Ministry of Education and Science of Ukraine
Sumy State University

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OCCUPATIONAL SAFETY

Lecture notes

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
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Occupational safety

Lecture notes
for English-speaking students of faculty ELIT
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Department of Applied Ecology

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1.1 The legal framework for the regulation of occupational safety

1.1.1 Main objectives of occupational safety

Occupational safety is generally defined as the science of the anticipation, recognition, evaluation and control of hazards arising in or from the work place that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment. This domain is necessarily vast, encompassing a large number of disciplines and numerous workplace and environmental hazards.

Occupational health and safety are factors and conditions that can affect the well-being of persons within the workplace, i. e. employees, contractors, temporary workers and visitors.

Safety is the freedom from unacceptable risk from harm.

The failure to manage safety adequately all too often results in death or injury, chronic illness and damage to property and/or the environment. Such results have a significant impact on the physical and economic wellbeing of society. The actual industrial conditions are characterized, as a rule, by the presence of certain hazardous and harmful factors.

Dangerous factor is the industrial factor, the impact of which on the employee under certain conditions can lead to injury or other sudden health deterioration. Examples of hazards can be: open live parts of equipment, machine parts and mechanisms moving the red-hot parts and blanks, work with explosive substances, etc.

Harmful factor is the industrial factor, prolonged exposure of workers to which in certain conditions can lead to a disease or a decrease in efficiency. Examples of hazards are mechanical or toxic impurities in the air of the working area, adverse weather conditions, insufficient lighting, excessive vibration, noise, infrasound, ionizing and laser radiation, etc. Depending on the intensity and duration of harmful factor can become dangerous.

Accident at work is the result of dangerous industrial factor effect on a worker while performing job duties or job supervision.

Occupational disease is the result of long term effect of harmful industrial factor.

Danger zone is a space in which the effects on the running of hazardous and (or) harmful factors are possible.

Personal Protective Equipment (PPE) is tool designed to protect a single employee.

Collective Protective Equipment (CPE) is tool designed to protect two or more employees.

Promoting good standards of safety within an organization has three main reasons: moral, financial and legal.

The impact on victim persons and their families can be significant and wide ranging, e. g.:

- the emotional stress of seeing a family member suffer;
- financial hardship due to loss of earnings;
- the loss of social amenities;
- the potential requirement for the provision of long term care.

In addition to those directly affected, work colleagues and other witnesses of any serious work-related injury are proven to be susceptible to a number of related physiological disorders such as post-traumatic stress disorder (PTSD).

Regardless of whether people are injured or not, there will be a financial cost to organizations. The Accident Prevention Advisory Unit (APAU) of the Health and Safety Executive (HSE) has carried out extensive research into the cost of accidents at work, the results of which are summarized in the publication “The Cost of Accidents at Work (HS(G)96)”.

Some accident costs are obvious, e. g. compensation payments, property damage, damaged product, sick pay, etc. These costs are referred to in HS(G)96 as the direct costs. The indirect costs of accidents are not so obvious, e. g. replacement staff, investigation costs, poor publicity. In addition, many of the direct and indirect costs are not recoverable as insured losses.

1.1.2 Legislation on OS in Ukraine

Legislative acts which determine the main provisions of OS are general laws of Ukraine and special acts.

The fundamental laws of Ukraine which determine the main OS provisions are:

1) the Constitution of Ukraine;
2) the Labor Code of Ukraine;
3) the laws of Ukraine such as:

– “Mandatory state social insurance against occupational accidents and diseases which caused loss of work abilities”;

– “Labor Protection Act”;

– “Fundamentals of the Ukrainian legislation on health care”;

– “Fire Safety Act”;

– “Nuclear Power Application and Radiation Safety Act”;

– “Assurance of Sanitary and Epidemiological Security of Population Act”.

There are next special legislative acts on OS in Ukraine:

– labor protection normative acts;
– international standards of labor safety standards system;
– Ukrainian state standards;
– construction rules and regulations, state construction regulations;
– sanitary rules and regulations;
– rules of technical exploitation of consumer electrical devices;
– rules of safe exploitation of consumer electrical devices;
– radiation safety regulations of Ukraine.

1.1.3 EU legislation

Within the EU there are four basic types of legislation:

1. Regulations which have direct applicability in Member States and take precedence over national laws. They arise mainly in respect of the coal and steel industries. They are rarely used for health and safety matters but have been used on transboundary environmental matters.

2. Directives