrusive, and such capabilities as freeze and playback enhance the observer’s analysis capabilities significantly.

(d) **Drawing or Sketching**
Making a neat sketch of a workstation or a drawing showing workflow can help identify problems. Before using a drawing or sketch as part of task analysis, make sure it is accurate. Ask an employee who is familiar with the area or process to check the drawing.

(e) **Measuring the Work Environment**
Measurements can help identify specific ergonomic problems. They can be carried out to identify the following:

(i) How far must a worker carry the material manually?
(ii) How high does a worker have to lift an object?
(iii) How much does an object weigh?
(iv) How often is a given motion repeated?

Answers to these questions can enhance the effectiveness of the analysis process.
(f) **Understanding the Ergonomics of Aging**
When identifying specific ergonomic problems in the workplace, do not overlook the special challenges presented by older workers. A good ergonomics programme adapts the job to the person. For example, if many members of its workforce are 45 years of age or older, an organisation must be prepared to adapt workstations to their older employees whose physical needs are different from those of their younger counterparts.

The following rules must be taken into consideration when adapting the job to the worker:

(a) Nerve conduction velocity, hand-grip strength, muscle mass, range of motion and flexibility, all begin to diminish upon reaching the age of 45;
(b) Weight and mass tend to increase starting from the age of the early fifties;
(c) Height begins to slowly diminish from the age of 30;
(d) Lower back pain is more common in people 45 years of age and older; and
(e) Visual acuity at close range diminishes with age.

These rules mean that employers cannot take a “one-size-fits-all” approach to ergonomics. Adaptations for older workers must be individualised and should take aging factors into account.

5.6 **HAZARD PREVENTION AND CONTROL**

Typically, when a problem becomes serious, only then will we try to find solutions. In dealing with ergonomic problems, it is more cost-effective for employers to take proactive actions to prevent ergonomic stress. Engineering solutions, where feasible, are the preferred method for ergonomic hazard prevention and control. The focus of an ergonomics programme is to make the job fit the person – not to make the person fit the job. This is accomplished by redesigning the workstation, work methods, or tools to reduce the demands of the job, which include high force, repetitive motion, and awkward postures.
Table 5.2 presents three examples of engineering controls that have proven to be effective and achievable.

**Table 5.2: Examples of Engineering Controls**

<table>
<thead>
<tr>
<th>No.</th>
<th>Example</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Workstation Design</strong></td>
<td>Workstations should be designed to accommodate the persons who actually use them; it is not sufficient to design for the average or typical worker. Workstations should be easily adjustable and should be either designed or selected to fit a specific task, so that they are comfortable for the workers who use them. The work space should be large enough to allow for the full range of required movements, especially where knives, saws, hooks, and similar tools are used.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Design of Work Methods</strong></td>
<td>Traditional work method analysis considers static postures and repetition rates. This should be supplemented by addressing the force levels and the hand, arm and leg postures involved. The tasks should be altered to reduce these and the other stresses associated with cumulative trauma disorders (CTDs). The results of such analyses should be shared with the healthcare providers to assist in compiling and updating the lists of light-duty and high-risk jobs.</td>
</tr>
<tr>
<td>3</td>
<td><strong>Tool Design and Handles</strong></td>
<td>Tools should be selected and designed to minimise the risks of upper extremity CTDs and back injuries. Examples of criteria for selecting tools include the following: <em>(a)</em> Designing tools to be used by either hand, or providing tools for both left- and right-handed workers. <em>(b)</em> Selecting pneumatic and power tools that exhibit minimal vibration and maintaining them in accordance with the manufacturer’s specifications. <em>(c)</em> Using handles and grips that distribute the pressure over the fleshy part of the palm, so that the tool does not dig into the palm.</td>
</tr>
</tbody>
</table>
Apart from engineering controls, the following steps can be used to prevent and control ergonomic problems.

(a) **Periodic Health Surveillance**
Periodic health checks – every two to three years – should be conducted on all workers who are assigned to positions involving exposure of a particular body part to ergonomic stress. The purpose of this periodic surveillance is to monitor any change in the health of workers, particularly those assigned to positions involving exposure to ergonomic stress.

(b) **Ergonomics Programme**
An effective ergonomics programme must include continuous training and education. The purpose of training and education is to ensure that employees are sufficiently informed about the ergonomic hazards to which they may be exposed and thus able to participate actively in their own protection. Training and education allow managers, supervisors and employees to understand the hazards associated with a job or process, their prevention and control, and their medical consequences.

The team involved in the ergonomics training programme consists of:

(i) Health care providers.
(ii) Supervisors.
(iii) Site management officers.

The education programme must expose workers to:

(i) Types of CTDs and preventive measures;
(ii) Causes of CTDs;
(iii) Early signs and symptoms of CTDs; and
(iv) Treatments for CTDs.

Such information must be given when the team responsible for the ergonomics programme visits work sites, and when workers conduct medical checkups. For new workers, the information and training must be given during the orientation programme.

Through such education and training programmes, CTDs can be detected at an early stage, hence reducing their effects.
(c) **Early Report of CTD Symptoms**

Employees should be encouraged to report early signs and symptoms of CTDs to the in-plant health facility. This allows for timely and appropriate evaluation and treatment by employers.

**ACTIVITY 5.3**

For information on ergonomic controls, visit
http://www.osha.gov/SLTC/ergonomics/solutions.html

### 5.7 STRATEGIES TO SOLVE ERGONOMIC PROBLEMS

At the beginning of this topic, the eight variables that can influence the amount of physical stress were presented. Figure 5.11 shows eight types of work which may increase physical stress.

![Figure 5.11: Types of work which may increase physical stress](image)
Now, let us take a look at strategies which can be used to solve or reduce ergonomic problems related to the above types of work.

(a) **Seated Repetitive Work with Light Parts**
This type of work can produce more physical stress than one may suspect. Back, neck, shoulder and lower leg pain are commonly associated with this type of work. The fixed work position and repetitive motion can contribute to ergonomic problems. To solve these problems, it may be necessary to modify both the job and the workstation. Improvement strategies are shown in Figure 5.12.

![Figure 5.12: Strategies for seated repetitive work with light parts](image)

(b) **Seated Work with Larger Parts**
This type of work, which involves interacting with objects that may be too large to manipulate manually, is associated with assembly and welding jobs. Problems associated with this type of work are typically related to posture, illumination, reach and lifting. Ergonomic strategies for improving work conditions are presented in Figure 5.13.

![Figure 5.13: Strategies for seated work with larger parts](image)
(c) **Seated Control Work**

This type of work involves sitting in one location and using wheels, levers, knobs, handles and buttons to control a process, system or piece of equipment. The physical stress associated with this type of work is typically the result of excessive vibration or bending and twisting to achieve better visibility. Ergonomic strategies for improving work conditions are listed in Figure 5.14.

![Strategies for Seated Control Work](image)

**Figure 5.14:** Strategies for seated control work

(d) **Standing Work**

This category includes most jobs that are performed while standing. Such jobs do not involve a great deal of repetitive motion but do involve handling medium to heavy materials. An example is a machine operator’s job (lathe, mill, drill, punch, saw, and so on).

Physical stress associated with this type of work includes leg, arm, and back strains. Occasionally, side strains occur when bending and twisting are necessary. Ergonomic strategies for improving work conditions are listed in Figure 5.15.
Standing for Heavy Lifting and Carrying
This type of work involves heavy lifting and moving materials while standing. Lifting and moving may be a relatively small part of the job but are required somewhat regularly. The physical stress most commonly associated with this type of work is back and muscle strains resulting from improper lifting. Falls can also be a problem. Ergonomic strategies for improving work conditions are listed in Figure 5.16.

Figure 5.15: Strategies for standing work

Figure 5.16: Strategies for standing for heavy lifting and carrying
(f) **Work with Hands above the Chest**
This type of work can be done in either a standing or sitting position. It may or may not involve material handling. Physical stress associated with this type of work includes neck, upper body and heart strain. Of these, the potentially most dangerous is heart strain.

Prolonged work with the arms above the shoulder level requires the heart to work harder to pump blood to the elevated areas. Ergonomic strategies for improving work conditions are listed in Figure 5.17.

![Figure 5.17: Strategies for work with hands above the chest](image)

(g) **Work with Hand Tools**
All of the types of work presented in this section may involve the use of hand tools to some extent. However, because hand tools introduce a variety of potential hazards that are indigenous to their use, they are best examined as a separate work type. Physical stress associated most commonly with the use of hand tools includes carpal tunnel syndrome (CTS) and muscle strains of the lower arm, hand and wrist. Ergonomic strategies for improving the work conditions focus primarily on improving hand positions during the use of tools, enhancing the worker’s grip on tools, and minimising the amount of twisting involved. Figure 5.18 presents some of these strategies.
(h) **Work with Video Display Terminals (VDTs)**

The video display terminal is now the most widely used piece of office equipment. In Figure 5.19, there are some strategies that can be used to reduce the hazards associated with VDTs.
## Strategies for Work with Video Display Terminals (VDTs)

- Arrange the keyboard properly. It should be located in front of the user, not to the side. Body posture and the angle formed by the arms are critical factors.

- Adjust the height of the desk. Taller employees often have trouble working at average height desks. Raising the desk with wooden blocks can solve this problem.

- Adjust the tilt of the keyboard. The rear portion of the keyboard should be higher than the front.

- Encourage employees to use a soft touch on the keyboard and when clicking a mouse. A hard touch increases the likelihood of injury.

- Encourage employees to avoid wrist resting. Resting the wrist on any type of edge can increase pressure on the wrist.

- Place the mouse within easy reach. Extending the arm to its full reach increases the likelihood of injury.

- Remove dust from the mouse ball cavity. Dust can collect, making it difficult to move the mouse. Blowing out accumulated dust once a week will keep the mouse easy to manipulate.

- Locate the VDT at a proper height and distance. The VDT's height should be such that the top line on the screen is slightly below eye level. The optimum distance between the VDT and user will vary from employee to employee, but it will usually be between 40cm and 81cm (16 and 32 inches).

- Minimise glare. Glare from a VDT can cause employees to adopt harmful postures. Changing the location of the VDT, using a screen hood, and closing or adjusting blinds and shades can minimise glare.

- Reduce lighting levels. Reducing the lighting level in the area immediately around the VDT can eliminate vision strain.

- Dust the VDT screen. VDT screens are magnets to dust. Built-up dust can make the screen difficult to read, contributing to eye strain.

- Eliminate telephone cradling. Cradling a telephone receiver between an uplifted shoulder and the neck while typing can cause a painful disorder called cervical radiculopathy (compression of the cervical vertebrae in the neck). Employees who need to talk on the telephone while typing should wear a headphone.

- Require typing breaks. Continuous typing for extended periods should be avoided. Repetitive strain injuries are cumulative. Breaking up the repetitive motion in question at least 15 minutes every two hours can help prevent the accumulation of strain.

---

**Figure 5.19:** Strategies for work with VDTs
Figure 5.20 illustrates the proper way of sitting in front of a computer.

**Figure 5.20:** The proper way of sitting in front of a computer

**ACTIVITY 5.4**

Briefly explain a strategy that can be used to overcome ergonomic problems related to two work postures of your choice.

**SUMMARY**

- Ergonomics is important to ensure the quality of life of workers, prevent productivity from declining and enhance work performance.

- It takes some time for workers who are exposed to illnesses due to inappropriate workstations, work processes and work equipment to realise that they have actually fallen ill.
• Employers must take proactive measures and implement ergonomics programmes to educate workers on ways to overcome ergonomic risks, and provide suitable workstations, equipment and processes.

### KEY TERMS

<table>
<thead>
<tr>
<th>Cumulative Trauma Disorders (CTDs)</th>
<th>Stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ergonomics</td>
<td>Surface contact</td>
</tr>
<tr>
<td>Horizontal work area</td>
<td>Tool design</td>
</tr>
<tr>
<td>Mobile</td>
<td>Vertical work area</td>
</tr>
<tr>
<td>Posture</td>
<td>Workstation design</td>
</tr>
<tr>
<td>Physical stress</td>
<td>Work methods</td>
</tr>
<tr>
<td>Repetitive</td>
<td></td>
</tr>
</tbody>
</table>

### SELF-TEST 1

**Essay Questions**

1. Explain briefly the meaning of ergonomics.

2. Explain briefly three common indicators of ergonomic problems in organisations.

### SELF-TEST 2

**Multiple Choice Questions**

1. Which among the following is **NOT** an indicator of an ergonomic problem?
   a. High rate of absenteeism
   b. Low turnover rate
   c. Complaints from workers
   d. Apparent trends in accidents and injuries
2. Musculoskeletal injuries increase when workers are involved in the following activities EXCEPT:
   A. Lifting big objects
   B. Lifting heavy objects
   C. Frequent lifting
   D. Lifting object from tables

3. The process of identifying specific ergonomic problems is as follows EXCEPT:
   A. Observation
   B. Interview
   C. Adapting the worker to the job
   D. Measuring the work environment

4. The following activities are engineering controls to prevent ergonomic problems EXCEPT:
   A. Workstation design
   B. Selection of hand tools
   C. Health surveillance
   D. Work process design

5. Strategies to overcome ergonomic problems for seated repetitive work are the following EXCEPT:
   A. Adjust workstation height
   B. Repetitive task
   C. Rotation of work
   D. Space for the legs

True (T) or False (F) Statements

1. The ergonomics principles involve the work system, sports, health and safety.
2. Workers must adjust themselves to the workstation and work process.
3. Standing posture is found not to cause ergonomic stress to workers.
4. A good flat workstation requires workers to bend a lot.
Essay Questions

1. Explain briefly three strategies which can be used to reduce ergonomic stress when lifting and removing a heavy object.

2. Explain briefly four prevention and control strategies for ergonomic problems.
Industrial hygiene in the safety and health profession is concerned with predicting, recognising, assessing, controlling, and preventing environmental stressors in the workplace that can cause sickness or serious discomfort to workers. The common stressors that result in illness and discomfort include gases, fumes, vapours, dusts, mists, noise and radiation.

This topic will discuss issues related to industrial hygiene at the workplace such as hazard recognition, and hazard prevention and control, in order to reduce accident risks at the workplace.
6.1 HAZARDS AT THE WORKPLACE

Industrial hygiene is a discipline which studies the relationship between environmental stressors in the workplace that affect the safety and health of workers. These environmental stressors can be divided into four broad categories, as listed below:

(a) Chemical hazards;
(b) Physical hazards;
(c) Biological hazards; and
(d) Ergonomic hazards.

Table 6.1 explains briefly the four categories of hazards.

<table>
<thead>
<tr>
<th>No.</th>
<th>Category</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chemical Hazards</td>
<td>Chemical compounds in solid, liquid or gaseous forms, such as mists, vapours, sprays, powders, gases, dusts and fumes.</td>
</tr>
<tr>
<td>2.</td>
<td>Physical Hazards</td>
<td>Physical hazards include noise, vibrations, extremes of temperature and excessive radiation (electromagnetic or ionising).</td>
</tr>
<tr>
<td>3.</td>
<td>Biological Hazards</td>
<td>Threats from living organisms such as moulds, fungi, bacteria and insects.</td>
</tr>
<tr>
<td>4.</td>
<td>Ergonomic Hazards</td>
<td>These are related to the design and condition of the workplace (see Topic 5).</td>
</tr>
</tbody>
</table>

This topic will focus primarily on the first category, i.e. hazards caused by chemical substances. In our daily lives, we use a wide range of chemical substances – some of which are highly beneficial while others may have negative effects if used improperly. In some cases, abuse of chemical compounds or any mishandling may lead to workplace accidents.

The issue of AIDS (Acquired Immune Deficiency Syndrome) will also be discussed in this topic, as it is a type of disease caused by biological hazards that may create unsafe work conditions if left unchecked.
DEFINITION OF CHEMICAL SUBSTANCES

The discipline that studies whether a chemical compound is toxic or non-toxic to humans is known as toxicology. A person can be exposed to toxic substances in two possible scenarios: at work, or outside work hours.

The toxicity of a chemical substance, once it enters the human body, will depend on the following five factors:

(a) Chemical properties of the substance;
(b) Amount of the dose;
(c) Level of exposure to the substance;
(d) Route of entry into the human body; and
(e) Level of body resistance such as the immune system and detoxification ability of the human body.

In Malaysia, the Government enacted the Occupational Safety and Health Regulations (Classification, Packaging and Labelling of Hazardous Chemicals), 1997 under the Occupational Safety and Health Act 1994, to control and prevent chemical hazards at the workplace. The regulation specifies, among others, that suppliers of chemical substances are responsible for:

(a) Classifying such substances according to a standard method of classification;
(b) Packing and storing them in a proper manner;
(c) Labelling the chemical substances supplied;
(d) Providing clearly visible and readable information on the packing of such substances; and
(e) Placing of hazard symbols and signs as well as risk and safety phrases to warn people of their possible threats.
6.2.1 Entry Points of Toxic Agents

Before learning about how to protect against chemical hazards, we must first learn how toxic agents can enter the human body. There are four routes of entry for toxic agents:

(a) Inhalation;
(b) Skin absorption;
(c) Injection; and
(d) Ingestion.

Table 6.2 gives some explanation on the four routes of entry for toxic agents.

Table 6.2: The Four Routes of Entry for Toxic Agents to Enter the Human Body

<table>
<thead>
<tr>
<th>Route of Entry</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhalation</td>
<td>Safety and health professionals are most concerned with this route of entry. Airborne toxic substances such as gases, vapours, dust, smoke, fumes, aerosols, and mists can be inhaled and pass through the nose, throat, bronchial tubes, and lungs to enter the bloodstream. The amount of a toxic substance that can be inhaled depends on the concentration of the substance, duration of exposure, and breathing volume.</td>
</tr>
<tr>
<td>Absorption</td>
<td>The second most common route of entry in an industrial setting is absorption, or passage through the skin and into the bloodstream. The human skin is a protective barrier against many hazards. However, certain toxic agents can penetrate the barrier and enter the bloodstream directly. Of course, unprotected cuts, sores, and abrasions facilitate the process of penetration, but even healthy skin will absorb certain chemicals. Skin absorption depends on four main factors: molecular size of the chemical compound, degree of ionisation, aqueous (water) solubility, and lipid (fat) solubility.</td>
</tr>
<tr>
<td>Injection</td>
<td>Injection involves the introduction of a substance into the body by way of a needle and syringe, compressed air, high-pressure hydraulic leaks, or any other capable medium. However, this is not a common route of entry for a toxic substance at the workplace. Injection may be one method to experiment the effects of new compounds on animals, e.g. in medical research. However, due to human negligence, accidental injection to humans might occur, although the possibility is remote.</td>
</tr>
</tbody>
</table>
Ingestion, which is entry through the mouth (i.e. swallowing), is not a major concern in an industrial setting. An ingested substance moves through the stomach into the intestines and from there, into the bloodstream. Toxic agents sometimes enter the body by ingesting foods that are already polluted or contaminated with such substances. Airborne contaminants can also rest on food or the hands and, as a result, be ingested during a meal or snack. The possibility of ingesting toxic agents makes it critical to confine eating and drinking to sanitary areas away from the work site and to make sure that workers practise good personal hygiene such as washing their hands thoroughly before eating or drinking.

As the toxic substance moves through the gastrointestinal tract, its toxicity may be diluted. In addition, depending on the amount and toxicity of the substance, the liver may be able to convert it to a non-toxic substance through a process called detoxification. At least, the liver can help decrease its level of toxicity and the substance may be removed by the kidneys in the form of urine.

### 6.3 EFFECTS OF TOXIC SUBSTANCES ON HEALTH

The effects of toxic substances vary widely, as do the substances themselves. However, all of the various effects and exposure times can be categorised as shown in Table 6.3.

**Table 6.3: Types of Effects from Toxic Substances**

<table>
<thead>
<tr>
<th>Category</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Effects</td>
<td>Acute effects involve a sudden dose of a highly concentrated substance. These exposures result in an immediate health problem ranging from irritation to death.</td>
</tr>
<tr>
<td>Chronic Effects</td>
<td>Chronic effects involve limited continual exposure over time. Consequently, the associated health problems develop slowly. Most victims will suffer tissue damage or serious injuries.</td>
</tr>
</tbody>
</table>
There are four prevention and control strategies which can be taken to develop a programme for workplace industrial hygiene. These are shown in Table 6.4.

Table 6.4: Prevention and Control Strategies to Develop a Prevention and Control Programme for Workplace Industrial Hygiene

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Control</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Engineering Controls</td>
<td>The category of engineering controls includes such strategies as replacing a toxic material with one that is less hazardous, redesigning a process to make it less stressful and reducing to reduce exposure to hazardous materials or conditions. Other engineering controls include isolating a hazardous process to reduce the number of people exposed to it and introducing moisture to reduce airborne dust.</td>
</tr>
<tr>
<td>2.</td>
<td>Ventilation</td>
<td>Exhaust ventilation involves trapping and removing contaminants from the air. This type of ventilation is typically used with such processes as abrasive blasting, grinding, polishing, buffing, spray painting and finishing. Dilution ventilation involves simultaneously removing and adding air to dilute contaminants to acceptable levels.</td>
</tr>
<tr>
<td>3.</td>
<td>Personal Protection from Hazards</td>
<td>When the work environment cannot be made safe by any other method, personal protective equipment (PPE) is used as a last resort. Typical equipment includes safety goggles, face shields, gloves, boots, earmuffs, earplugs, full-body clothing, barrier creams, and respirators.</td>
</tr>
<tr>
<td>4.</td>
<td>Administrative Controls</td>
<td>Administrative controls involve limiting the exposure of employees to hazardous conditions using such strategies as rotating schedules, enforced breaks, work shifts, and other schedule-oriented strategies.</td>
</tr>
</tbody>
</table>

Visit http://www.emedice.com/emerg.htm for information on the effects of exposure to toxic substances categorised as chronic and acute.
Apart from the strategies given in Table 6.4, additional strategies to reduce toxic hazards are:

(a) Practising good housekeeping, including workplace cleanliness.
(b) Using special control methods for specific hazards.
(c) Setting up medical programmes to detect intake of toxic materials.
(d) Providing training and education for workers.

Hazard prevention and control programmes will only succeed if the workers participate in these programmes and observe all procedures and regulations set by their employers. One of the best ways to protect employees from workplace hazards is to teach them to protect themselves and carry out their task in a safe manner in order to reduce the risks of accidents.

6.5 OCCUPATIONAL ISSUES: AIDS AT THE WORKPLACE

AIDS (Acquired Immune Deficiency Syndrome) is a condition caused by the virus known as HIV (Human Immunodeficiency Virus). HIV is a virus that attacks the human immune system, specifically the white blood cells which guard the body against infection. The white blood cells include a lymphocyte, in particular, the CD-4 cell. When the immune system is infected by HIV, its ability to defend the human body against infections becomes weak, so much so that even normal diseases that are not dangerous to a healthy person can be life-threatening to an AIDS patient.

HIV is found in bodily fluids of an infected person, such as seminal and vaginal fluids, and blood. It is transmitted through direct blood contact including blood transfusion, blood products, and HIV-infected organ transplants. HIV can only spread once it has entered into the bloodstream of humans. HIV can be transmitted to others through certain ways regardless of race, sex, religion or sexual orientation. However, HIV may remain in the body of an infected person without showing clear signs of AIDS, which is the full-blown disease caused by HIV.

A person may be infected by HIV through the following ways:

(a) Having sexual intercourse with an HIV-infected person without wearing a condom, through blood transfusion or infected blood materials.

(b) From a pregnant mother infected by HIV to her baby.
(c) Through sharp objects such as syringe needles, medical equipment and tattoo needles.

(d) Receiving piercing services at public places by sharing the same needle.

AIDS at the workplace is a serious issue. It will result in a decline of work productivity. AIDS has a great impact on workers especially those who are considered the main source of income for their dependants. Furthermore, AIDS affects the financial position of a company and indirectly threatens the country’s economy.

Those working in environments that are exposed to infected blood, such as hospital workers attending to AIDS patients, face the risk of contracting AIDS. When a person’s skin or mucous membranes get in contact with the blood or bodily fluids of an HIV-infected patient, he or she can be infected with the disease.

Apart from that, needles and sharp objects such as needle syringes, tattoo needles and shaving razors which have been infected by the blood of an HIV worker may cause another worker to contract the disease at the workplace unknowingly.

In other words, AIDS at the workplace is a serious issue which must not be neglected. The relevant authorities must make an effort and collaborate to solve this problem by taking the necessary actions. Understandably, AIDS is a terrible disease that brings much social stigma. AIDS patients are unfairly shunned by the public or even despised, in the belief that they contracted the disease through immoral ways. Such discrimination should never be encouraged. In addition, we must show our love and compassion to AIDS patients so that they can live their lives with dignity and a sense of well-being.

### 6.5.1 The Relationship Between AIDS and Cost

AIDS, which causes workers to suffer and die (as there is no cure), is a threat to employers because it will increase costs and reduce revenues.

Employers’ revenues will decrease due to absenteeism of workers who are suffering from AIDS; or workers taking time off to attend the funeral of colleagues who died of AIDS; or the time spent to train and develop workers. The company may bring in new workers to replace those who have left or deceased, but these newcomers are less experienced and thus will not be able to reach the same level of productivity as before.
However, the relationship between HIV/AIDS, cost and revenue is not given due attention by employers nowadays. In the long run, these organisations will experience a decline in profits for not taking proactive actions to anticipate and avoid the effects of HIV/AIDS.

Figure 6.1 illustrates the negative effects of AIDS on organisations.

![Figure 6.1: The negative effects of AIDS at the workplace](source)


Employment sectors that are more likely to encounter AIDS-related problems are those requiring workers to travel away from home for long periods to conduct business affairs. Some of these include the transportation, mining and fishery sectors.

Business sectors which are seasonal, such as agriculture and tourism, are also affected by the disease. Other sectors such as health care, engineering and bio medics depend heavily on highly skilled professionals whose job responsibilities may affect many others working under them. Thus, if these experts fall victims to AIDS, it is possible that entire operations within the organisation may be crippled if no contingencies have been planned.
6.5.2 **Measures Taken by Employers to Overcome AIDS Problems among Workers**

The key element in solving the AIDS problems at the workplace is the employer. He must play the crucial role to protect his workplace by implementing several programmes or measures.

Preventive programmes, medical services and social support are among the chief efforts that must be implemented. Examples of HIV/AIDS programmes at the workplace are the following:

- HIV/AIDS motivation programmes
- Prevention and training activities
- Communication programmes between healthy workers and HIV-Positive workers
- Medical assistance and social support programmes

(a) **HIV/AIDS Motivation Programmes**

Employers must motivate their staff and workers in order to boost their morale and productivity, and not be excessively affected emotionally by the presence of HIV threats.

Discrimination must not occur. Employers must not dismiss their HIV-positive workers or neglect their welfare and well-being.

Employers must also create awareness among their healthy workers so that they will not isolate other workers who are suffering from HIV/AIDS. They must also be aware of the ways in which HIV is transmitted, and be enlightened that the disease is not communicable so long as they do not come into contact with bodily fluids from infected persons.

(b) **Prevention and Training Activities**

Employers must make suitable arrangements in the workplace for HIV-positive workers so that they will not feel humiliated or isolated. Supervision and training for HIV-positive workers must be carried out continually in order to prevent unnecessary problems such as interpersonal conflict, lowered performance and so on.

Training programmes are highly important and must be implemented continually in order to increase the productivity of workers, and protect not only the interest of the organisation but also the workers.
(c) **Communication Programmes between Healthy Workers and HIV-Positive Workers**

Employers must eliminate the negative perception among healthy workers towards HIV-positive staff members, change their attitudes and allay their unfounded fears.

A campaign to do so must be given high priority, with a clear focus on its target and strategy. Its approach should neither leave workers confused about AIDS nor sew more fear among the workforce. AIDS education must be inculcated among all members of the organisation so that collaboration carries on as before, and operations continue smoothly. Communication is key in raising awareness about this disease.

If the campaign is effective, good relations between healthy workers and HIV-positive workers will be established at the workplace, hence motivating HIV-positive workers and making them feel that they are not being isolated.

Those who suffer from HIV/AIDS must be appreciated so that they will not feel stressed at the workplace. Cooperating with them might help them in their struggle to fight HIV/AIDS at the workplace and in the society.

(d) **Medical Assistance and Social Support Programmes**

Medical assistance can help lessen the burden carried by HIV-positive workers. Social support is also another very important aspect, as it ensures the smooth flow of work and allows HIV/AIDS workers to work comfortably. Figure 6.2 shows a patient receiving medical attention at a hospital.

![Figure 6.2: A patient receiving medical attention at a hospital](image)
Employers must take great care of their workers by providing counselling services, not discriminating against them, and giving them hope to continue living and working normally.

They must always try to motivate them in all ways, lift their spirits and increase the morale of both patients as well as non-patients. Ensure there is good communication between normal workers and HIV-positive workers, and that they treat one another as normal human beings.

Furthermore, managers must take the initiative to draw up flexible work schedules to ease their workers’ tasks. They must also be granted medical leave as necessary to seek medical attention. Other initiatives include creating wide task structures, assistance programmes that provide counselling services, and educational seminars on HIV/AIDS awareness.

No cure has been found yet for AIDS. The best step forward is to prevent it. Employers must pay more attention to their workers so that they are not unduly exposed to the disease, particularly those working in the medical sector where they face a higher risk of contracting HIV.

Employers must provide AIDS patients with new opportunities and hope by recruiting them. Meanwhile normal workers must be educated and informed that they will not be infected with HIV simply by working together with these patients as this disease is not transmitted through casual contact.

Employers must also take precautionary steps at the workplace to protect normal workers. They must provide special facilities for HIV-positive workers to enable them to receive treatment at appointed times, and provide financial assistance for those in need. Normal workers must respect the feelings of HIV-positive workers and accept them as human beings regardless of their condition.

In conclusion, HIV-positive workers must be given a second chance to live their lives while the community must accept them and give them the strength they need to be a part of the community.
Economic progress has given rise to higher demands for goods and services.

Manufacturing, among other sectors, has therefore seen much development in the range of products made, the methods to produce them, and new, related services.

Nevertheless, this development has created new hazards and increased accident risks.

The greater risk has in turn increased the need for hygiene experts.

However, accidents can never be prevented if employers do not develop prevention and control programmes, and receive the cooperation of their employees to ensure success.

### KEY TERMS

- Absorption
- Biological hazard
- Chemical hazard
- Ergonomic hazard
- Industrial hygiene
- Ingestion
- Injection
- Inhalation
- Physical hazard
- Toxic substances

### SELF-TEST 1

**Essay Questions**

1. Give one example of an occupation that involves vibration hazards.

2. Explain briefly how training can reduce workers’ exposure to toxic substances at the workplace.
3. List the factors that might influence the toxic effects of a substance on human beings.

4. Explain the basic strategies to prevent and control toxic hazards at the workplace.

5. State the strategies which can be implemented by employers to overcome the problem of AIDS at the workplace.

**SELF-TEST 2**

**True (T) or False (F) Statements**

1. Toxic substances have a negative effect on health if they enter the human body.

2. Chronic effects involve the consumption of a fatal dose of a highly concentrated toxic substance.

3. Most chemical and toxic substances used in the manufacturing sector are highly flammable.

4. HIV/AIDS is a health problem which has an effect on the field of occupational safety and health.

5. Each workplace needs an industrial hygiene specialist.

6. Engineering controls involve the use of personal protective equipment.

7. Medical doctors have a high risk of being infected with HIV.
Introduction

As the term suggests, mechanical hazards are associated with power-driven machines, whether automated or manually operated. Concerns about mechanical hazards date back to the Industrial Revolution and the earliest days of mechanisation.

Machines – whether driven by steam, hydraulic or electric power – introduced new hazards into the workplace. In spite of advances in safeguarding technologies and techniques, mechanical hazards are still major concerns today. In addition, the advent of automated machines has also brought fresh concerns about workplace safety.

7.1 Common Mechanical Injuries

In an industrial setting, people operate machines that are designed to drill, cut, shear, punch, chip, staple, stitch, abrade, shape, stamp, and slit materials such as metals, composites, plastics and elastomers. These processes are purely mechanical; they cause material to be deformed or broken into smaller pieces. If
appropriate safeguards are not in place or if the operators themselves fail to follow safety precautions, they may be hurt by these machines. Common mechanical injuries are illustrated in Figure 7.1.

![Figure 7.1: Common mechanical injuries](image)

### 7.1.1 Wound and Tearing

A cut occurs when our skin suddenly comes into contact with a sharp edge. Tearing implies further opening of a cut through strong forces. The human body’s skin consists of the epidermis, which is the tough outer covering; the dermis, which is the thick part beneath the epidermis; the capillaries, which are the tiny blood vessels that branch off from small arteries and veins, in the dermis; the veins which are the blood vessels that collect blood from the capillaries and return it to the heart; and the arteries, which are the larger vessels that carry blood from the heart to the capillaries in the skin. Deeper down below the skin are the muscle tissues which wrap around the bones. How serious is a cut or tear depends on how much damage is done to the skin, veins, arteries, muscles, and even bones.

### 7.1.2 Shearing

To understand what shearing means, imagine using a paper cutter. Power-driven shears for cutting paper, metal, plastic, elastomers, and composite materials are dangerous because of their extreme cutting properties. However, they are widely used in manufacturing for cutting various materials to different sizes.
You must have heard of, or read news reports about, how such machines often amputated fingers and hands of careless workers. Such tragedies typically occurred when the operators reached under the shearing blade to make an adjustment or placed materials there and accidentally activated the blade before fully removing their hands.

### 7.1.3 Crushing

Injuries from crushing can be particularly debilitating, painful and difficult to heal. They occur when a part of the body is caught between two hard surfaces that progressively move together, thereby crushing anything between them. Crushing hazards can be divided into two categories: squeeze-point types and run-in points. Explanation on these two categories is presented in Table 7.1.

**Table 7.1: Types of Crushing Hazards**

<table>
<thead>
<tr>
<th>Squeeze-point Hazards</th>
<th>Squeeze-point hazards exist where two hard surfaces, at least one of which must be in motion, close in together to crush any object that may be between them.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run-in point Hazards</td>
<td>Run-in point hazards exist where two objects, at least one of which is rotating, come progressively closer together. Any gap between them need not become completely closed. It needs only to be smaller than the width of the object or body part to be lodged in it. Meshing gears and belt pulleys are examples of run-in point hazards.</td>
</tr>
</tbody>
</table>

### 7.1.4 Fracture

Machines used to deform raw materials such as wood and steel in factories can easily break human bones. A break in the bone is known as a fracture. Fractures are classified as:

(a) Simple;
(b) Compound;
(c) Complete; and
(d) Incomplete.
To help you understand these types of fractures, refer to Table 7.2.

<table>
<thead>
<tr>
<th>Type of Fracture</th>
<th>Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Fracture</td>
<td>A break in a bone that does not pierce the skin.</td>
</tr>
<tr>
<td>Compound Fracture</td>
<td>A break that has broken through the surrounding tissue and skin.</td>
</tr>
<tr>
<td>Complete Fracture</td>
<td>Divides the affected bone into two or more separate pieces.</td>
</tr>
<tr>
<td>Incomplete Fracture</td>
<td>Leaves the affected bone in one piece but cracked.</td>
</tr>
</tbody>
</table>

Other types of fractures include transverse fracture, oblique fracture and comminute fracture. A transverse fracture is a break at right angles to the axis of the bone, while an oblique fracture is diagonal. Comminate fracture, on the other hand, occurs when the bone is broken into a number of small pieces at the point of fracture.

### 7.1.5 Straining and Spraining

There are numerous situations in an industrial setting when straining of muscles or spraining of ligaments is possible. A strain results when muscles are overstretched or torn. A sprain is the result of torn ligaments in a joint. Strains and sprains can cause swelling and intense pain.

### 7.1.6 Puncturing

Punching machines that have sharp tools can puncture a body part if safety precautions are not observed or if appropriate safeguards are not in place. Puncturing results when an object penetrates straight into the body and pulls straight out, creating a wound in the shape of the piercing object. The greatest risk with puncture wounds is causing damage to internal organs.

**ACTIVITY 7.1**

Why are mechanical accidents considered serious?


7.2 SAFEGUARDS

Modern machinery has various mechanisms that can rotate, reciprocate, or do both. You can find many types of tools, bits, chucks, blades, spokes, screws, gears, shafts, belts, and a huge variety of other equipment for manufacturing products. Certainly, safeguards have to be devised to protect workers from coming into contact with such mechanisms while at the same time allowing work to progress at a productive rate. The National Safety Council in the US has established the following requirements for safeguards (Figure 7.2).

![Figure 7.2: Requirements for safeguards](image)

(a) **Prevent Contact**
Safeguards would prevent human contact with any potentially harmful machine part. The prevention extends to machine operators and any other person who may need to do so, e.g. the technician or service engineer.

(b) **Secure and Durable**
Safeguards should be firmly attached so that they are secure. This means that workers cannot render them ineffective by tampering with or disabling them. This is critical because removing safeguards in an attempt to speed up production is a common practice. This should not be encouraged at the expense of work safety. Safeguards must also be durable enough to withstand the rigours of the workplace. Worn-out safeguards will become less effective over time in protecting workers properly.
(c) **Protect against Falling Objects**
Objects falling onto moving machine mechanisms increase the risk of accidents, property damage and injury. Objects that fall on a moving part can be quickly hurled out, creating a dangerous projectile. Therefore, safeguards must do more than just prevent human contact. They must also shield the moving parts of machines from falling objects.

(d) **Create No New Hazard**
Safeguards should overcome the hazards in question without creating new ones. For example, a safeguard with a sharp edge, unfinished surface, or protruding bolts introduces new hazards while protecting against the old.

(e) **Create No Interference**
Safeguards can interfere with the progress of work if they are not properly designed. Such safeguards are likely to be disregarded or disabled by workers who find such safeguards a nuisance rather than a safety feature.

(f) **Allow Safe Maintenance**
Safeguards should be designed to allow frequently performed maintenance tasks (e.g., lubrication) to be accomplished without removing them.

(g) **Construction of Safeguards**
Design and construction of safeguards are highly specialised activities requiring a strong working knowledge of machines, production techniques and safety. However, it is critical that all of the factors explained in this section be considered and accommodated during the design process.

### 7.2.1 Point-of-Operation Guards
Safeguards are most effective when used at the point of operation, which is where hazards to humans exist. Point-of-operation hazards are those caused by the shearing, cutting, or bending motions of a machine. Pinch-point hazards result from guiding material into a machine or transferring motion (e.g., from gears, pressure rollers, or chains and sprockets). Single-purpose safeguards, because they guard against only one hazard, typically are permanently fixed and non-adjustable. Multiple-purpose safeguards, which guard against more than one hazard, typically are adjustable.
There are three types of point-of-operation guards: fixed, interlocked and adjustable as shown in Table 7.3. Each has its own advantages and limitations.

### Table 7.3: The Three Types of Point-of-Operation Guards

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Guard</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fixed guards</td>
<td>Fixed guards provide a permanent barrier between workers and the point of operation. They offer the following advantages: They are suitable for many specific applications, can be constructed in-plant, require little maintenance and are suitable for high-production, repetitive operations. Limitations include the following: They sometimes limit visibility, are often limited to specific operations, and sometimes inhibit normal cleaning and maintenance.</td>
</tr>
<tr>
<td>2.</td>
<td>Interlocked guards</td>
<td>Interlocked guards shut down the machine when the guard is not securely in place or is disengaged. The main advantage of this type of guard is that it allows safe access to the machine for removing jams or conducting routine maintenance without the need for taking off the guard. There are also limitations. Interlocked guards require careful adjustment and maintenance and, in some cases, can be easily disengaged.</td>
</tr>
<tr>
<td>3.</td>
<td>Adjustable guards</td>
<td>Adjustable guards provide a barrier against a variety of different hazards associated with different production operations. They have the advantage of flexibility. However, they do not provide as dependable a barrier as other guards do, and they require frequent maintenance and careful adjustment.</td>
</tr>
</tbody>
</table>

#### 7.2.2 Point-of-Operation Devices

A number of different point-of-operation devices can be used to protect workers. The six most widely used are explained in Table 7.4.

- (a) Photoelectric devices;
- (b) Radio-frequency devices;
- (c) Electromechanical devices;
- (d) Pullback devices;
- (e) Restraint devices; and
- (f) Two-hand controls.
### Table 7.4: The Six Point-of-Operation Devices

<table>
<thead>
<tr>
<th>No.</th>
<th>Point-of-Operation Device</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Photoelectric devices</strong></td>
<td>Photoelectric devices are optical devices that shut down the machine whenever the light beam is broken. These devices allow operators relatively free movement. They have limitations, including the following: They do not protect against mechanical failure, they require frequent calibration, and they can be used only with machines that can be stopped.</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Radio-frequency devices</strong></td>
<td>Radio-frequency devices are capacitance devices that brake or quickly slow down the machine if the capacitance field is interrupted by a worker’s body or another object. These devices have the same limitations as photoelectric devices.</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Electromechanical devices</strong></td>
<td>Electromechanical devices are contact bars that allow only a specified amount of movement between the worker and the machine. If the worker moves the contact bar beyond a specified point, the machine will not work. These devices have the limitation of requiring frequent maintenance and careful adjustment.</td>
</tr>
<tr>
<td>4.</td>
<td><strong>Pullback devices</strong></td>
<td>Pullback devices pull the operator’s hands out of the danger zone when the machine starts to operate. These devices eliminate the need for auxiliary barriers. However, they also have limitations. They limit operator movement, must be adjusted for each individual operator, and require close supervision to ensure proper use.</td>
</tr>
<tr>
<td>5.</td>
<td><strong>Restraint devices</strong></td>
<td>Restraint devices hold the operator back from the danger zone. They work well, with little risk of mechanical failure. However, they do limit the operator’s movement, must be adjusted for each individual operator, and require close supervision to ensure proper use.</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Two-hand controls</strong></td>
<td>Two-hand controls require the operator to use both hands concurrently to activate the machine (e.g., a paper cutter or metal-shearing machine). This ensures that his hands cannot stray into the danger zone. Although these controls do an excellent job of protecting the operator, they do not protect onlookers or passers-by. In addition, some two-hand controls can be tampered with and made operable using only one hand to save time.</td>
</tr>
</tbody>
</table>
7.2.3 Feeding and Ejection System

Feeding and ejection systems can be effective safeguards if properly designed and used. There are four types of feeding and ejection systems available for use with modern industrial machines, as summarised in Table 7.5.

(a) Automatic feed systems;
(b) Semi-automatic feed systems;
(c) Automatic ejection systems; and
(d) Semi-automatic ejection systems.

Table 7.5: The Four Types of Feeding and Ejection Systems

<table>
<thead>
<tr>
<th>No.</th>
<th>Feeding and Ejection System</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Automatic Feed Systems</td>
<td>Automatic feed systems feed stock to the machine from rolls. Automatic feeds eliminate the need for operators to enter the danger zone. Such systems are limited in the types and variations of stock that they can feed. They also typically require an auxiliary barrier guard and frequent maintenance.</td>
</tr>
<tr>
<td>2.</td>
<td>Semi-automatic Feed Systems</td>
<td>Semi-automatic feed systems use a variety of approaches for feeding stock to the machine. Prominent among these are chutes, movable dies, dial feeds, plungers, and sliding bolsters. They have the same advantages and limitations as automatic feed systems.</td>
</tr>
<tr>
<td>3.</td>
<td>Automatic Ejection Systems</td>
<td>Automatic ejection systems eject the work pneumatically or mechanically. The advantage of either approach is that operators do not have to reach into the danger zone to retrieve work pieces. However, these systems are restricted to use with relatively small stock. Potential hazards include blown chips or debris and noise. Automatic ejectors can be noisy.</td>
</tr>
<tr>
<td>4.</td>
<td>Semi-automatic Ejection Systems</td>
<td>Semi-automatic ejection systems eject the work using mechanisms that are activated by the operator. Consequently, the operator does not have to reach into the danger zone to retrieve work pieces. These systems do require auxiliary barriers and can be used with a limited variety of stock.</td>
</tr>
</tbody>
</table>
7.2.4 Lockout/Tagout Systems

One of the most effective systems to control hazardous energy today is the tagout system. This method is created to protect people from accidental activation of a machine when it is supposed to be shut. This is very important because OSHA’s statistics show that six percent of workplace deaths are caused by accidental or inadvertent activation of a machine while it is being serviced or repaired.

In the lockout system, a lockout device such as a padlock is placed on an energy-isolating device to prevent the accidental or inadvertent energising of a machine until the padlock is unlocked. The padlock will normally bear the name, department and phone extension of the person in-charge.

The tagout system is similar to the lockout system except that a tag is used instead of a padlock. The tag must only be used when the lockout system cannot be implemented. Sometimes, a tag and a padlock are used together.

SELF-CHECK 7.1

Differentiate between the lockout and tagout systems.

7.3 MECHANICAL HAZARD PREVENTION

The types of safeguards explained in this topic are critical. In addition to these specific safeguards, there are a number of general precautions that apply across the board where machines are used. Some of the more important general precautions are as follows:

(a) All operators should be trained on the safe operation and maintenance of their machines.

(b) All machine operators should be trained in the emergency procedures to take when accidents occur.

(c) All employees should know how to activate emergency shutdown controls. This means knowing where the controls are and how to activate them.

(d) Inspection, maintenance, adjustment, repair and calibration of safeguards should be carried out regularly.
(e) Supervisors should ensure that safeguards are properly in place when machines are in use. Employees who disable or remove safeguards should be disciplined appropriately.

(f) Operator teams (two or more operators) of the same system should be trained on coordination techniques and proper use of devices that prevent premature activation by a team member.

(g) Operators should be trained and supervised to ensure that they dress properly for the job. Long hair, loose clothing, neckties, rings, watches, necklaces, chains and earrings can become caught in equipment and, in turn, pull the employee into the hazard zone.

(h) Shortcuts that violate safety principles and practices should be avoided. Deadline pressures should never be the reason for unsafe work practices.

(i) Other employees who work around machines but do not operate them should be made aware of the emergency procedures to take when an accident occurs.

**SUMMARY**

- Mechanical safety is important and must be addressed consistently with the development of technology worldwide.

- The management must conduct a safety risk analysis on all mechanical equipment installed at their facilities.

- From this analysis, a safety procedure to handle each machine must be developed and made known to all workers.

- This will enable workers to understand how to use the machines safely, hence, reducing the number of mechanical-related accidents.

- Workers must also be exposed to periodical mechanical safety training to ensure that they are able to use mechanical equipment at their workplace safely and correctly.
Crushing
Fracturing
Feeding and ejection system
Lockout/tagout system
Mechanical injuries
Point-of-operation devices

Point-of-operation guards
Puncturing
Shearing
Spraining
Straining
Tearing

Essay Questions
1. List three requirements for safeguards.
2. List three types of point-of-operation guards.
3. Give a brief explanation on three frequently used point-of-operation devices.
4. State briefly how the feeding and ejection systems can be effective safeguards.

True (T) or False (F) Statements
1. Sprains occur due to a tear of joint ligaments.
2. Safeguards are created to protect workers from coming into contact with potentially harmful machine parts.
3. Pinch-point hazards result from guiding material into a machine or transferring motion.
4. Semi-automatic ejection systems require the operator to reach into the danger zone to retrieve work pieces.
5. The outer layer of the human body is the dermis.
6. The lockout/tagout systems are created to protect the accidental activation of a machine which is supposed to be shut down.
Imagine walking in the middle of a city. Look around you. Can you see many high-rise buildings? Have you ever imagined how dreadful it would be if you fell from the top of such a building? Can you imagine the fear felt by construction workers who build these tall buildings?

According to the statistics of the US Labour Department, accidental falls at the workplace cause the highest number of fatalities in the construction sector. Every year, about 150 to 200 workers may sacrifice their lives, while more than 100,000 may be injured, due to falls at construction sites.

This topic presents information that is required by safety and health experts to overcome fall accidents at the workplace. It will also discuss the techniques that can be used to reduce such accidents.

**LEARNING OUTCOMES**

By the end of this topic, you should be able to:

1. Analyse the causes of fall hazards at the workplace;
2. Explain the types of falls at the workplace;
3. Discuss protective equipment which can be used at the workplace; and
4. Evaluate the programmes for the prevention of workplace falls.
8.1 CAUSES OF FALLS

Is pulling the chair away from a person about to sit, and letting him fall, considered a fall hazard? Why? Discuss.

Today’s workplace has many hazards. Most of these hazards may be caused by the workplace itself or by the various types of complex equipment installed at the workplace. It is important to identify the causes of falls as these hazards may cause injuries, leading to temporary or permanent disability. There have also been cases of neck injuries that led to fatalities. Figure 8.1 illustrates the four primary causes of falls at the workplace.

![Diagram of the four primary causes of falls at the workplace]

**Figure 8.1:** The four primary causes of falls at the workplace

### 8.1.1 A Foreign Object on the Walking Surface

Paths are specially designated walkways for workers to walk from one place to another. However, there are workers who like to take “short cuts” to save time. These short cuts – some crossing through areas not meant for walking – may have obtrusive objects laid out that might cause such hurried workers to trip and fall. Moreover, these workers who resort to short cuts normally do not pay close attention to what they walk on or whether they should avoid such obstacles.
Nevertheless, designated walking paths, although usually cleared of obstacles, are not completely free of hazards. The workplace must be neat and well-organised while its walking paths must not have foreign objects lying around or stacked alongside. Among the foreign objects often found on walking surfaces are wires, pipes, stones, sticks, trash such as fruit skins, and so on.

The safety and health officer is responsible for ensuring that the designated paths do not contain foreign objects that may represent a hazard to workers. If a foreign object is placed on the walking surface, it must be clearly marked and labelled so that workers who use the path can notice it. Figure 8.2 illustrates an untidy and unorganised workplace which may cause accidents to workers working in that area.

![Figure 8.2: Untidy and unorganised workplaces may cause accidents to workers working in that area](image)

### 8.1.2 A Design Flaw in the Walking Surface

Walking surfaces must also be free of defects. Sometimes, renovation works may require paths to be dug up. However, the holes left behind after renovation are often not properly covered. If the scale of renovation is massive, the affected area must be marked and sealed off so that people would not use it. Such surfaces under repair increase the risk of a worker slipping or stumbling, and sustaining a fall eventually.
In open areas where there are trees and plants, walkways and pavements may become uneven over time, as a result of roots overgrowing from nearby trees. Such conditions are hazardous to users of these paths, particularly when they are in a hurry. Although these accidents occur outside the working area, they are still within the organisation and it is the organisation’s responsibility to tend to such problems. Figure 8.3 illustrates a defect on a walking surface which may cause accidents to those using it.

![Figure 8.3: A walking surface which is not taken care of properly, may cause accidents to those using it](image)

### 8.1.3 Slippery Surfaces

Soap solutions, chemical cleaning solvents and lubricants are commonly found in workplaces. These materials can bring about a hazardous situation if not used properly. For example, when the floor is being washed using cleaning solvents/chemical materials, the cleaner should put up a sign warning others of wet or slippery floor conditions. The warning sign must be clear and comprehensible. Not putting up such warning signs can cause accidents.

Lubricants are used regularly to repair and maintain machines. However, left on the floor, lubricants are hazardous, since they make the floor extremely slippery. Any walking surface stained with lubricants must be cleaned up as soon as repair works are completed. Failing to clean such surfaces may cause workers to fall. The negligence of a worker can cause the suffering of another. Figure 8.4 illustrates a workplace being cleaned by a cleaner.
Figure 8.4: Cleaning a workplace without putting up a warning sign may cause workers to fall

8.1.4 Individual's Impaired Physical Condition

Age, gender and medical history affect the physical condition of a person. Old workers require walking surfaces with better grip (such as carpets). They also move at a slower pace than young workers. Apart from that, older workers have weaker bones, thus any workplace accidents may cause their bones to fracture easily, unlike their younger counterparts.

If an organisation has more older workers, it should provide walking surfaces with better grip or shoes with high grip designs. Figure 8.5 illustrates a good walking surface provided for workers.

Figure 8.5: Good walking surfaces reduce the risk of accidents
### KINDS OF FALLS

There are four categories of falls, each occurring under different conditions and with different effects. These categories are as shown in Table 8.1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Fall</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 1.  | Trip and fall      | • Trip and fall accidents occur when workers encounter an unseen foreign object in their path. For example, electrical cables are often in the way and might cause an employee's foot to strike them, causing him to trip and fall.  
  • When an uneven walking surface, e.g. where one part is higher than the other, is painted in the same or similar colours, workers might not notice that the surface is uneven. Thus, different colours must be used to distinguish between the different heights. |
| 2.  | Stumble and fall   | • Floors covered with sticky chemical substances may cause workers to stumble and fall. Such accidents may cause back and leg injuries. Spilled syrup and beverages can also cause similar accidents. |
| 3.  | Step and fall      | • Step and fall accidents occur when a person's foot encounters an unexpected hole. Such an accident can cause back and leg injuries.  
  • Drain covers can also cause workers to step and fall if the gaps on the metal cover are too big.  
  • This can also happen when there are too many steps on a staircase; the worker might think he has reached the bottom of the stairs when, in reality, there is one more step to go. |
| 4.  | Slip and fall      | • Slip and fall accidents occur when the worker’s centre of gravity is suddenly thrown out of balance. This can occur when there is an oily spot causing a foot to shoot out from under the worker.  
  • Apart from oil, fruit skins may also cause workers to slip and fall.  
  • Wet walking surfaces, particularly if there is excessive detergent, can cause workers to slip. This is the most common type of fall at the workplace. |
8.3 PROTECTION FROM FALLING OBJECTS

There are several personal protective equipment (PPE) which may be used to minimise fall accidents at the workplace. Employers must assess accident risks and equip workers with PPE to reduce fall accidents.

8.3.1 Head Protection

It is estimated that around 120,000 workers suffer from head injuries every year (Goetsch 2005). The highest accident rates in the Malaysian industrial sector involve falling objects. In fact, some of these accidents occurred in spite of the fact that many victims were wearing their hard hats. This is due to the fact that these hard hats were not worn properly.

The hard hats were originally introduced in 1919 for head protection. These hats are made of thermoplastic polyethylene material. They are designed to protect the head against impact and reduce injuries to the neck and spine. Figure 8.6 illustrates a safety hat widely used by construction workers.

![Figure 8.6: The safety helmet which must be used by construction workers at work](image)

8.3.2 Eye and Face Protection

It is estimated that 80,000 workers suffer injuries to the eyes and face every year (Goetsch 2005). It is the employer’s responsibility to provide safety equipment, first aid facilities and training to the workers in order to cut down on such cases.
There are two types of PPE that protect the eyes and face, i.e. safety glasses/goggles and face shields. These two equipment protect the eyes and face from flying particles. Figure 8.7 illustrates an example of safety equipment which protects the eyes and face of the worker.

Besides providing PPE, employers must also train workers on conditions which require the use of PPE, suitable eye and face shields, correct way of using the PPE and the limitations of PPE.

![Safety equipment](image)

**Figure 8.7:** Safety equipment which shields the eyes and face must be used when doing work using this kind of equipment

### 8.3.3 Foot Protection

It is estimated that about 100,000 workers suffer foot and toe injuries every year (Goetsch 2005). Foot and toe injuries are caused by:

(a) Falls or impact from sharp or heavy objects;
(b) Compression when rolled over by or pressed between heavy objects;
(c) Punctures through the sole of the foot;
(d) Electrical shocks or burns due to high temperatures;
(e) Slips;
(f) Hot liquid or metal splashed into shoes or boots; and
(g) Temperature extremes.
The best safety boots provide all the following types of protection:

(a) Steel toe cover for impact protection;
(b) Rubber or vinyl for chemical protection;
(c) Puncture-resistant soles for protection against sharp objects;
(d) Slip-resistant soles for protection against slippery surfaces; and
(e) Electricity-resistant material for protection from electric shock.

Figure 8.8 illustrates a pair of safety boots which should be used by workers at work.

Figure 8.8: A pair of safety boots which workers, particularly construction workers, should use

8.4 LIFTING HAZARDS

Each year, there are approximately 46,000 cases of back injuries in the workplace (Goetsch 2005). Back injuries are typically caused by improper lifting, reaching, sitting and other ergonomic factors. Therefore, employers must ensure that their workers learn the proper way of lifting heavy objects, so that they do not sustain any back injury.

Secondly, employers must also identify where assistance may be needed for tasks exceeding an individual’s capacity. They must also emphasise the proper way of lifting heavy objects, such as emphasising the use of legs and not the back when lifting a heavy object. Workers must also be encouraged to adopt the pushing method to move heavy objects instead of pulling.
The following are strategies which can be adopted to reduce back injuries:

(a) Display poster illustrations;
(b) Pre-employment screening;
(c) Regular safety inspections;
(d) Education and training; and
(e) Use of external services (consultants).

Figure 8.9: Proper posture and lifting technique must be used when lifting heavy objects in order to prevent back injuries

8.5 FALL PREVENTION PROGRAMME

To ensure the safety of the workplace and to minimise workplace accidents, employers must play an important role in coming up with a fall prevention programme. There are six steps that can be taken to prevent fall hazards. These are shown in Table 8.2.
### Table 8.2: Fall Hazard Prevention Strategies

<table>
<thead>
<tr>
<th>No.</th>
<th>Strategy</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Do Not Be in a Hurry</td>
<td>Workers should work systematically without rushing to catch up on time. Workers must also be aware of their surroundings and identify any falling hazards and report them to the safety and health officer so that further action can be taken.</td>
</tr>
<tr>
<td>2.</td>
<td>Do Not Take Short Cuts</td>
<td>Short cuts have a higher risk of hazards because they often contain foreign objects and are not specified for pedestrians. They might be paths for forklifts and this may endanger workers. If an accident occurs in such places and there are no passers-by, help cannot be provided instantly. Help can only be given when someone discovers the victim.</td>
</tr>
<tr>
<td>3.</td>
<td>Cleaning Spills</td>
<td>Spills have to be cleaned up immediately because failing to do so may create an unsafe situation. If the spill requires complex cleaning techniques, then the place of spillage must be isolated and a warning sign must be put up.</td>
</tr>
<tr>
<td>4.</td>
<td>Lighting</td>
<td>Good lighting can increase visibility which in turn helps workers identify hazards that exist. Workers can then protect themselves or avoid unsafe conditions.</td>
</tr>
<tr>
<td>5.</td>
<td>Scheduled Inspection</td>
<td>Scheduled inspections at the workplace must be conducted to identify and rectify unsafe conditions. Such inspections can be done in teams in order to identify all hazards that exist at the workplace. Meanwhile, workers who discover a hazard must report it to their supervisors or safety and health officer so that further action can be taken.</td>
</tr>
<tr>
<td>6.</td>
<td>Warning Signs</td>
<td>Warning signs must be stationed at places which have been identified as having high risk of fall accidents. Phrases such as “Wet Floor”, “Slippery Floor” or “Use High-traction Footwear” can be used to warn workers during work. The phrases must be clear and legible from afar and in striking colours such as red, yellow and orange. Workers can also be given prior notice about renovations carried out so that they will be more prepared and cautious.</td>
</tr>
</tbody>
</table>

**ACTIVITY 8.2**

Each workplace must be analysed for the possibility of workers being exposed to falling hazards.

The analysis must be conducted for all tasks carried out by workers of the organisation.

At this level, all hazards which have been identified must be listed and their risks assessed.

Apart from that, the organisation must also stress on prevention programmes.

There are two main causes of falling accidents at the workplace: (a) direct cause due to failure to use PPE appropriately and the ineffective use of working platforms; (b) basic cause which includes lack of supervision on high risk tasks, lack of safety procedures which suit the tasks performed, lack of assessment for providing suitable operations, and lack of safety training for workers involving heights.

Therefore, employers must provide safety work procedures according to the task carried out; conduct job hazard analysis and assessments to provide the appropriate operations; provide occupational safety and health training, particularly for tasks involving heights; and conduct optimum supervision during high risk tasks.

**KEY TERMS**

<table>
<thead>
<tr>
<th>Design flaw</th>
<th>Short cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall hazards</td>
<td>Slip</td>
</tr>
<tr>
<td>Foreign objects</td>
<td>Slippery surfaces</td>
</tr>
<tr>
<td>Impaired physical condition</td>
<td>Stumble</td>
</tr>
<tr>
<td>Protective equipment</td>
<td>Trip</td>
</tr>
</tbody>
</table>
Essay Questions

1. List the causes of falls at the workplace.
2. List the kinds of falls at the workplace.
3. Explain briefly three falling hazard prevention programmes at the workplace.
4. State briefly with examples two main causes of falls at the workplace.

True (T) or False (F) Statements

1. According to the US Department of Labour, falling accidents comprise the second highest rate of fatalities in the construction sector.
2. Neck injuries can cause deaths.
3. It is good to use short cuts as it is safe and saves time.
4. Old workers require walking surfaces with less traction so that they would not slip and fall.
5. Falls at the workplace occur when a person loses his balance.
6. Safety hats are made of thermoplastic polyethylene.
7. Pre-employment screening is not a strategy to reduce back injuries.
Part of providing a safe and healthy workplace is appropriately controlling the temperature, humidity, and air distribution in work areas. A work environment in which the temperature is not properly controlled can be uncomfortable. Extremes of either heat or cold can cause more than just discomfort — they can be dangerous.

Understanding the basic concepts of thermal energy is very important in preventing hazards of extreme temperatures. Not knowing or neglecting the preventive measures will result in negative effects such as heat stress and cold stress. Therefore, let us educate ourselves on how to prevent problems caused by heat and temperature hazards.
### 9.1 THERMAL COMFORT

Thermal comfort in the workplace is the result of a number of different factors. Temperature, humidity, air distribution and acclimatisation are all determinants of comfort. To understand fully the hazards posed by temperature extremes, firstly we have to familiarise ourselves with several basic concepts related to thermal energy. Refer to Figure 9.1 to know what these concepts are.

![Figure 9.1: The five basic concepts of thermal energy](image)

Now, refer to Table 9.1 to learn more about these concepts.

**Table 9.1: The Basic Concepts Related to Thermal Energy**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convection</td>
<td>Convection is the transfer of heat from one location to another by way of a moving medium (a gas or a liquid). Convection ovens use this principle to transfer heat from an electrode or heating element by air or gases flowing through the ovens.</td>
</tr>
<tr>
<td>Radiant Heat</td>
<td>Radiant heat is the result of electromagnetic non-ionising energy that is transmitted through space without the movement of matter within that space.</td>
</tr>
<tr>
<td>Environmental Heat</td>
<td>Environmental heat is produced by external sources. Try to think of some sources of environmental heat. Gas or electric heating systems produce environmental heat, as do sources of electricity and a number of industrial processes.</td>
</tr>
<tr>
<td>Metabolic Heat</td>
<td>Metabolic heat is produced within the human body as a result of complex processes that break down food into energy. All humans produce metabolic heat. This is why a room that is comfortable when occupied by just a few people may become uncomfortable when it is crowded. Unless the thermostat is lowered (i.e. to chill the room more) to compensate for the temperature rise, the metabolic heat of a crowd will cause the temperature to rise to an uncomfortable level.</td>
</tr>
</tbody>
</table>
Conduction

Conduction is the transfer of heat between two bodies that are touching or from one location to another within the same body. For example, if an employee touches a metal component that has just been welded, it will feel hot; heat is conducted from the welded end to where the hand touches. Of course, when the hand touches the hotter end, the result of this heat transfer is a burn.

### 9.2 BODY’S RESPONSE TO HEAT

**SELF-CHECK 9.1**

What would happen to your body if your sweat did not evaporate properly?

Now, let us learn about our body’s response to heat. The human body can maintain a balance between the metabolic heat it produces and the environmental heat to which it is exposed. Sweat evaporation is how the body tries to maintain the body temperature. As sweat evaporates, it cools the skin, which in turn brings down the body temperature. This balance is achieved as follows:

\[ H = M + R + C - E \]

where

- \( H \) = body heat
- \( M \) = internal heat (metabolic)
- \( R \) = radiant heat
- \( C \) = conduction
- \( E \) = evaporation

The outcome of this equation is: no additional heat gained, and this is the usual state when we feel comfortable about the temperature around us. Unless the radiant heat, conduction and metabolic heat exceed the heat lost through the process of sweat evaporation, the body will not experience stress or hazards.

When the heat received from any source exceeds the degree of heat lost through sweat evaporation, heat stress will occur.
BODY’S RESPONSE TO COLD

9.3

In your opinion, how can exposure to cold be fatal?

Figure 9.2: Excessive exposure to cold can lead to hypothermia

Why is excessive exposure to cold considered dangerous for the human body? One of the effects of extreme cold is hypothermia, a condition where one’s body temperature drops to very low levels, weakening the muscles and adversely affecting brain functions. Left unchecked, hypothermia can lead to death. Therefore, it is the goal of safety and health professionals to protect employees from cold stress.

Cold stress occurs when the body temperature falls below 36°C (96.8°F), which is the normal human temperature.

Safety and health personnel must prevent cold injuries to body extremities, especially the hands, feet and head. A fatal exposure to cold typically results from failure to remove the employee from a cold air environment or immersion in cold water.

Furthermore, excessive exposure to cold stress, even when not fatal, can result in impaired judgement, reduced alertness, and poor decision-making. All of these factors increase the likelihood of workplace accidents and injuries. Wind (air) plays an important role in cold stress. Whether employees are exposed to cold air or are immersed in cold water, wind can amplify the negative effects of cold stress. As such, care should be taken to keep cold victims well wrapped up in blankets or other thermal sheets.
BODY’S RESPONSE TO HEAT STRESS

Figure 9.3: Excessive heat may result in negative body reactions

Heat stress is of major concern among safety and health professionals as it might pose a hazard or even lead to death if the body is exposed to extreme heat.

Heat stress may show several symptoms, depending on the level of stress. The most common symptom is heat stroke, heat fatigue, heat cramps, heat rash, transient heat fatigue, and chronic heat fatigue.

These types of heat stress may cause some negative body reactions such as heat rash, inadequate venous blood flow back to the heart, insufficient blood flow to vital organs, cramps, thirst and fatigue.

(a) Heat Stroke
Heat stroke is a type of heat stress caused by a sudden increase in body temperature. Heat stroke is very dangerous and must be treated immediately as it could be fatal. Symptoms of heat stroke are as follows:

(i) Hot, dry, red and spotted skin;
(ii) Fainting; and
(iii) Confusion and fits or seizures.

In your opinion, are alcohol consumption and obesity closely related to heat stress? Explain.

SELF-CHECK 9.3
Heat stroke victims will also record a rectal temperature of 104.5°F or more. If left unchecked, the body temperature will increase further. There are several factors that make people more prone to heat stroke among which are:

(i) Obesity;
(ii) Bad physical conditions;
(iii) Alcohol consumption;
(iv) Cardiovascular diseases; and
(v) Excessive exposure to heat.

When heat stroke occurs, the body’s ability to produce sweat decreases and temperature begins to elevate abnormally. Such a condition can be fatal if not treated immediately.

If a person becomes a victim of heat stroke, immediate action must be taken to reduce his body temperature. Do not wait for help to arrive. Immerse the victim in cool (not cold) water in order to reduce his body temperature. If that is not possible, his body should be covered with a piece of thin wet cloth; then, fan him to quickly bring down his body temperature. Keep the cloth wet until normal body temperature returns.

(b) **Heat Exhaustion**

Heat exhaustion is a form of heat stress which occurs due to lack of water and salt in the body. The observable symptoms of heat exhaustion are as follows:

(i) Fatigue
(ii) Nausea and/or vomiting
(iii) Headache
(iv) Light-headedness
(v) Clammy, moist skin
(vi) Pale or flushed complexion
(vii) Fainting when trying to stand
(viii) Rapid pulse
(ix) Oral temperature may be less than normal temperature while rectal temperature is higher than normal (99.5°F to 101.3°F).

![Figure 9.5: Heat exhaustion may cause headache](http://newsimg.bbc.co.uk/media/images/40170000/jpg/_40170259_tired203.jpg)

Heat exhaustion may occur when a person works very hard in a hot environment for a long period and fails to replace the water and salt lost through sweat. The condition might worsen if the temperature of the workplace is not adjusted gradually.

When heat exhaustion occurs, the body will experience dehydration. Dehydration reduces the total volume of blood which will further reduce blood flow. Since there is not enough blood circulating within the system, the body tries to maintain blood volume to the muscles by constricting blood vessels, resulting in the symptom mentioned earlier.

Victims of dehydration must be transferred to a cooler place (not cold) and left to rest. Water must be consumed slowly at a constant rate until the urine shows that the water level in the body has returned to normal.

Heat fatigue preventive measures practised at the workplace must also be practised during sports events. Gradually adjusting to the temperature for at least one week is important for workers who work in hot environments.
(c) **Heat Cramp**
Heat cramp is a type of heat stress which occurs when the body loses too much salt and potassium. The symptoms are muscle cramps in the arms, legs and abdomen. Heat cramp is caused by the loss of salt and potassium due to excessive sweating. Drinking water without salt replacement may also cause heat cramps.

With too much water and not enough salt, electrolyte imbalance takes place. Excess water will then enter the muscles and cause cramps. When heat cramp occurs, the proper treatment is to replace salt and potassium orally. In other words, heat cramp victims may drink commercially available drinks that contain salt, potassium, electrolytes and other necessary elements to restore the body’s electrolyte balance.

Heat cramps can be prevented by gradually adapting the workers to the work environment for about one week. Water loss from the body must be replaced with fluids containing the proper amount of salt, potassium and electrolytes.

(d) **Heat Rash**
Heat rash is a type of heat stress which shows up as tiny spots on different parts of the body, causing an irritating itch and prickling sensation. Heat rash is caused by blockage and inflammation of sweat ducts during times of exposure to heat and high humidity. These blocked sweat ducts cause sweat to escape into adjacent tissues, thus producing the itching and prickling sensations associated with the condition.

![Figure 9.6](http://search.msn.com/images/results.aspx?FORM=IRIR&q=heat%20rash)

**Figure 9.6:** A symptom of heat rash is tiny spots appearing on the body causing an irritating itch

**Source:** http://search.msn.com/images/results.aspx?FORM=IRIR&q=heat%20rash

Heat rash can be treated easily by transferring the victim to a cooler place which is less humid, cleaning the affected body part, and changing into damp clothes. Specific lotions can also be applied in treating heat rash.
(e) **Transient Heat Fatigue and Chronic Heat Fatigue**

Transient heat fatigue is a type of heat stress which causes discomfort and mental or psychological strain arising from prolonged heat exposure. Workers unaccustomed to the heat are particularly susceptible and can suffer transient heat fatigue. The degree and rate of transient heat fatigue depend on the physical condition.

Workers who are physically well conditioned and have adjusted to the work environment are less likely to suffer heat fatigue compared to those who are not. Thus, the prevention of transient heat fatigue involves having a good physique and heat acclimatisation.

Chronic heat fatigue is similar to transient heat fatigue, except that the recovery period is longer. Workers suffering from chronic heat fatigue may be transferred to a work area which does not require them to work in a hot environment. Prolonged chronic heat fatigue may cause physiological and psychological stress. The psychological stress may show the symptoms of substance abuse and unacceptable psychological behaviour.

### 9.5 COLD STRESS PREVENTION

Taking the following steps can prevent cold stress.

When air temperature reaches \(-32^\circ\text{C}\) or \(-25.6^\circ\text{F}\) (for example, in a cold room), no part of the human skin should be exposed. At air temperatures of \(2^\circ\text{C}\) (35.6°F), employees who are immersed in water or whose clothing gets wet should be treated for hypothermia immediately. Figure 9.8 illustrates how a hypothermia patient must be treated.

![Figure 9.7: Hypothermia wrap](http://www.princeton.edu/~oa/safety/hypocold.shtml)
When work is to be performed in an environment with an air temperature of 4°C (39.2°F) or less, full-body protective clothing is advisable. Table 9.2 shows several strategies that can be used to minimise cold stress.

**Table 9.2: Strategies to Decrease the Hazards of Cold Stress**

<table>
<thead>
<tr>
<th>Strategies to Minimise Cold Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) When working in a scenario where wind chill is a factor, reduce the effect of the wind by erecting a windscreen; or wear suitable clothing to keep warm.</td>
</tr>
<tr>
<td>(b) When working in a surrounding where clothing may get wet, apply one or more of the following strategies: wear an outer layer that is water repellent, but not impermeable; or wear outer garments that are ventilated to prevent internal wetting from sweat.</td>
</tr>
<tr>
<td>(c) If adequate clothing appropriate for the conditions in question is not available, the work should be modified or suspended until conditions change or until the right clothing is available.</td>
</tr>
</tbody>
</table>

**ACTIVITY 9.1**

Why must a safety and health professional be familiar with the strategies of preventing heat and cold hazards? Discuss the steps that must be taken in dealing with heat stress.

**SUMMARY**

- The concept of a more conducive workplace must be implemented and practised effectively.
- Doing so will increase the productivity and morale of employees.
- In practice, providing a workplace with fewer hazards of temperature extremes can reduce problems related to occupational safety and health.
- One cannot deny the negative effects of extreme heat on workers. Extreme heat can be a major cause of workplace accidents.
KEY TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air distribution</td>
<td>Heat rash</td>
</tr>
<tr>
<td>Chronic heat fatigue</td>
<td>Heat stroke</td>
</tr>
<tr>
<td>Cold stress</td>
<td>Humidity</td>
</tr>
<tr>
<td>Conduction</td>
<td>Hypothermia</td>
</tr>
<tr>
<td>Convection</td>
<td>Metabolic heat</td>
</tr>
<tr>
<td>Environmental heat</td>
<td>Radiant heat</td>
</tr>
<tr>
<td>Heat</td>
<td>Temperature</td>
</tr>
<tr>
<td>Heat cramp</td>
<td>Thermal comfort</td>
</tr>
<tr>
<td>Heat exhaustion</td>
<td>Transient heat fatigue</td>
</tr>
</tbody>
</table>

SELF-TEST 1

Essay Question

1. What is the body temperature that will cause cold stress?

2. Explain five basic concepts related to thermal energy.

3. State the strategies to reduce cold stress.

SELF-TEST 2

True (T) or False (F) Statements

1. Sweat evaporation is how the body maintains temperature balance.

2. Drinking water with high content of salt may also cause heat cramps.

3. Cold stress can be experienced when the body temperature drops below 36°C (below 96.8°F).

4. Exposure to cold stress can result in impaired judgement, reduced alertness, and poor decision-making.

5. Chronic heat fatigue is not related to psychological stress.
INTRODUCTION

This topic discusses workplace hazards involving pressure from equipment used at the workplace such as boilers, pressure vessels, high temperature water tanks and the like. A workplace that requires high-temperature water to carry out its operations is exposed to pressure hazards. Handling high-temperature equipment involves effective preventive measures to ensure that workers are not involved in accidents due to pressure hazards.

Our surrounding environment also contains pressure hazards. Those who love extreme sports such as mountain climbing or scuba diving must be cautious because they might be exposed to pressure hazards when they ascend to high altitudes or dive in the sea. Those who love these outdoor activities must make sure that they are well equipped, and know what to do to prevent such hazards, failing which they might face the risk of suffering from altitude sickness or decompression sickness or even much more serious injuries if these activities involve greater altitudes or water depths.

LEARNING OUTCOMES

By the end of this topic, you should be able to:
1. Explain the importance of pressure hazards;
2. Examine two sources of hazards related to pressure;
3. Evaluate three ways of detecting a leak in a pressured vessel; and
4. Formulate strategies to prevent pressure hazards at the workplace.
DEFINITION OF PRESSURE HAZARDS

Do you know what a pressure hazard is? In your opinion, what are the causes of pressure hazards?

Pressure hazard is a hazard caused by a dangerous condition involving pressure.

For example, opening the cap of the radiator of a car when the engine is still hot will cause hot water to gush out strongly due to the high pressure in the radiator. The person who opens the water radiator under such a condition will face a pressure hazard – hot water will cause injuries to the face, hands and parts of his body.

THE PRESSURE LAW

When we talk about air pressure, we are referring to the pressure exerted by the earth’s atmosphere. The average air pressure at sea level is 100kN per square metre, or about the weight of 10 tonnes exerting on a square of one metre. Approximately 21 percent of the atmosphere is oxygen; the rest is mostly nitrogen. The atmosphere contains trace amounts of several other gases such as helium, argon, neon, krypton and xenon.
Atmospheric pressure is usually measured using a barometer. As the altitude above sea level increases, atmospheric pressure decreases. For example, the atmosphere pressure at 18,000 feet (5,486m) above sea level is only half of that at sea level. At 27,480 feet (8,376m), the pressure drops to about a third of that at sea level.

Boyle’s law states that, at a given temperature, the product of a given pressure and volume is constant, as illustrated by the formula below.

\[ P_1V_1 = P_2V_2, \text{ when } T \text{ is constant whereby} \]
\[ P = \text{Pressure} \]
\[ V = \text{Volume} \]
\[ T = \text{Temperature} \]

A simple example for Boyle’s law is our breathing motion. Air moves in and out of the lungs because of a pressure gradient or difference. When atmospheric pressure is greater than the pressure within the lungs, air flows from the outside into the lungs. This is called inspiration, or breathing in, and occurs when we expand our chest cavity (volume increased but pressure decreased). When pressure in the lungs is greater than the atmospheric pressure, air moves outward from the lungs. Expiration occurs when air leaves the lungs (when we relax our chest muscles and diaphragm), increasing pressure within the lungs.

SELF-CHECK 10.3

To enhance your understanding of the human breathing system, explain briefly what happens during the breathing process.
Let us now focus on the various sources of pressure hazards. Refer to Figure 10.1 for the two sources of these hazards.

![Figure 10.1: Two sources of pressure hazards](image)

Pressure hazards which occur naturally can result from air being trapped or expanded within body cavities. For example, when the sinuses leading to the nasal cavity are blocked, air cannot pass through easily from the sinuses to the nose. The air trapped in the sinuses can lead to problems if it expands. The same complication can occur with air trapped inside the Eustachian tube to the middle ear which helps balance air pressure on either side of the eardrum. Expansion of the air in blocked sinus passages or the middle ear occurs when ascending quickly (e.g. in an aeroplane) or moving too quickly to the surface while diving. This can cause pain and, if not relieved, lead to diseases.

Humans create the second source of pressure hazards. These may be caused by work processes, tools or equipment such as boilers, pressure vessels, extremely hot water, and others.

**SELF-CHECK 10.4**

Are pressure hazards caused by humans only? Explain your views.
Pressure hazards that occur naturally can affect our health. Some sicknesses related to air pressure problems are shown in Figure 10.2.

Figure 10.2: Atmosphere pressure related sickness

(a) **Hypoxia**
Hypoxia is a condition that results from lack of oxygen. It is a type of altitude sickness. This condition occurs when oxygen available in the atmosphere becomes rarefied, especially at high altitudes. Some of its effects on humans at different altitudes are as follows:

(i) 10,000 feet above sea level – the person will experience shortness of breath and fatigue.

(ii) 14,000 to 15,000 feet above sea level – the person will experience euphoria along with a decrease in reasoning power, judgement and memory.
(iii) 20,000 to 25,000 above sea level – the person will lose consciousness after approximately five minutes at this altitude.

(iv) 30,000 above sea level – the person will lose consciousness after approximately one minute or less.

(v) More than 38,000 feet above sea level – the person may fall into a coma within 30 seconds and possibly die.

(b) **Decompression Sickness**

Decompression sickness can result from the following activities:

(i) A rapid ascent from the depth of around 132 feet to 66 feet underwater.

(ii) A rapid rise from sea level to at least 18,000 feet.

There are several factors which influence the onset of decompression sickness:

(i) History – previous decompression sickness.

(ii) Age – being over 30 increases the chances of an attack.

(iii) Physical fitness – people in good physical condition have a reduced chance of the sickness.

(iv) Exercise during exposure to decompression increases the likelihood and brings on an earlier onset of symptoms.
(v) Low temperature increases the probability of the sickness. Speed of decompression also influences the sickness.

(vi) A rapid rate of decompression increases the possibility and severity of symptoms.

(vii) Length of exposure – the longer the exposure, the greater the chances of decompression sickness.

**ACTIVITY 10.2**


(c) **Hyperoxia**

Breathing too much oxygen leads to a condition called hyperoxia. For example, failure to set the scuba diving equipment properly may cause cramps due to breathing too much oxygen during the dive. Normal air will become toxic at depths of 300 metres or more. Thus, deep-sea divers are particularly careful about the air mixture they breathe while diving. Increase in oxygen intake will also cause the person to feel dizzy, panic, have blurred vision and nausea. Continuous exposure will cause confusion, cramp and even death.

(d) **Bends**

Bends is a condition that affects divers who surface too quickly. Under the sea, water pressure will cause air to dissolve into the blood. During surfacing, the lessened pressure causes the dissolved air to turn into bubbles that can bring severe pain, forcing the sufferer to “bend” in pain. In serious cases, bends can kill.

(e) **Dysbarism**

This is the opposite of bends. In dysbarism, the formation of gas bubbles in the bloodstream is due to rapid ambient pressure reduction. The major causes of dysbarism are:

(i) The release of gas from the blood, and

(ii) The attempted expansion of trapped gas in the body.
(f) **Trapped Gas Effect**
Changes in overall pressure can induce trapped gas effects. According to Boyle's law, with a decrease in pressure, trapped gases will increase in volume. Trapped gases in the body include air pockets in the ears, sinuses and chest. Jet travel causes the most commonly occurring instance of trapped gas effects. Takeoff and landing may cause relatively sudden shifts in pressure, which may lead to discomfort and pain. With very rapid ascent or descent, injury can develop. Lung rupture can be caused by a swift return to the surface from diving or decompression during high-altitude flight.

(g) **Evolved Gas Effect**
Evolved gas effects are associated with the absorption of nitrogen into body tissues. When breathed, nitrogen can be absorbed into all body tissues in concentrations proportional to the partial pressure of nitrogen in the air. When a person is ascending in altitude, on the ground, in flight, or under water, nitrogen must be exhaled at a rate equal to or exceeding the absorption rate to avoid evolved gas effects.

(h) **Nitrogen Narcosis**
Nitrogen narcosis results from a higher-than-normal level of nitrogen pressure (atmospheric composition: 21% oxygen and 79% nitrogen). When breathed under pressure, nitrogen causes a reduction of cerebral and neural activity. Breathing nitrogen at great depths underwater can cause a feeling of euphoria and loss of reality. At depths greater than 100 feet (30 m), nitrogen narcosis can occur even when breathing normal air. The effects may become pathogenic at depths greater than 200 feet (60 m).

**SELF-CHECK 10.5**

Explain how nitrogen narcosis can be prevented.
10.5 PRESSURE HAZARDS

Equipment and apparatus used every day at the workplace may be a source of danger. Some of the sources of dangers are illustrated in Figure 10.4.

(a) Pressurised vessels – steam boilers, storage tanks, transport tanks and others.

(b) Unfired pressure vessels – vessels that can create heat internally by various means rather than by external fire.

(c) Leaks from safety valves in vessels.

(d) Dynamic pressure – rapid gas release from a cylinder, or water from a hose.

(e) Water hammer – air chambers and accumulators.

(f) Negative pressure – flow of air across the roof, filling hot or cold water into a bottle or container.

Figure 10.4: Sources of pressure hazards
The failure of pressurised equipment to function properly may cause serious injuries, kill nearby workers, and cause damage to properties at the workplace. Examples of pressurised equipment are as follows:

(a) Steam boilers and steam heating systems;
(b) Pressurised processes and piping;
(c) Air compression system (permanent and mobile);
(d) Pressure container, autoclave, retort;
(e) Cooling and heat exchange plants;
(f) Valves and steam filters;
(g) Piping and hoses; and
(h) Pressure gauges.

**ACTIVITY 10.3**

For more information on “Pressure Systems – Safety and You”, please visit:

**10.6 HAZARDS FROM BOILERS**

**SELF-CHECK 10.6**

Have you ever seen a boiler? Do you know what it is for? How can a boiler be hazardous and what are the preventive measures?

After seeing some examples of pressurised equipment, the following part will focus only on hazards caused by equipment used in industries, such as boilers, high temperature water, high pressure systems and unfired pressure vessels. Now, let us find out what a boiler is.
Refer to Table 10.1 for the preventive measures against potential hazards associated with boilers.

**Table 10.1: Preventive Measures against Potential Hazards Associated with Boilers**

<table>
<thead>
<tr>
<th>Preventive Measures against Potential Hazards Associated with Boilers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daily check</strong>: Check the water to make sure that it is at the proper level.</td>
</tr>
<tr>
<td><strong>Weekly check</strong>: At least once every week, test the low-water automatic shutdown control and record the results of the test on a tag that is clearly visible.</td>
</tr>
<tr>
<td><strong>Monthly check</strong>: At least once every month, test the safety valve and record the results of the test on a tag that is clearly visible.</td>
</tr>
<tr>
<td><strong>Yearly check</strong>: The low-level automatic shutdown control mechanism should either be replaced or completely overhauled and rebuilt.</td>
</tr>
</tbody>
</table>

**ACTIVITY 10.4**

Yearly inspection of steam boilers is better than daily inspection. Do you agree with this statement? Discuss.
10.7 HIGH-TEMPERATURE WATER (HTW) HAZARDS

High-temperature water hazards can be fatal. Can you state the causes of high-temperature water hazards?

High-temperature water (HTW) is water that has been heated to a very high temperature but not high enough to produce steam.

It occurs when the energy released is lower than the energy required to produce steam. In some cases, HTW can be used as an economical substitute for steam such as for industrial heating systems. It can also be used as a hot water supply in industries.

Although the energy released is lower compared to the energy produced by steam, there are hazards associated with HTW. Human contact with HTW can result in extremely serious burns and even death. The two most prominent sources of hazards associated with HTW are shown in Table 10.2.

Table 10.2: The Two Most Prominent Sources of Hazards Associated with HTW

<table>
<thead>
<tr>
<th>No.</th>
<th>Two Most Prominent Sources of Hazards Associated with HTW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Operator Error</strong></td>
</tr>
<tr>
<td></td>
<td>Operator error can result in burns. Proper training and</td>
</tr>
<tr>
<td></td>
<td>careful supervision are the best guards against operator</td>
</tr>
<tr>
<td></td>
<td>error.</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Improper Design and Installation</strong></td>
</tr>
<tr>
<td></td>
<td>The design of HTW systems is a highly specialised process</td>
</tr>
<tr>
<td></td>
<td>that should be undertaken only by experienced engineers.</td>
</tr>
<tr>
<td></td>
<td>Mechanical forces such as water hammer, thermal</td>
</tr>
<tr>
<td></td>
<td>expansion, thermal shock, and faulty materials are</td>
</tr>
<tr>
<td></td>
<td>often the cause of system failure. Therefore, it is</td>
</tr>
<tr>
<td></td>
<td>important to take note of the following when designing</td>
</tr>
<tr>
<td></td>
<td>an HTW system. The best designs should be simple and</td>
</tr>
<tr>
<td></td>
<td>operator-friendly. Furthermore, maintenance works must</td>
</tr>
<tr>
<td></td>
<td>be carried out regularly to prevent system failure.</td>
</tr>
</tbody>
</table>
HAZARDS OF UNFIRED PRESSURE VESSELS

Not all pressure vessels are fired. Unfired pressure vessels include compressed air tanks, steam-jacketed kettles, digesters, and vulcanisers, as well as others that can create heat internally by various means rather than by external fire. The various means of creating internal heat include chemical action within the vessel, and application of some heating medium such as electricity, steam, hot oil, and so on to the contents of the vessel. Refer to Table 10.3 to find out about the potential hazards associated with unfired pressure vessels.

Table 10.3: The Potential Hazards Associated with Unfired Pressure Vessels

<table>
<thead>
<tr>
<th>No.</th>
<th>Potential Hazards Associated with Unfired Pressure Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hazardous interaction between the material of the vessel and the materials that will be processed in it;</td>
</tr>
<tr>
<td>2.</td>
<td>Inability of the filled vessel to carry the weight of its contents and the corresponding internal pressure;</td>
</tr>
<tr>
<td>3.</td>
<td>Inability of the vessel to withstand the pressure introduced into it and the pressure caused by chemical reactions that occur during processing; and</td>
</tr>
<tr>
<td>4.</td>
<td>Inability of the vessel to withstand any vacuum that may be created accidentally or intentionally.</td>
</tr>
</tbody>
</table>
For each type of hazard, there would be measures to prevent it and the most effective preventive measures for overcoming the potential hazards above are shown in Table 10.4.

**Table 10.4: Preventive Measures for Overcoming the Potential Hazards Associated with Unfired Pressure Vessels**

<table>
<thead>
<tr>
<th>No.</th>
<th>Preventive Measures for Overcoming the Potential Hazards Associated with Unfired Pressure Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Proper Design</strong>&lt;br&gt;Specifications for the design of unfired pressure vessels include: working pressure range, working temperature range, types of materials to be processed, welding or joining measures, and radiography. Designs that meet the specifications set forth for unfired pressure vessels will overcome most predictable hazards.</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Precautions</strong>&lt;br&gt;Beyond proper design, precautions taken such as continual inspection, proper housekeeping, periodic testing, visual observation for detecting cracks, and the use of appropriate safety devices will overcome most predictable hazards.</td>
</tr>
</tbody>
</table>

**ACTIVITY 10.5**

For information on pressure hazards, please visit:<br>http://www.technology.ewu.edu/tech462/462_02/ch11.html

**10.9 HAZARDS OF HIGH-PRESSURE SYSTEMS**

The hazards most commonly associated with high-pressure systems are leaks, pulsation, vibration, release of high-pressure gases, and whiplash from broken high-pressure pipe, tubing, or hose.

To ensure that high-pressure systems function properly at the workplace, strategies for reducing these hazards must be implemented. These strategies are listed in Table 10.5.
Table 10.5: Strategies for Reducing High-pressure Systems Hazards

<table>
<thead>
<tr>
<th>No.</th>
<th>Strategies for Reducing High-pressure Systems Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Decreasing the potential for leaks by limiting the number of joints in the system;</td>
</tr>
<tr>
<td>2.</td>
<td>Limiting vibration through the use of vibration dampening;</td>
</tr>
<tr>
<td>3.</td>
<td>Putting a border around the high pressure system;</td>
</tr>
<tr>
<td>4.</td>
<td>Using pressure gauges; and</td>
</tr>
<tr>
<td>5.</td>
<td>Using remote control for monitoring.</td>
</tr>
</tbody>
</table>

10.10 CRACKING HAZARDS IN PRESSURE VESSELS

One of the most serious hazards in pressure vessels is the potential for cracking. It can lead to either a complete rupture or to leaks. The consequences of a complete rupture include the following:

Blast effects due to the sudden expansion of the contents of the vessel; and possible injuries and damage from fragmentation.

Cracking in pressure vessels can also result in the following:

(a) Suffocation or poisoning of employees depending on the contents of the vessel;
(b) Explosion and fire; and
(c) Chemical and thermal burns from contact with the contents of the vessel.

Pressure vessels are used in many different applications to contain many different types of substances ranging from water to extremely toxic chemicals. Leakage or rupture may occur at the joints.
10.11 SIGN OF PRESSURE HAZARDS

Confirming the point of pressurised gas leakage can be difficult. The cracking of a pressure vessel will lead to pressure hazards. A sign of pressure hazard due to cracking is leakage. There are several methods of detecting pressure hazards. Refer to Table 10.6 to learn how a leak can be detected.

Table 10.6: Methods of Detecting a Leakage

<table>
<thead>
<tr>
<th>No.</th>
<th>Methods of Detecting a Leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sounds can be used to signal a pressurised gas leak;</td>
</tr>
<tr>
<td>2.</td>
<td>Workers suffering from poisoning due to leakage of vessel;</td>
</tr>
<tr>
<td>3.</td>
<td>Vessel explodes and burns;</td>
</tr>
<tr>
<td>4.</td>
<td>Rust appearing on parts of the vessel;</td>
</tr>
<tr>
<td>5.</td>
<td>Odour coming from the vessel; and</td>
</tr>
<tr>
<td>6.</td>
<td>Corrosion in the vessel leading to cracking.</td>
</tr>
</tbody>
</table>

As for pressure vessels containing gas, the potential causes of leak are:

(a) **Contamination**: Dirt on gas valves;

(b) **Overpressurisation**: This can overstress the gas vessel;

(c) **Excessive temperatures**: Causing materials to crack because of excessive cold. The temperature must be monitored to indicate the possibility of gas release; and

(d) **Operator errors**: Supervisors must monitor the operators and the operators must receive proper training on the proper way of closing valves and filling the vessels appropriately to prevent overfilling of vessels.
Figure 10.5 illustrates the diagrams of a pressure vessel.

Figure 10.5: The a front and top views of a pressure vessel
Figure 10.6 shows some photographs of pressure vessels.

Cracking and leakages are interrelated and can cause serious hazards. In your opinion, what are the recommended strategies to reduce the potential of a leak?

To see more diagrams of pressure vessels, you can visit: http://www.arl.psu.edu/facilities/hi_pressure.html
To overcome the problem of leakage or incorrect pressure level, it is necessary to examine pressure vessels periodically. There are two methods of testing to detect pressure leaks and incorrect pressure levels in pressure vessels and they are as follows:

(a) **Destructive Testing**
Destructive testing methods destroy the material being checked. There are two types of testing, i.e. proof pressure test, and stress and strain test. Firstly, the proof pressure test is conducted on the pressure vessel to test the strength of the vessel. Then, the stress and strain test is carried out to discover the changes after the pressure is released.

(b) **Non-destructive Testing**
Non-destructive testing methods do not harm the material being tested. There are five non-destructive methods for testing, i.e.

(i) Visual examination, which involves taking a thorough look at the vessel to detect signs of corrosion or erosion on the cleaned surface of the vessel;

(ii) Liquid penetration test, which involves placing a specifically formulated liquid penetrant over an area and letting it seep in. The crack can be detected when some of the penetrant remain entrapped in the area;

(iii) Magnetic particle test, which uses ferromagnetism to test the surface of the vessel;

(iv) Gamma and x-ray radiography; and

(v) Ultrasonic test, which is used to detect cracks and leaks.
STRATEGIES TO REDUCE PRESSURE HAZARDS

Reducing pressure hazards usually requires maintenance and inspections to be carried out on pressure vessels. Several strategies as shown in Table 10.7 can be applied to reduce pressure hazards at the workplace.

Table: 10.7: Strategies to Reduce Pressure Hazards at the Workplace

<table>
<thead>
<tr>
<th>No.</th>
<th>Strategies to Reduce Pressure Hazards at the Workplace</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Install safety valves and inspect them periodically to ensure that they are capable of withstanding working pressures;</td>
</tr>
<tr>
<td>2.</td>
<td>Store pressure vessels at the proper temperature and place them far from sources of heat including the sun, sources of ignition and cold temperature;</td>
</tr>
<tr>
<td>3.</td>
<td>Do not expose closed containers to heat because gas compression may occur. Eg: aerosol cans must never be thrown near sources of heat as they might explode due to gas compression;</td>
</tr>
<tr>
<td>4.</td>
<td>Clean the pressure vessel periodically;</td>
</tr>
<tr>
<td>5.</td>
<td>Pressure systems must only be operated under the conditions for which they were designed as advised by the manufacturer;</td>
</tr>
<tr>
<td>6.</td>
<td>Relieve all pressure from the system before performing any work;</td>
</tr>
<tr>
<td>7.</td>
<td>Label pressure system components to indicate inspection status;</td>
</tr>
<tr>
<td>8.</td>
<td>Exercise good housekeeping to ensure that the pressure system is in good condition;</td>
</tr>
<tr>
<td>9.</td>
<td>Examine labels before using pressurised systems to ensure correct matching of gases and uses; and</td>
</tr>
<tr>
<td>10.</td>
<td>Train and test personnel dealing with pressurised vessels. Only tested personnel should be permitted to operate pressurised vessels. Personnel working on pressure systems should wear personal protection equipment such as face shields.</td>
</tr>
</tbody>
</table>

SELF-CHECK 10.10

Imagine that there are many empty aerosol cans at your workplace. In your opinion, what must be done with these cans to reduce pressure hazards?
Malaysia has a law on steam boilers and unfired pressurised vessels. The law referred to is the **Factories and Machinery (Steam Boiler and Unfired Pressure Vessel) Regulations 1970**. This regulation came into force on 1 February 1970 and applies to all organisations using steam boilers and unfired pressurised vessels with the purpose of creating a safe and healthy work environment. This regulation also applies to designers, makers and manufacturers of such equipment. Imported steam boilers and unfired pressurised vessels are not exempted from this law as their owners are required to notify the Director General of Occupational Safety and Health Department, in order to obtain their certificates of fitness.

This regulation is divided into four sections. These are shown in Table 10.8.

**Table 10.8: The Four Sections of the Factories and Machinery Regulations**

<table>
<thead>
<tr>
<th>Section</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>General regulations on fitness certificate application.</td>
</tr>
<tr>
<td>2.</td>
<td>Steam boilers and the necessary components of the steam boiler for safe operation.</td>
</tr>
<tr>
<td>3.</td>
<td>Unfired pressure vessel and the necessary components for safe operation.</td>
</tr>
<tr>
<td>4.</td>
<td>Various provisions such as piping, hydrostatic tests, maintenance and repair, safe work environment, fees, compliance and penalties for non-compliance.</td>
</tr>
</tbody>
</table>
Operating steam boilers and pressure vessels requires skilful operators who have sound knowledge of such equipment.

Errors committed by operators are often the cause of pressure hazards besides insufficient periodical inspections.

Employers, employees, designers, manufacturers and suppliers must adhere to the Factories and Machinery (Steam Boiler and Unfired Pressure Vessel) Regulations 1970 in order to create a safe work environment.

Atmosphere  Barometer  Bends  Boilers  Boyle’s law  Decompression  Dysbarism  Expiration

High-temperature Water (HTW)  Hyperoxia  Hypoxia  Inspiration  Nitrogen narcosis  Pressure hazard  Pressure vessel

Essay Questions

1. Explain briefly the meaning of pressure hazards.

2. Explain briefly three types of pressure-related illnesses.

3. Explain briefly three methods of detecting leaks on pressure vessels.

4. Cracks on pressure vessels pose a danger to workers. State briefly three effects of the cracking of pressure vessels.

5. Explain briefly four strategies to reduce hazards.
True (T) or False (F) Statements

1. The atmosphere contains 21% of oxygen and 79% nitrogen.

2. Atmosphere pressure can be measured using a spherometer.

3. There are three sources of pressure hazards.

4. Hyperoxia occurs when there is too much oxygen in the atmosphere.

5.Leaks from safety valves represent pressure hazards.
In today’s modern life, electricity is one of the most utilised energies. Electricity has many benefits but may also create hazards. Ignoring the possible dangers of electricity can cause workplace accidents. The neurological system in the human body is very sensitive to electric shocks even if the current is at a very low level. Most electrical hazards can be controlled easily and economically if safety procedures and control are introduced at the initial designing stage. Most electrical hazard accidents occur due to the behaviour of workers who refuse to follow safety procedures.
11.1 DEFINITION OF ELECTRICAL HAZARDS

SELF-CHECK 11.1

What is electric current? What happens when electric current passes through a conductor? Is metal a weak conductor? Give your views.

Electricity is the flow of negatively charged particles called electrons through an electrically conductive material. Electrons orbit the nucleus of an atom, which is located approximately in the atom’s centre. The negative charge of the electrons is neutralised by particles called protons, which are held together by neutrons. Neutrons act as temporary energy repositories for the interactions between positively charged protons and the negatively charged electrons.

Electrical current passing through a circuit is like fluid running through a pipe. When electricity passes through a conductor, resistance will cause heat. This resistance is measured in ohms. Pure conductors such as copper, metal and alloy offer low resistance, while weak conductors such as plastic, rubber, fabric and paper offer high resistance and are used as insulators.

The resistance level of conductors depends on the dimension and material of the conductor. Conductors are substances that have many free electrons at room temperature and can allow electrons to flow through when there is a difference in electric charge. Insulators do not have a large number of free electrons at room temperature and as such, do not conduct electricity. Substances that are neither conductors nor insulators can be called semiconductors. Semiconductors offer medium resistance to electrical current.

Electrical current passing through a cable or wire is measured in amperes or amps (A). Electrical shocks are normally measured in milliamperes (mA). Ohm’s law states that the current (I) passing through a conductor between two points is proportional to the potential difference (i.e. voltage, V) across the two points, and inversely proportional to the resistance (R). Ohm’s law is summarised as follows:

\[ V = IR \]

where

\[ V = \text{volts}, \]
\[ I = \text{current flow in amperes}, \]
\[ R = \text{resistance to current flow in ohms}. \]
Power is measured in watts which can be determined by Ohm’s law:

\[ W = VI \]

or

\[ W = I^2R \]

where \( W \) = power in watts

**SELF-CHECK 11.2**

Electric current flows very rapidly, at about 186,000 miles per second. If you took two seconds to turn on the light, how far has the electric current travelled?

**11.2 SOURCES OF ELECTRICAL HAZARDS**

_Figure 11.1:_ Be careful when handling electricity in order to avoid accidents

We cannot avoid using electricity in our daily life. Because electricity is widely and extensively used, we tend to forget the dangers posed by this source of energy. We often read about accidents involving electrical hazards. Short circuits are one of many potential electrical hazards that cause electrical shock and fire. To know more about the sources of electrical hazard, refer to Table 11.1.
Table: 11.1: Sources of Electrical Hazards

<table>
<thead>
<tr>
<th>No.</th>
<th>Source of Electrical Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Contact with a bare wire carrying current</td>
</tr>
<tr>
<td>2.</td>
<td>Improper wiring</td>
</tr>
<tr>
<td>3.</td>
<td>Working with electrical equipment in a damp surrounding</td>
</tr>
<tr>
<td>4.</td>
<td>Static electricity discharge</td>
</tr>
<tr>
<td>5.</td>
<td>Using metal ladders</td>
</tr>
<tr>
<td>6.</td>
<td>Power source not switched off</td>
</tr>
<tr>
<td>7.</td>
<td>Lightning strikes</td>
</tr>
<tr>
<td>8.</td>
<td>Arcs and sparks</td>
</tr>
<tr>
<td>9.</td>
<td>Combustive and explosive materials</td>
</tr>
<tr>
<td>10.</td>
<td>Insulation failure</td>
</tr>
<tr>
<td>11.</td>
<td>Equipment failure</td>
</tr>
</tbody>
</table>

Now, let us look at these sources of electrical hazards in detail.

(a) **Contact with a Bare Wire Carrying Current**
   A person can get electrical shock if he comes into contact with a bare wire carrying current, such as when walking on a surface with electrical current due to an exposed, high-voltage wire cut by a storm.

(b) **Improper Wiring**
   Improper wiring of equipment or buildings may cause danger. One common mistake is to “jump” the ground wire to the neutral wire. In this case, the ground wire is actually connected to the neutral wire. Equipment usually operates in a fixed way, but the hazard occurs when low voltages are generated on exposed parts of the equipment, such as the housing. If the neutral circuit becomes corroded or loose, the voltage on the ground wire may increase to a dangerous level. Sometimes, a socket may have too many plugs or extensions attached to it. Remember that connecting too many electrical devices to a single socket is dangerous.
Improper wiring (or miswiring) can cause other hazards. For example, the proper way to wire an electrical device is to ensure that the three different wires – live, neutral and ground – are connected correctly to ensure that electricity flows properly. When the ground wire is connected improperly, the situation is referred to as open ground. Usually, the equipment with such miswiring may still operate normally. If a short circuit occurs in an equipment without proper grounding, anyone touching that equipment may be severely shocked.

Temporary wiring installations sometimes remain in place for years and can cause a short circuit, resulting in accidents. Therefore, temporary wires should be substituted for fixed wiring. These steps must be taken to protect lives and property from the dangers of electricity.

(c) **Working with Electrical Equipment in a Damp Surrounding**

The rate of discharge of electrical charges increases with lower humidity. Electrostatic sparks are often greater during cold, dry winter days. Adding humidity to the air is not commonly used to combat static discharge. In fact, higher humidity may result in an uncomfortable work environment and adversely affect equipment.

(d) **Static Electricity Discharge**

Electrostatic hazards may cause minor shocks. Sources of electrostatic discharge include the following:

(i) Briskly rubbing a nonconductive material over a stationary surface. One common example of this is scuffing shoes across a wool or nylon carpet. Multilayered clothing may also cause static sparks.

(ii) Moving large sheets of plastic may discharge sparks.
(iii) The explosion of organic and metallic dusts, which has occurred from static build-up in farm grain silos and mine shafts.

SEL-F-CHECK 11.3

List the areas at your workplace which you think are potential electrostatic hazard areas.

(e) **Using Metal Ladders**
Using ladders made of metal such as aluminium and steel while working with electrical equipment can provide a direct line from the power source to the ground, again causing a shock.

![Figure 11.3](http://www.fplsafetyworld.com/hurt/travel_through.html)

(f) **Power Source Not Switched Off**
A common mistake that leads to hazards is not ensuring that the power has been switched off before carrying out maintenance works. Electric current can still flow from the power point to the equipment and cause electric shock.

(g) **Lightning Strikes**
Lightning strikes are static charges from clouds following the path of least resistance to the earth, but at very high voltage and current. If this path to the earth involves humans, serious disability may result, including electrocution (i.e. death due to electric shock). Lightning may also damage aeroplanes from intra-cloud and cloud-to-cloud flashes. Electrical equipment and building structures are commonly subject to lightning hazards. Lightning tends to strike the tallest object since they offer the shortest distance from the clouds. A tree is a common natural path for lightning.
(h) **Arches and Sparks Hazards**
With close proximity of conductors or contact of conductors to complete a circuit, an electric arc can “jump” the gap between the conductors and ignite combustible gases or dusts. When the electric arc is a discharge of static electricity, it may be called a spark. A spark or arc may involve relatively little or a great deal of power and is usually discharged into a small space.

(i) **Combustible and Explosive Materials**
High currents through contaminated liquids may cause the contaminants to expand rapidly and explode. This situation is particularly dangerous with contaminated oil-filled circuit breakers or transformers. A poor match between current and capacitors can cause an explosion. In each of these cases, the conductor is not capable of carrying a current of such high magnitude. Overheating from high currents can also lead to short circuits, which in turn may generate fires or explosions.

(j) **Insulation Failure**
Degradation of insulation can result in a bare wire which may cause shock to anyone coming in contact with it. Most insulation failures are caused by environmental factors. These factors include the following:

(i) Direct sunlight or other sources of ultraviolet light, which can induce gradual breakdown of plastic insulation material.

(ii) Repeated exposure to elevated temperatures, which can produce slow but progressive degradation of insulation material.

(iii) Abrasive surfaces, which can result in erosion of the material strength of the insulation.
(iv) Substance incompatibility with the atmosphere around the insulation and the insulation material, which can induce chemical reactions. Such reactions may include oxidation or dehydration of the insulation and eventual breakdown.

(v) Animals such as rodents or insects chewing the insulation material, leading to exposure of the wires within.

(k) **Equipment Failure**

The following are some of the more common types of equipment failure:

(i) Wet insulation can become a conductor and cause an electrical shock.

(ii) Portable tool defects can result in the device’s housing carrying an electric current.

(iii) Broken power lines carry high current and voltage and can cause severe disabling shocks.

(iv) When equipment is not properly grounded or insulated, an unshielded worker may receive a bad electrical shock.

Therefore, all electrical appliances that we buy for our homes or workplace must comply with safety standards. There are various organisations which have developed codes and standards on electrical appliance safety. These codes and standards must be taken into consideration when choosing an electrical appliance to ensure its safety. Among these codes and standards are:

### Code and Standard

- National Electrical Code (NEC)
- National Electric Safety Code (NESC)
- National Fire Protection Association (NFPA)
- American National Standards Institute (ANSI)
- Underwriters Laboratories (UL)
- SIRIM (Standards and Industrial Research Institute of Malaysia; applicable in Malaysia only)
The severity of injury with electrical shock depends on how strong the electrical current is, and how long the current has been flowing through the human body. There are also other factors which influence the severity of injury such as the body part involved and the frequency of exposure to the hazard.

ACTIVITY 11.1
For more information on electrical appliance standards, you may visit:
(a) http://www.nfpa.org
(b) http://www.sirim.my

SELF-CHECK 11.4
What must you do if you experience an electrical shock?

The severity of injury with electrical shock differs based on the person, the position of the victim during the incident and other factors. Electrical shock can be the result of either direct current (DC) or alternating current (AC) entering the human body. As a result of electrical shock, the victim will not be able to control his muscles. Prolonged contact with electric current will have more serious effects compared

Figure 11.5: Electrical shock may cause muscle contraction, weakness, unconsciousness, severe burns, rapid heartbeat, paralysis of respiratory muscles and death
Source: http://www.fplsafetyworld.com/hurt/path_to_ground.html
to shorter contact period. High levels of alternating current (AC) will make the heart beat rapidly and will subsequently render the heart ineffective at pumping blood to vital organs in the body. The victim will experience unconsciousness, weak lungs and diaphragm. Contact to electrical current exceeding 100mA may cause ventricular fibrillation of the heart and death.

Electrical shock can cause the human heart and lungs to not function normally. If a person experiences electrical shock, the victim must be moved from the place of accident and given mouth-to-mouth or cardiopulmonary resuscitation (CPR). The quicker the CPR is done, the better the chances of the victim’s survival. Figure 11.6 illustrates CPR being administered on a victim.

![Figure 11.6: Administration of CPR](image)

Apart from that, the victim’s skin may burn due to electric arcs of high voltage. If the victim experiences electrical shock while being at a high altitude, the victim may fall unconscious, resulting in him falling down. This is even more dangerous compared to the other electrical hazards just discussed.

### 11.4 DETECTION OF ELECTRICAL HAZARDS

There are many test equipment that can be used to verify electrical safety. A circuit tester is an inexpensive piece of equipment with two wire leads capped by probes and connected to a small bulb. Most circuit testers are capable of verifying voltages ranging from 110 V to 220 V. This simple tester can ensure that power has been turned off before electrical maintenance begins. The tester may also be used to determine whether housings and other equipment parts are carrying “live” current. If the bulb lights up, it means that there is current in the equipment.
A receptacle wiring tester is a device with two standard plug probes for insertion into an ordinary 110 V outlet and a probe for the ground. Indicator lights show an improperly wired receptacle (outlet). This tester will only reveal an incorrectly wired outlet and correction steps must be taken to prevent electrical hazards. Figure 11.8 shows a receptacle wiring tester.

A continuity tester may be used to determine whether a conductor is properly grounded or has a break in the circuit. Continuity is checked on circuits that are disconnected from a power source. Continuity testers often have an alligator clip on one end of a wire which is connected to the equipment being tested, and a bulb and probe on the other end of the same wire. The unlit bulb of a continuity tester indicates that the equipment is improperly grounded or there is a break in the circuit. Figure 11.9 shows a continuity tester.
WAYS TO REDUCE ELECTRICAL HAZARDS

There are several methods which can be used to reduce electrical hazards such as those listed in Table 11.2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Methods to Reduce Electrical Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Electrical system grounding</td>
</tr>
<tr>
<td>2.</td>
<td>Bonding</td>
</tr>
<tr>
<td>3.</td>
<td>Electrostatic neutralisers</td>
</tr>
<tr>
<td>4.</td>
<td>Humidification</td>
</tr>
<tr>
<td>5.</td>
<td>Fuses</td>
</tr>
<tr>
<td>6.</td>
<td>Double insulation</td>
</tr>
<tr>
<td>7.</td>
<td>Interlocks</td>
</tr>
<tr>
<td>8.</td>
<td>Lightning hazard control</td>
</tr>
</tbody>
</table>

Now, let us take a look at these methods in detail.
(a) **Electrical System Grounding**
Grounding of electrical equipment is the primary method of reducing electrical hazards. The purpose of grounding is to safeguard people from electrical shocks, reduce the probability of a fire, and protect equipment from damage. Grounding ensures a path to the earth for the flow of excess current.

Electrical system grounding is achieved when one conductor of the circuit is connected to the earth. Power surges and voltage changes are attenuated and usually eliminated with proper system grounding.

(b) **Bonding**
Bonding is used to connect two pieces of equipment by a conductor. Bonding can reduce potential differences between the equipment and thus reduce the possibility of sparking.

(c) **Humidification**
As discussed earlier in this topic, humidification can be used as a mechanism for reducing electrical static. Raising the humidity above 65 percent reduces charge accumulation. Antistatic materials have also been used effectively to reduce electrical static hazards.

(d) **Electrostatic Neutralisers**
Electrostatic neutralisers ionise the air surrounding a charged surface to provide a conductive path for the flow of charges. Radioactive neutralisers include a radioactive element that emits positive particles to neutralise collected negative electrical charges.

(e) **Fuses**
Fuses can also be used to prevent electrical hazards when there is a sudden surge of electric current in a circuit. Fuses which are installed in electrical appliances consist of a metal strip or wire that melts if a current above a specific value is conducted through the metal. Melting the metal causes the circuit to open at the fuse, thereby stopping the flow of current.

(f) **Double Insulation**
Double insulation is another means of increasing electrical equipment safety. Most double-insulated tools have plastic nonconductive housings.
(g) **Interlocks**
Interlocks automatically break the circuit when an unsafe situation is detected. Interlocks are usually used around high-voltage areas to keep personnel from entering the area. Warning devices to alert personnel about detected hazards may include warning labels and audible signals.

(h) **Lightning Hazard Control**
There are several methods to reduce lightning hazards, among which are the following:

(i) Use lightning rods.
(ii) Avoid standing on high places or near tall objects.
(iii) Do not work near flammable materials during thunderstorms.
(iv) Make sure all electrical appliances are grounded properly.
(v) Wear safety or rubber boots when working outdoors and exposed to lightning.
(vi) Do not use the telephone during an electrical storm.
(vii) Avoid using electrical appliances during an electrical storm.
(viii) Do not stand near open doors and windows during electrical storms.

11.6 **ELECTRICAL HAZARDS SAFETY AND PREVENTION PROGRAMME**

There are 12 steps that can be taken to develop an electrical hazard safety and prevention programme at your workplace such as the following:

(a) Provide all workers with adequate training in the identification and control of the hazards associated with electrical energy in their workplace.

(b) Provide additional specialised electrical safety training to those working with or around exposed components of electric circuits. This training should include, but not be limited to, training in basic electrical theory, proper safe work procedures, hazard awareness and identification, proper use of personal protective equipment (PPE), proper lockout/tagout procedures, first aid including CPR, and proper rescue procedures. Employers may also provide periodic training as necessary.
(c) Develop and implement procedures to control hazardous electrical energy that include lockout and tagout procedures. Ensure that workers follow these procedures.

(d) Provide testing or detection equipment for those who work directly with electrical energy so as to ensure their safety during the performance of their assigned tasks.

(e) Ensure compliance with the National Electrical Code and the National Electrical Safety Code.

(f) Conduct safety meetings regularly.

(g) Conduct scheduled and unscheduled safety inspections at work sites.

(h) Actively encourage all workers to participate in workplace safety.

(i) In a construction setting, conduct a job site survey before starting any work to identify all electrical hazards, implement appropriate control measures, and provide training to employees on how to identify electrical hazards.

(j) Ensure that proper personal protective equipment is available and worn by workers where required.

(k) Conduct job hazard analyses of all tasks that may expose workers to the hazards associated with electrical energy and implement control measures that will adequately insulate and isolate workers from electrical energy.

(l) Identify potential electrical hazards and appropriate safety interventions during the planning phase of construction or maintenance projects. This planning should address the project from start to finish to ensure that workers have the safest possible work environment.

**SUMMARY**

- Electricity has many benefits but may also create hazards.

- Sources of electrical hazards include: contact with a bare wire carrying current, improper wiring, working with electrical equipment in a damp surrounding, static electricity discharge, using metal ladders, power source not switched off, lighting strikes, arcs and sparks, combustive and explosive materials, insulation failure, and equipment failure.
• Electrical hazards can be detected using a circuit tester, a receptacle wiring tester or a continuity tester.

• Methods to reduce electrical hazards are: electrical system grounding, bonding, electrostatic neutralisers, humidification, fuses, double insulation, interlocks and lighting hazard control.

**KEY TERMS**

<table>
<thead>
<tr>
<th>Fire detection system</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire extinguisher</td>
<td>Ignition</td>
</tr>
<tr>
<td>Fire triangle</td>
<td>Oxygen</td>
</tr>
<tr>
<td>Flammability</td>
<td>Spontaneous combustion</td>
</tr>
</tbody>
</table>

**SELF-TEST 1**

**Essay Questions**

1. Explain the complete steps of conducting mouth-to-mouth resuscitation or cardiopulmonary resuscitation (CPR) when trying to save someone’s who has suffered electric shock.

2. Explain the meaning of the following terms:
   - (a) Lightning.
   - (b) Open ground.

3. Explain four strategies to develop an electrical hazard safety and prevention programme at the workplace.
True (T) or False (F) Statements

1. Electrical system grounding is a technique to reduce resistance of the insulator.

2. Electrical shock in a wet environment is far more dangerous than a dry environment.

3. Most industrial and domestic use of electricity is supplied by direct current (DC).

4. A television antenna does not require electrical system grounding.

5. Raising the humidity level of the room above 65 percent helps to prevent electrostatic shocks.

6. The nucleus of an atom is made up of protons and neutrons with negative charges.
INTRODUCTION

According to the fire statistics issued by the Fire and Rescue Department in Malaysia, most fire cases occur due to causes such as human failure, absence of proper fire prevention systems, usage of flammable materials, and intentional burning. Fire often occurs at places such as processing plants and confined spaces in factory buildings, residential houses, external equipment and warehouses.

Fire not only causes loss of property, injuries and death, but also loss of time and employment. Fire hazards can actually be prevented. This topic will discuss how fire hazards occur and methods to control and prevent them.
DEFINITION OF FIRE HAZARDS

Most fire cases occur as a result of human negligence in handling fuel and heat. Fire, or combustion, is a chemical reaction between oxygen and a combustible fuel. Combustion is the process where fire converts fuel and oxygen into energy, usually in the form of heat. By-products of combustion include light and smoke. For the reaction to start, a source of ignition, such as a spark or open flame, or a sufficiently high temperature is needed. Given a sufficiently high temperature, almost every substance will burn. The ignition temperature or combustion point is the temperature at which a given fuel can burst into flames. Figure 12.2 illustrates the reaction.

Figure 12.1: The definition of fire hazards

Figure 12.2: The fire triangle
Based on the Fire Triangle, the three elements, i.e. fuel, oxygen and source of ignition, must be present to start a fire. Without any of the three elements, there would be no fire; such a condition would thus provide an opportunity to prevent a fire. Fuel seems to be the easiest element to control in preventing it from meeting the source of ignition and oxygen, as the sources of ignition are too many and difficult to avoid. Table 12.1 lists the common sources of ignition at the workplace.

**Table 12.1: Sources of Ignition**

<table>
<thead>
<tr>
<th>Source</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical (motor or engine wiring)</td>
<td>23</td>
</tr>
<tr>
<td>Smokers’ material</td>
<td>18</td>
</tr>
<tr>
<td>Friction and shock</td>
<td>10</td>
</tr>
<tr>
<td>Extremely hot materials</td>
<td>8</td>
</tr>
<tr>
<td>Hot surfaces</td>
<td>7</td>
</tr>
<tr>
<td>Burners</td>
<td>7</td>
</tr>
<tr>
<td>Spark ignition</td>
<td>5</td>
</tr>
<tr>
<td>Self-ignition</td>
<td>4</td>
</tr>
<tr>
<td>Hot works (cutting, welding and riveting)</td>
<td>4</td>
</tr>
<tr>
<td>Exposure to fire (fire moving to other areas)</td>
<td>3</td>
</tr>
<tr>
<td>Explosives</td>
<td>3</td>
</tr>
<tr>
<td>Spark ignition from mechanical activities</td>
<td>2</td>
</tr>
<tr>
<td>Spillage of hot substances/liquids</td>
<td>2</td>
</tr>
<tr>
<td>Chemical reaction</td>
<td>1</td>
</tr>
<tr>
<td>Electrostatic discharge</td>
<td>1</td>
</tr>
<tr>
<td>Lightning strikes</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
</tr>
</tbody>
</table>

Do you know that 18% of fires are caused by smokers?
Figure 12.3: 18 percent of fires are caused by smokers

SELF-CHECK 12.2

Why is electricity considered the main source of fire hazards?

Chemical reactions may cause fire hazards, as shown in Figure 12.4.

Figure 12.4: Chemical reactions are an ignition source which can cause fire

Exothermic reactions in fuels or flammable materials may involve various materials such as gases, vapours, flammable liquids and solids. Usually, flammable liquids and solids will first convert into flammable vapours by heat. The mixture of gases and vapours will then combine with oxygen in the air and form a flammable mixture. When the flammable material is oxidised, it will produce heat. If the combustion process results in a sudden increase in heat, it will cause an explosion.
In the process of combustion, materials are broken down into basic elements. Carbon is found in almost every flammable substance. When a substance burns, carbon is released and then combined with oxygen that must be present to form either carbon dioxide or carbon monoxide. Carbon dioxide is produced when there is more oxygen than the fire needs. It is not toxic, but it can be produced in such volumes that it seriously reduces the concentration of oxygen in the air surrounding the fire site. Carbon monoxide – a colourless, odourless, deadly gas – is the result of incomplete combustion of a fuel. It is produced when there is insufficient oxygen to efficiently burn the fuel present. In general, most fires have insufficient oxygen and therefore produce large quantities of carbon monoxide. Hydrocarbon gases such as methane and ethane have higher combustion heat compared to coal or hydrocarbon liquids.

Hydrogen, found in most fuels, combines with oxygen to form water. Hydrogen also generates higher combustion heat compared to other fuels. The ratio of hydrogen to carbon is an important factor in any heat content. The higher the ratio, the higher the heat content of a material is. Therefore, the higher the hydrogen molecule content is relative to carbon in a fuel, the hotter the fuel burning will be. Hydrogen is usually found in polymers and plastics. Fumes produced by the burning of polymers and plastics are toxic and can be deadly.

Heat always flows from a high temperature area to a low temperature area. Fires generate heat. Excess heat is then transferred to surrounding objects, which may ignite. Heat transfer is accomplished by three means:

(a) Conduction, which is direct thermal energy transfer that enables heat to be transferred through solid materials;
(b) Convection, which is heat transfer through the movement of hot gases. The gases may be the direct products of the fire, the results of chemical reactions, or additional gases brought to the fire by the movement of air and heated at the fire surfaces by conduction;

(c) Radiation, which is the electromagnetic wave transfer of heat to a solid.

12.1.1 Spontaneous Combustion

Spontaneous combustion is a chemical oxidisation process in an exothermic reaction which produces heat. It is a phenomenon which is quite rare. Normally, when the temperature of a flammable material is below its ignition temperature, no combustion will occur. But when the material is degraded through the process of oxidisation, it will produce heat. The temperature will increase abruptly, causing self-ignition, which leads to combustion. Spontaneous combustion often occurs to materials containing animal and vegetable oils during processing, storage and transport. For example, during the storage of flour or nut husks, the organic compounds will decompose and, as they degrade, they release methane gas, an excellent fuel. The degradation process produces heat. Once the ignition temperature is reached, spontaneous combustion will take place, causing fire to erupt. The situation will be even worse if the materials are stored when they are still hot.

12.1.2 Flammability Limit

Although the three elements of the Fire Triangle are present, a fire will not necessarily occur. The combination of the flammable material and air only in the right proportions will propagate a fire. In other words, if the mixture is too lean (beyond its lower flammability limit or LFL), it will not catch fire, and if the mixture is too rich (above its upper flammability limit or UFL), it also will not burn. Therefore, combustion will only occur when the mixture of flammable material and air is between the LFL and the UFL. Table 12.2 illustrates the LFL and the UFL of several chemical substances.
Table 12.2: The Range of Flammability Limit of Selected Fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>LFL (% ip/ip)</th>
<th>UFL (% ip/ip)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>Acetylene</td>
<td>2.6</td>
<td>100</td>
</tr>
<tr>
<td>Benzene</td>
<td>1.4</td>
<td>8.0</td>
</tr>
<tr>
<td>Butane</td>
<td>1.8</td>
<td>8.4</td>
</tr>
<tr>
<td>Ethane</td>
<td>3.0</td>
<td>12.4</td>
</tr>
<tr>
<td>Methane</td>
<td>5.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>1.3</td>
<td>7.0</td>
</tr>
</tbody>
</table>

12.2 CLASSES OF FIRE

There are five classes of fire. To know more, refer to Figure 12.6.
When a fire occurs, it produces four things: fire, heat, fumes and smoke. Most people die in fires from suffocating or breathing smoke and toxic fumes, as well as from exposure to heat and flame. The composition of toxic fumes from the fire depends on the chemical composition and structure of the burning fuel, oxygen supply and burning temperature.

Most fuels contain carbon. Thus, carbon dioxide and carbon monoxide will be released in a fire. Carbon dioxide is produced when there is more oxygen than the fire needs. It can be produced in such volumes that it seriously reduces the concentration of oxygen in the air surrounding the fire site. Carbon monoxide is the result of incomplete combustion of a fuel. It is very hazardous as it inhibits the blood’s capacity to carry oxygen and interferes with the exchange of oxygen in the blood. Even in low concentrations, carbon monoxide can be lethal. Sometimes, there are other toxic fumes such as sulphur dioxide, nitrogen dioxide, hydrogen chloride, hydrogen sulphide, and ammonia in the air, depending on the elements of the burning fuel. Table 12.3 illustrates the products of combustion.

### Activity 12.1

Apart from the above classification, there are also other techniques that can be used to determine classes of fire. For more information, visit the following website:

http://www.nfpa.org

---

### 12.3 Fire Danger to Humans

#### Self-Check 12.3

Fire fumes are dangerous, but how damaging can they be? What will happen if you inhale carbon monoxide? What about nitrogen dioxide?
### Table 12.3: Products of Combustion

<table>
<thead>
<tr>
<th>Product</th>
<th>Fuel</th>
<th>Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrolein</td>
<td>Cellulose, fatty substances, woods and paints.</td>
<td>Highly toxic irritant to eyes and respiratory system.</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>Wool, silk, nylon, melamine and refrigerants.</td>
<td>Toxic irritant to eyes and respiratory system.</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>All carbon and organic compounds.</td>
<td>Not toxic but depletes available oxygen.</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>All carbon and organic compounds.</td>
<td>Can be deadly.</td>
</tr>
<tr>
<td>Hydrogen sulphide (H₂S)</td>
<td>Sulphur-containing compounds, rubber and crude oil.</td>
<td>Highly toxic gas.</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>Cellulose nitrate, celluloid, textiles, and other nitrogen oxides.</td>
<td>Lung irritant, causing death or damage.</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>Sulphur and sulphur-containing compounds.</td>
<td>Toxic irritant.</td>
</tr>
</tbody>
</table>

**DETECTION OF FIRE HAZARDS**

A protection system can be operated effectively through an early fire detection system and the implementation of preventive measures. The main purpose of fire detection is to reduce injuries and damage to properties. Early detection allows factory operators to follow the prevention and control procedures such as closing a fuel leakage, activating the fire or toxic protection system, and facilitating the emergency action plan to save workers.

Visit [http://burnsurvivor.com/burn_types.html](http://burnsurvivor.com/burn_types.html) for more information on the effects of fire hazards on humans and how to treat them.
There are various fire detection systems in the market. Selecting a system depends on the type of the fire which might occur. Figure 12.7 lists some of these systems that can be found in the market.

There are several important features that must be taken into consideration when choosing a fire detection system. Table 12.4 shows some of the features.

**Table: 12.4: Feature that Must be Taken into Consideration When Choosing a Fire Detection System**

<table>
<thead>
<tr>
<th>No</th>
<th>Feature to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Accuracy:</strong> Shows an accurate value within an acceptable margin of error.</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Stability:</strong> Long-term stability and accuracy over extended periods at different temperature and humidity levels.</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Repeatability:</strong> Provides same measurement on different occasions.</td>
</tr>
<tr>
<td>4.</td>
<td><strong>Sensitivity:</strong> Minimum value of detection.</td>
</tr>
<tr>
<td>5.</td>
<td><strong>Response time:</strong> Time elapsed between exposure and full detection.</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Recovery time:</strong> Time required by the detector to show a value after a sudden decrease or increase in value.</td>
</tr>
<tr>
<td>7.</td>
<td><strong>Selection of type of gas for detection:</strong> Ability to separately measure the concentration of a specific gas without the interference of other gases.</td>
</tr>
<tr>
<td>8.</td>
<td><strong>Self-safety:</strong> Gas detector in a flammable environment must not be a source of ignition.</td>
</tr>
<tr>
<td>9.</td>
<td><strong>Easy to determine measurement, use and maintain:</strong> An effective detector is one that is easy to determine measurement, use and maintain.</td>
</tr>
<tr>
<td>10.</td>
<td><strong>Reliability:</strong> Capable of measuring the mean time between failures (MTBF), fail-safe and fail-deadly functions.</td>
</tr>
</tbody>
</table>
The type of fire detection system to be used depends on the type of the potential fire. Other considerations include the physical environment in which the system is installed and the cost of purchasing such a system. A good way of installing fire sensors is to consider the distance between them such that they are not too far apart to quickly detect any fire breakouts. Other considerations include the physical arrangement of the area, the starting point of fire and the expected wind movement.

The location of an alarm system will depend on the expected location of the fire, the location of trained personnel and the nature of the surrounding. Audible alarms such as horns and bells are very suitable for noisy working areas. For very noisy workplaces, alarms with lights are often used. Alarms must be placed at locations where fire might break out and close to areas often visited by personnel trained in fire control. Figure 12.8 shows an example of an audible alarm, a bell.

![Figure 12.8: An audible alarm such as a bell is suitable to be used in fire detection systems](image)

Both the fire detection device and alarm must be combined together to form a control system which controls the fire detection system and activates the emergency alarm. Electricity must be supplied to the control system so that the fire detection system and alarm will function properly. Fire control systems at workplaces will normally activate the fire protection system and shut off critical operations at the place of the incident.

Fire detection systems, alarms and fire control systems must be selected based on manual or automatic response requirements. Alarm systems range from the most basic type to the sophisticated automatic type which can be connected to the closest fire station. Effective safety steps can be taken if fire safety officers are able to identify the location of the fire, the amount of hazardous materials involved, the situation of the fire and the steps which can be taken before the arrival of the fire service to the place of incident.
REDUCING FIRE HAZARDS

The best way to reduce fires is to prevent them. A major cause of industrial fires is hot, poorly insulated machinery and processes. One means of reducing a fire hazard is the isolation of the three triangle elements: fuel, oxygen and heat. In the case of fluids, closing a valve may effectively cut off the fuel supply.

Fires may also be prevented by proper storage of flammable liquids. There are three ways to store flammable liquids as shown in Table 12.5.

<table>
<thead>
<tr>
<th>No</th>
<th>Ways to Store Flammable Liquids</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>In flame-resistant buildings that are isolated from places where people work. Proper drainage and ventilation should be provided for such buildings.</td>
</tr>
<tr>
<td>2.</td>
<td>In tanks below ground level.</td>
</tr>
</tbody>
</table>

Substituting flammable materials with less flammable ones is another effective technique for fire reduction. For example, concentrated hydrochloric acid used in processing activities can be substituted with tetrachloride carbon which is less dangerous and small atom polymers can be substituted with larger polymer pallet. Apart from that, for dangerous substances that cannot be substituted with other substances, fire reduction can be achieved by producing them at the workplace so as to prevent accidents during transportation or storage. Raw materials used to produce dangerous or highly flammable products should be non-combustible or hardly flammable so that they will be safer for transport. For example, chlorine can be produced locally as it is highly toxic, unstable, difficult to store and transport.

ACTIVITY 12.3

Look around your workplace. Identify where the fire detectors are placed.
Furthermore, ignition sources around the workplace must also be eliminated or isolated from fuels. Listed in Table 12.6 are some steps to follow.

**Table 12.6: Steps to Eliminate Ignition Sources**

<table>
<thead>
<tr>
<th>No</th>
<th>How to Eliminate Ignition Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Prohibit smoking near any possible fuels.</td>
</tr>
<tr>
<td>2.</td>
<td>Store fuels away from areas where electrical sparks from equipment, wiring or lightning may occur.</td>
</tr>
<tr>
<td>3.</td>
<td>Keep fuels separate from areas where there are open flames. These may include welding torches, heating elements, or furnaces.</td>
</tr>
<tr>
<td>4.</td>
<td>Isolate fuels from tools or equipment that may produce mechanical or static sparks.</td>
</tr>
</tbody>
</table>

Other strategies for reducing the risk of fires are as follows:

(a) Clean up spills of flammable liquids as soon as they occur.

(b) Keep work areas free from extra supplies of flammable materials (e.g., paper, wood, and so on). Have only what is needed on hand with the remaining inventory properly stored.

(c) Run electrical cords along walls rather than across aisles or areas with heavy human traffic. Cords that are walked on can become frayed and dangerous.

(d) Turn off the power and completely de-energise equipment before conducting maintenance procedures.

(e) Do not use spark- or friction-prone tools near combustible materials.

(f) Routinely test fire extinguishers.
In larger or isolated industrial facilities, the employees themselves may form fire fighting teams or fire brigades consisting of trained personnel. Nevertheless, forming a fire brigade is not an easy task and can be quite expensive. Therefore, a wise and economical step will be to create a fire extinguishing system at the workplace.

This system can include various fire extinguishing equipment depending on the type of fire anticipated and the cost involved. Generally, there are four methods of extinguishing fires, namely:

(a) Cooling.
(b) Reducing fuel by cooling, diluting, smothering and shielding.
(c) Reducing oxygen by using foam.
(d) Breaking the chain of fire reaction by using chemicals.

Table 12.7 illustrates the different types of fire extinguishers which are suitable for the corresponding types of fire.
Table 12.7: Fire Extinguishers According to Fire Class

<table>
<thead>
<tr>
<th>Fire Class</th>
<th>Type of Fuel</th>
<th>Example</th>
<th>Extinguishing Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Typical fuel</td>
<td>Wood, paper, textile and plastic.</td>
<td>Water, dry chemical and foam</td>
</tr>
<tr>
<td>B</td>
<td>Flammable liquid and gas</td>
<td>Gasoline, oil, grease and liquefied petroleum gas.</td>
<td>CO₂, dry chemical, foam and halone</td>
</tr>
<tr>
<td>C</td>
<td>Electrical appliances in operation</td>
<td>Electrical motors</td>
<td>CO₂, dry chemical and halone</td>
</tr>
<tr>
<td>D</td>
<td>Flammable metals</td>
<td>Magnesium, sodium and potassium.</td>
<td>Dry chemical powder</td>
</tr>
</tbody>
</table>

Water-based extinguishers are the most common extinguishers at the workplace. Not only are they cheap and easily available, but also not toxic and would not produce toxic substances due to fire. They are also capable of absorbing heat effectively and extinguishing fire. However, using water-based extinguishers have some negative effects, among which is the fact that it may react with certain hazardous materials and produce toxic gases. Furthermore, water cannot be used to put out fire caused by electric sparks, as it is an electrical conductor and might endanger the lives of the rescuers. Water-based fire extinguishers include fire brigade hydrants and hoses, and water sprinklers in buildings. Building designers are required to provide an effective fire extinguishing system in all building designs. Fire hydrants and hoses are normally placed in buildings. Such a system provide hoses with high water pressure to combat fire.

Apart from that, automatic permanent sprinklers installed in buildings can react quickly when a fire breaks out and prevent it from spreading. This system consists of sprinkler heads that are classified according to activation temperatures and times during fire incidents. Water sprinklers must be designed so that their heads are supplied with water at the same pressure. Therefore, they require balanced piping by using pipes of the same shape for all sprinkler heads.
There are also portable fire extinguishers which are classified according to the
types of fire they act on. These extinguishers can be seen around homes and
workplaces. These cylinder-shaped extinguishers, which are normally hung on
walls, include extinguishers which contain sodium bicarbonate and calcium
bicarbonate – both dry chemical agents. They serve to break the progress of fires.
The bicarbonate chemical agent will release carbon dioxide when heated by the
fire. The released gas will snuff out the fire, while the dry powder covers the
burning liquid and cools it down. Meanwhile, the powder also reduces the
transfer of heat between the liquid and fire. Figure 12.9 illustrates a fire
extinguisher often seen at the workplace.

![Fire Extinguisher](http://search.msn.com/images/results.aspx?q=fire+&first=41&count=20&size=fp&color=both&FORM=PEIR2)

Employers and building owners are responsible for choosing suitable fire
extinguishers based on the anticipated type of fire that may occur. The correct
choice is important to ensure that fire can be extinguished if it happens. In
addition, employers and building owners are also responsible for ensuring that
all fire extinguishers are in good working condition, regularly maintained, and
can be used effectively in the event of an emergency. Fire drills must also be
conducted regularly so that the employees or building occupants know how to
use them when needed.

**Activity 12.4**

Here is one way to enhance your understanding of the use of fire
extinguishers: list the fire extinguishers installed at your workplace and
indicate where they are located.
12.7  FIRE SAFETY PROGRAMME

As the saying goes, prevention is better than cure. This principle is certainly valid in fire safety management. At the beginning of this course, we discussed the basic concepts of prevention applied in design, education and enforcement. The same concepts apply in a fire safety programme. Section 15 of the Occupational Safety and Health Act 1994 requires employers to look after the safety, health and well-being of their employees.

There are four components that must be included in the programme to ensure its effectiveness: assessment, planning, awareness and prevention, and response. Figure 12.10 illustrates these four main components.

![Figure 12.10: Fire safety programme](image)

To effectively develop, implement, and maintain a comprehensive fire safety programme, the first step is to establish a cross-functional fire safety committee. By “cross functional”, we mean that it should have members from all the departments or functional units within the organisation. It should also have at least one high-level manager to facilitate smooth implementation, as well as represent the management’s support.

12.7.1  Assessment

Assessment of the workplace for fire hazards should be an ongoing exercise. Although the organisation’s safety and health professionals will have primary responsibility for this, committee members should also involve the departments that they represent in ensuring that the programme is effective. Members of the safety committee should be trained in the fundamentals of fire hazard assessment by the safety and health professionals. They should then pass this
knowledge on to employees in their departments, units and teams so that they can participate in the assessment process. This is because they are the only ones who would truly understand where the risks are, and could help identify all the potential hazards at their workplace.

12.7.2 Planning

The provisions of the Occupational Safety and Health Act 1994 requires that an organisation’s emergency fire safety plan has at least the following components:

(a) Emergency escapes procedures and routes;
(b) Critical shutdown procedures;
(c) Employee headcount procedures;
(d) Rescue and medical procedures;
(e) Procedures for reporting fires and emergencies; and
(f) Important contact personnel for additional information.

Once the plan is in place, it should be reviewed at least annually and updated as necessary.

12.7.3 Awareness and Prevention

Once the fire safety plan has been drawn up and endorsed by the senior management, it is time to get all employees familiarised with the plan. They should receive awareness training so that they understand their roles in carrying out the emergency plan. To monitor whether the training is effective, the fire safety committee should evaluate the training programme periodically, using guidelines such as the following:

(a) Do all employees know their roles in implementing the emergency plan?
(b) How are employees with disabilities provided for?
(c) Do all employees understand the escape plans? Evacuation procedures?
(d) Do all new and temporary employees receive training?
(e) Are all employees informed when the plan is revised?
(f) Is a comprehensive fire drill undertaken at least once each year?
(g) Are all employees familiar with the sound of the alarm system?
(h) Is the alarm system checked periodically?
(i) Are sufficient fire detection devices in place? Are they tested periodically?
(j) Do all employees know the most likely causes of fires at the workplace?

12.7.4 Response

Accidents can happen in even the most heavily protected organisations. Therefore, it is important that employees understand the emergency plan and be familiar about how to respond correctly when accidents happen.

People do not always think clearly in an emergency situation. They will, however, do what they have learned through practice. Thus, one of the fire safety committee’s most important responsibilities is to arrange periodic drills so that employees will be prepared to respond properly during emergencies.

A fire will exist if there is adequate supply of oxygen, fuel, and a source of ignition.

Based on the Fire Triangle, the three elements, i.e. fuel, oxygen and source of ignition must be present to start a fire.

Fire detection systems that can be found in the market are smoke sensors, gas detectors, fire detectors and heat detectors.

Ten important features to be taken into consideration when choosing a fire detection system are: accuracy; stability; repeatability; sensitivity; response time; recovery time; selection of type of gas for detection; self-safety; easy to determine measurement, usability and maintenance; and reliability.

The four main components that must be included in a fire safety programme are assessment; planning; awareness and prevention; and response.

ACTIVITY 12.5

To help you understand better, draw a simple diagram of the activities that can be included in a fire safety programme.

SUMMARY

- A fire will exist if there is adequate supply of oxygen, fuel, and a source of ignition.
- Based on the Fire Triangle, the three elements, i.e. fuel, oxygen and source of ignition must be present to start a fire.
- Fire detection systems that can be found in the market are smoke sensors, gas detectors, fire detectors and heat detectors.
- Ten important features to be taken into consideration when choosing a fire detection system are: accuracy; stability; repeatability; sensitivity; response time; recovery time; selection of type of gas for detection; self-safety; easy to determine measurement, usability and maintenance; and reliability.
- The four main components that must be included in a fire safety programme are assessment; planning; awareness and prevention; and response.
**TOPIC 12  FIRE HAZARDS**

**KEY TERMS**

- Fire detection system
- Fire extinguisher
- Fire triangle
- Flammability
- Fuel
- Ignition
- Oxygen
- Spontaneous combustion

**SELF-TEST 1**

**Essay Questions**

1. Where can carbon be found in a combustion process?

2. Explain the difference between carbon monoxide and carbon dioxide.

3. List three elements found in the Fire Triangle.

4. Explain three techniques of heat transfer.

5. Explain three strategies to prevent and reduce fire hazards at the workplace.

---

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Lower Flammability Unit (LFL) (%ip/ip)</th>
<th>Upper Flammability Unit (UFL) (%ip/ip)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>Acetylene</td>
<td>2.6</td>
<td>100</td>
</tr>
<tr>
<td>Benzene</td>
<td>1.4</td>
<td>8.0</td>
</tr>
<tr>
<td>Butane</td>
<td>1.8</td>
<td>8.4</td>
</tr>
<tr>
<td>Ethane</td>
<td>3.0</td>
<td>12.4</td>
</tr>
<tr>
<td>Methane</td>
<td>5.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>1.3</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Based on the above table, which fuel has a higher risk of causing fire?
True (T) or False (F) Statements

1. Carbon is an element in the Fire Triangle.
2. The products of combustion are in the form of light.
3. Chemical reactions break down chemical compounds into simpler substances.
4. Exothermic reaction creates light.
5. Carbon monoxide is a lethal, colourless and odourless gas.
INTRODUCTION

Noise hazards are increasingly receiving the attention of safety and health professionals today. Noise causes two safety and health-related problems. The first is loss of concentration on the task being performed, thus causing workplace accidents. The second is hearing loss. Exposure to noises exceeding the permitted level may cause permanent hearing damage.

13.1 CHARACTERISTICS OF SOUND

Before we look at noise pollution, let us discuss first how sound is created. Refer to Figure 13.1 to understand what is meant by sound.

SELF-CHECK 13.1

How is a sound wave created? Is there any relation between sound and vibration?
Sound is a change in air pressure. However, it can also be a change in water pressure or any other pressure-sensitive medium. Music is sound which is nice to listen to. Noise, on the other hand, is unwanted sound. Consequently, the difference between noise and sound is in the perception of the person hearing it. Loud rock music may be considered “sound” by a rock fan but “noise” by a person trying to pray.

Sound and vibration are very similar. Sound typically relates to a sensation that is perceived by the inner ear as hearing. Vibration, on the other hand, may be inaudible and is perceived through the sense of touch. Sound can occur in any medium that has both mass and elasticity such as air, water, and so on.

Noise and vibration are often associated with the process of drilling rocks and concrete. Although technology has helped to design air compressors and drills which can reduce the worker’s exposure to noise and vibration, the level of exposure to noise remains above 90dBA.

The unit of measurement used for discussing the level of sound and, correspondingly, what noise levels are hazardous is the decibel, or one-tenth of a bel. One decibel represents the smallest difference in the level of sound that can be perceived by the human ear. The weakest sound that can be heard by a healthy human ear in a quiet setting is known as the threshold of hearing (10dBA). The maximum level of sound that can be perceived without experiencing pain is known as the threshold of pain (140dBA).
13.2 HAZARD LEVELS AND RISKS

Figure 13.2 shows the effect of being exposed to excessive noise.

The fundamental hazard associated with excessive noise is hearing loss. Exposure to excessive noise levels for an extended period can damage the inner ear so that the ability to hear high-frequency sound is diminished or lost altogether. Additional exposure can increase the damage until even lower frequency sounds cannot be heard.

Although researches on the effects of noise are still incomplete, they show that excessive noise can cause the heart to beat faster, increasing blood pressure and limiting blood flow. This additional pressure increases the burden of the heart and may cause heart diseases.
A number of different factors affect the risk of hearing loss associated with exposure to excessive noise. The most important of these are listed in Figure 13.3.

Figure 13.3: Factors that can increase the risk of hearing loss

Of these various factors, the most critical are the sound level, frequency, duration, and distribution of noise. The unprotected human ear is at risk when exposed to sound levels exceeding 115dBA. Exposure to sound levels below 80dBA is generally considered safe. Prolonged exposure to noise levels higher than 80dBA should be minimised through the use of appropriate personal protective devices.

13.2.1 Standards and Regulations

The primary sources of standards and regulations relating to noise hazards are the Occupational Safety and Health Administration (OSHA), and the American National Standards Institute (ANSI). OSHA regulations require the implementation of hearing conservation programmes under certain conditions. OSHA’s regulations should be considered as minimum standards. ANSI’s standard provides a way to determine the effectiveness of hearing conservation programmes such as those required by OSHA. The ANSI standard and OSHA regulations are discussed in Table 13.1.
Table 13.1: ANSI Standards and OSHA Regulations

<table>
<thead>
<tr>
<th>ANSI Standards</th>
<th>OSHA Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>In 1991, the American National Standards Institute (ANSI) published ANSI Standard S12.13–1991. Titled “Evaluation of Hearing Conservation Programs”, this standard was designed to help safety and health professionals determine if hearing conservation programmes work as they are intended. Federal regulations require that employees be protected from excessive noise in the workplace. However, they provide no methodology for determining the effectiveness of hearing conservation programmes. The primary reason for the development of ANSI S12.13–1991 was that conservation programmes were not actually protecting employees but were only recording their steadily declining hearing ability. The working group that developed the standard used audiometric database analysis (ADBA) to identify procedures for measuring variability in hearing threshold levels.</td>
<td>In 1983, OSHA made the Hearing Conservation Amendment to OSHA 29 C.F.R.1910.95 which requires employers to conduct hearing programmes at workplaces where the noise level is or exceeds an eight hour time-weighted average of 85dBA. Employers are required to apply the hearing conservation procedures at workplaces where the level of noise exceeds a time-weighted average of 90dBA. They are also required to provide personal protective equipment to workers who show signs of hearing loss, regardless of the noise level at the workplace. Apart from noise level, OSHA also takes into account the exposure time.</td>
</tr>
</tbody>
</table>
Identifying and assessing hazardous noise conditions in the workplace involve the activities listed in Figure 13.4.

Figure 13.4: Four methods of identifying and assessing hazardous noise conditions

13.3.1 Noise Surveys

Conducting noise surveys involves measuring noise levels at different locations in the workplace. The devices that are most widely used to measure noise levels are sound level meters and dosimeters. A sound level meter produces an immediate reading that represents the noise level at a specific instance in time.

A dosimeter provides a time-weighted average over a period of time such as one complete work shift. The dosimeter is the most widely used device because it measures total exposure, which is what OSHA and ANSI standards specify.

Figure 13.5: A dosimeter is a device used to measure noise levels
Source: http://www.safetyinstrumentati....com/images/NoiseDosimeter.jpg
13.3.2 Audiometric Testing

Audiometric testing measures the hearing threshold of employees. Tests conducted according to ANSI S12.13 can detect changes in the hearing threshold of the employee. A negative change represents hearing loss within a given frequency range.

13.3.3 Record Keeping

All forms should be completed and kept on file to allow for subsequent comparisons. It is also important to retain records containing a worker’s employment history, including all past positions and the work conditions in those positions.

13.3.4 Follow-up

According to Breisch:

A significant weakness related to audiometric control at the workplace is the failure of employers to take action at the earliest stage to monitor hearing loss due to noise.

Hearing loss can occur without producing any evidence of physiological damage. Therefore, it is important to follow up on even the slightest evidence of a change in an employee’s hearing threshold.

13.4 NOISE CONTROL STRATEGIES

Noise can be reduced by engineering and/or administrative controls applied to one or more of these components. The most desirable noise controls are those that reduce noise at the source. The second priority is to reduce noise along its path. The last resort is noise reduction at the receiver end, using personal protective devices. The last approach should never be substituted for the other two approaches.
13.4.1 Engineering Controls

Engineering controls are steps taken to reduce the sound level at the source or within the hearing zone of the workers. These controls focus primarily on the noise rather than the employees who are exposed to it. Table 13.2 presents some examples of engineering controls.

<table>
<thead>
<tr>
<th>No.</th>
<th>Example of Engineering Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Replacement or adjustment of worn, loose, or unbalanced parts of machines.</td>
</tr>
<tr>
<td>2.</td>
<td>Substitution of larger, slower machines for smaller, faster ones.</td>
</tr>
<tr>
<td>4.</td>
<td>Substitution of belt drives for gears.</td>
</tr>
<tr>
<td>5.</td>
<td>Substitution of compression riveting for impact riveting.</td>
</tr>
</tbody>
</table>

13.4.2 Administrative Controls

There are many operations in which the exposure of employees to noise can be controlled administratively, that is, production schedules can simply be changed or jobs can be rotated so that exposure periods are reduced. This includes such measures as transferring employees from a job location with a high noise level to a job location with a lower one if this procedure would make the employee’s daily noise exposure acceptable.

13.4.3 Hearing Protection Devices

In addition to engineering and administrative controls, employees should be required to use appropriate hearing protection devices (HPDs). The following are some HPDs which are widely used:

(a) Enclosures
(b) Ear plugs
(c) Superaural caps
(d) Earmuffs
Vibration hazards are closely associated with noise hazards because tools that produce vibration typically also produce excessive levels of noise. The strategies for protecting employees against the noise associated with vibrating tools are the same as those presented so far in this topic. This section focuses on other safety and health hazards associated with vibration.

The types of injuries associated with vibration depend on its source. For example, workers who operate heavy equipment often experience vibration over the whole body. This can lead to problems ranging from motion sickness to spinal injury. However, the most common vibration-related problem is known as hand-arm vibration syndrome or HAV.

This condition, which is a form of Reynaud’s Syndrome, has struck an alarming number of workers who used vibrating power tools all day long as part of their jobs. For HAV sufferers, the sensations in their hands are more than just minor, temporary discomfort. They are symptoms of the potentially irreversible damage their nerves and blood vessels have suffered. As the condition progresses, it takes less and less exposure to vibration or cold to trigger the symptoms, and the symptoms themselves become more severe and crippling.

Modern safety and health professionals must know how to prevent vibration-related injuries. Prevention is especially important with HAV because the disease is thought to be irreversible. This does not mean that HAV cannot be treated, but the treatments developed to date can only reduce the symptoms. They do not cure the disease. Figure 13.6 illustrates preventive strategies which can be used by safety and health professionals in any company regardless of its size.

**SELF-CHECK 13.5**

Can a worker be given a hearing protection device without identifying and assessing first the noise hazard to which he is exposed? Why?
Hearing loss is a main concern for safety and health practitioners. However, hearing loss is not the only detrimental effect of excessive noise. Noise can also cause communication, isolation and productivity problems. Vibration hazards affect workers who use tools that produce vibration in their work. Vibration can cause damage to the nerves and blood vessels. It is the responsibility of employers with the assistance of the safety and health officers to create and implement a policy which can reduce workers’ exposure to noise and vibration hazards.
Essay Questions

1. Explain briefly the difference between noise and vibration.

2. State four techniques to identify and assess hazardous noise conditions at the workplace.

3. Continuous exposure to noise is dangerous for workers. As a safety and health officer, explain three ways of controlling noise at the workplace.

4. Prevention is better than cure. Explain three strategies to prevent vibration hazards at the workplace.

True (T) or False (F) Statements

1. Sound can be produced by any change in water pressure or any medium sensitive to pressure.

2. The unit of measurement used when discussing the level of sound is the megahertz.

3. The maximum level of sound that can be perceived without experiencing pain is 140dBA.
4. Noise hazards cannot be linked to heart disease.

5. The most common vibration-related problem is known as hand-arm vibration syndrome.

6. Replacement or adjustment of worn, loose, or unbalanced parts of machines is a good form of administrative control.

7. The device used to measure noise levels is known as the dosimeter.
This topic discusses the legal aspects of occupational safety and health. The latest Act on workplace safety and health is the Occupational Safety and Health Act 1994, Act No. 514. Safety and health professionals must adhere to Act 514 in order to ensure a healthy and safe workplace for workers.
14.1 LEGAL STRUCTURE

Law and law enforcement are important to maintain a just environment. The Occupational Safety and Health Act 1994 (Act 514) was promulgated by the Malaysian Government to ensure that workers remain protected. There are three important legal structures in occupational safety and health. What are these structures? How does Act 514 play its role?

The Occupational Safety and Health Act 1994 consists of three important structures, that is, the Act, regulations and code of practice. Figure 14.1 explains these structures.

**Figure 14.1:** The Act, regulations and code of practice are three important structures of the Occupational Safety and Health Act 1994

### Act
Under the Act, there are 15 parts with 67 provisions and three schedules.

### Regulations
There are six regulations and two orders with the purpose of providing detailed explanations on several provisions under the Act.

### Code of Practice
The code of practice serves as a guide to comply with the provisions of Act 514.

14.2 PRINCIPLES OF THE OCCUPATIONAL SAFETY AND HEALTH ACT 1994 (ACT 514)

Act 514 is based on a self-regulation concept which implies that those who create risks and work with risks are responsible for ensuring safety and health at the workplace. People who create risks are employers while those who work with risks are the employees.
14.3 OBJECTIVES OF ACT 514

Act 514 has four main objectives, namely:

- To secure the safety, health and welfare of persons at work against risks to safety or health arising out of the activities of persons at work;
- To protect persons at a place of work other than workers against risks to safety or health arising out of the activities of workers;
- To promote an occupational environment for persons at work which is adapted to their physiological and psychological needs; and
- To provide the means whereby the associated occupational safety and health legislations may be progressively replaced by a system of regulations and approved industry codes of practice operating in combination with the provisions of this Act designed to maintain or improve the standards of safety and health.

14.4 APPLICATION OF THE ACT

This Act shall apply throughout Malaysia to the industries specified in Figure 14.2.

Figure 14.2: The 10 industries specified in Act 514
Although Act 514 applies to all industries in Malaysia, it does not apply to the two categories shown in Figure 14.3.

**Figure 14.3:** The two industries which are not subject to Act 514

### 14.5 IMPORTANT PROVISIONS IN ACT 514

The following are some of the important provisions in Act 514:

(a) The general duties of employers and self-employed persons, occupiers of place of work, employees, designers, formulators, manufacturers and suppliers and labour unions.

(b) Medical surveillance.

(c) Safety and health officers.

(d) Safety and health committee.

**SELF-CHECK 14.2**

By now, you should have known that the party that creates risks is the employer while the party that faces the risks are the employees. Now try to explain what employers should do to protect their employees from hazards. Is the role of the employer limited to implementing a safe work system? What if the employees find many improper wiring at the workplace? Can employers dismiss an employee for reporting such incidents to members of the Occupational Safety and Health Committee?
14.5.1 General Duties

(a) **Employers and Self-employed Persons**
Every employer and every self-employed person must adhere to Act 514 to ensure the safety, health and welfare of all employees at work. Their duties are as follows:

(i) The provision and maintenance of plant and systems of work that are, as far as is practicable, safe and without risks to health.

(ii) Making arrangements for ensuring safety and absence of risks to health in connection with the use or operation, handling, storage and transport of plant and substances.

(iii) Providing information, instruction, training and supervision to employees.

(iv) Ensuring that the access to and exit from the place of work are safe and without risks.

(v) The provision and maintenance of a work environment that is safe and without risks to health.

(vi) To prepare and revise a written statement of the general policy with respect to the safety and health at work from time to time.

(vii) To ensure that he and other persons not being his employees are safe and not exposed to risks to their safety or health due to the conduct of his undertaking by giving the prescribed information on such aspects of the manner in which he conducts his undertaking as might affect their safety or health.

(viii) To provide personal protective equipment (PPE) to workers who need them without any charges for the PPE provided.

(ix) To establish a safety and health committee at the workplace.

(x) To cooperate with the safety and health committee in ensuring the safety and health of employees.
(xi) Not to discriminate any employee by way of dismissal, causing injury or demotion if the employee:

- Makes a complaint about a matter which he considers is not safe or is a risk to health.
- Is a member of a safety and health committee at the workplace.
- Exercises any of his functions as a member of the safety and health committee at the workplace.

(xii) To report any accident, dangerous incident, occupational poisoning or sickness to the Department of Occupational Safety and Health.

(xiii) To assist the officer of the Department of Occupational Safety and Health during inspections.

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(b) **Workplace Occupiers**

To ensure that other persons at the premises are safe and without risks to health by:

(i) Ensuring that the premises are safe.

(ii) Ensuring that all access to and exit from the premises are safe.
(iii) Ensuring that the plant and all the substances in the premises are safe and without health risks.

(iv) Employing a competent person to act as a safety and health officer at the place of work.

(c) Employees

(i) To cooperate with the employers in complying with Act 514.

(ii) To comply with any instructions or measures on occupational safety and health at the workplace.

(iii) To use the personal protective equipment (PPE) supplied by the employer to prevent risks to health.

(iv) Not to misuse or interfere with anything provided or done by the employer in the interests of safety, health and welfare of employees.

(d) Designers, Manufacturers, Formulators and Suppliers

It shall be the duty of the person who designs, manufactures, imports or supplies any plant for use at work:

(i) To ensure that the plant is so designed and constructed as to be safe and without risks to health when properly used.

(ii) To carry out testing and examination on the plant.

(iii) To secure information on the plant so that it will be safe and without risks to health.

(iv) From time to time, carry out any necessary research with a view to the discovery and the elimination or minimisation of any risk to safety or health, to which the design or plant may give rise.

(v) To ensure that nothing about the way in which it is erected or installed makes it unsafe or a risk to health when properly used.
It shall be the duty of a person who formulates, manufactures, imports or supplies any substance for use at work:

(i) To ensure that the substance is safe and without risks to health when properly used.

(ii) To carry out testing and examination to ensure the safety of the substance before it is used.

(iii) To provide relevant information on substances to ensure that they will be safe and without risks to health when properly used.

(iv) To carry out any necessary research with a view to the discovery and the elimination or minimisation of any risk to safety or health to which the substance may give rise.

(e) Trade Unions

No trade union shall take any action on any of its members who, being an employee at a place of work:

(i) Makes a complaint about a matter which he considers is not safe or is a risk to health.

(ii) Is a member of a safety and health committee at the workplace.

(iii) Exercises any of his functions as a member of the safety and health committee at the workplace.

14.5.2 Medical Surveillance

Employers must always ensure that their employees carry out their work in a safe and healthy manner in order to avoid risks to their health. Therefore, employers must protect their employees against illnesses due to the nature of the process or substance used in a process. Persons below the age of 16 years must be prevented from work which may cause risk of injury. As for employees involved in occupations of special risk such as those listed in Figure 14.5, they must be protected by their employers against risks to health. In order to prevent occupational illnesses and injury, employers must carry out medical surveillance on employees particularly those who are involved in occupations of special risk.
14.5.3 Occupational Safety and Health Officer

All industries classified under the Occupational Safety and Health (Safety and Health Officer) Regulation 1997 must employ a qualified safety and health officer in order to ensure compliance with the provisions of Act 514. The types of industries which are subject to Act 514 are as follows:

(a) Building operation with total contract price exceeding RM20 million;
   “Building operation” means the construction, structural alteration, repair or maintenance of a building, including repainting, redecoration and external cleaning of the structure, the demolition of a building, and the preparation for and the laying of foundation of an intended building.

(b) Works of engineering construction where total contract price exceeds RM20 million;
   Here, it means the construction of any railway line or siding and the construction, structural alteration or repair including repointing and repainting or the demolition of any dock, harbour, inland navigation, tunnel, bridge, viaduct and waterworks.
(c) Ship building employing a peak of more than 100 employees; “Peak” means the time where the maximum possible number of workers are working at the site.

(d) Gas processing or petrochemical industries employing more than 100 employees; “Employees” includes an independent contractor engaged by an employer or a self-employed person and any employee of the independent contractor.

(e) Chemical and allied industries employing more than 100 employees;

(f) Boiler and pressure vessel manufacturers employing more than 100 employees;

(g) Metal industries with canning, stamping, blanking, shearing, bending operations and employing more than 100 employees;

(h) Wood industries with cutting, sawing, planning, moulding, sanding, peeling and employing more than 100 employees;

(i) Cement manufacturing employing more than 100 employees;

(j) Other manufacturing activities apart from (d) to (i), employing more than 500 employees.

The duty of a safety and health officer pursuant to the Act is as follows:

(a) To advise the employer on the measures to be taken in the interests of the safety and health of the persons employed in the place of work;

(b) To inspect the place of work;

(c) To investigate any accident, near miss accident, dangerous occurrence, occupational poisoning or occupational disease which has happened in the place of work;

(d) To assist the employer or the safety and health committee in organising and implementing occupational safety and health programme at the place of work;

(e) To become secretary to the safety and health committee;

(f) To assist the safety and health committee in any inspection of the place of work;
(g) To collect, analyse and maintain statistics on any accident, dangerous occurrence, occupational poisoning and occupational disease which have occurred at the place of work;

(h) To assist any officer in carrying on any matters pertaining to safety and health of the place of work.

(i) To submit a report on safety and health to the employer every month whereby the employer shall discuss the report with the safety and health officer after receiving the said report; and

(j) Other instructions pertaining to workplace safety and health issued from time to time.

14.5.4 Safety and Health Committee

Act 514 requires the employer to establish a safety and health committee at the workplace in order to ensure the safety, health and welfare of the employees. The committee is a formal structure in an organisation where the employer and employees can discuss and solve workplace safety and health problems. Figure 14.6 shows the conditions of establishing a safety and health committee.

Figure 14.6: The two conditions for the establishment of the safety and health committee

Membership of the committee, selection of committee members and functions of the committee are stipulated in the Occupational Safety and Health (Safety and Health Committee) Regulations 1996. Figure 14.7 explains the membership of the Safety and Health Committee.
Where there are 100 persons or less employed at a place of work, there shall not be less than two representatives each from the employees and the company management on the committee; and where there are more than 100 persons employed at the place of work, there shall not be less than four representatives each from the employees and the management.

An employer or his authorised manager shall be the chairman of a safety and health committee. The secretary of the committee shall be the person who is employed as the safety and health officer at the place of work. Where there is no person employed as a safety and health officer at the place of work, the chairman may appoint another person to act as the secretary of the committee or the members may, by ballot, appoint from amongst themselves the secretary of the committee.

The functions of the safety and health committee of a place of work are as follows:

(a) Develop safety and health rules and safe systems of work;

(b) Review the effectiveness of safety and health programmes;

(c) Carry out studies on the trends of accidents, near miss accidents, dangerous occurrences, occupational poisonings or occupational diseases which occur at the place of work, and report to the employer any unsafe or unhealthy condition or practices at the place of work together with recommendations for corrective actions;
(d) Review the safety and health policies at the place of work and make recommendations to the employer for any revision of such policies;

(e) Inspect the place of work at least once every three months to ascertain if there is anything prejudicial to the safety and health of persons employed therein;

(f) Investigate into any accident which occurs at the place of work;

(g) Investigate and solve any complaint made by any employee against any action or unsafe condition at the place of work;

(h) Assist the employer in any competition, talks on safety and health or any other activity related to safety and health;

(i) Take into consideration the following:
   - Any reports submitted by a safety and health officer;
   - The safety audits submitted by safety and health auditors;
   - The reports and factual information provided by occupational safety and health officers; and
   - The reports by other government agencies on matters pertaining to safety and health at a place of work.

(j) Form a sub-committee to assist the committee in the performance of its functions.

A safety and health committee shall meet at least once in three months. However, a meeting shall be called immediately in the event of an accident which results in loss of life or serious bodily injury to any person. An employer of a place of work shall provide a suitable place at the place of work for the safety and health committee to hold its meetings and permit every member of the committee to attend such meetings during work hours. At the inaugural meeting, the employer shall make known his safety and health policies, plans and proposals to establish safe and healthy work conditions at the place of work. Only matters relating to safety and health at the place of work shall be discussed at any meeting of a safety and health committee.
Compliance with the Occupational Safety and Health Act 1994, which is based on the self-regulation concept, has resulted in a reduction of workplace accidents and injuries.

This is due to the fact that employers, employees, workplace occupiers, suppliers and others have become more committed to their responsibilities relating to safety and health risks.

Summary:

- Compliance with the Occupational Safety and Health Act 1994, which is based on the self-regulation concept, has resulted in a reduction of workplace accidents and injuries.

- This is due to the fact that employers, employees, workplace occupiers, suppliers and others have become more committed to their responsibilities relating to safety and health risks.

Key Terms:

- Act: Occupational Safety and Health Act 1994
- Code of practice: Personal protective equipment (PPE)
- Medical surveillance: Regulations

Self-Test 1:

Essay Questions

1. Explain the concept of self regulation on which the Occupational Safety and Health Act 1994 is based.

2. State four of the duties of the safety and health officer in an organisation.

3. List the composition of the occupational safety and health committee.

4. Explain four of the functions of the occupational safety and health committee in an organisation.
True (T) or False (F) Statements

1. Self-regulation requires the involvement of employers only.

2. The code of practice is one of the main structures of the Occupational Safety and Health Act.

3. An organisation with 30 employees or less is not required to establish an occupational safety and health committee unless instructed to do so by the Director General of Occupational Safety and Health Department.

4. An occupational safety and health officer in an organisation must investigate any accident that occurs at the place of work.

5. An employer must dismiss any of his employees who makes a complaint about a matter which he considers is not safe or is a risk to health.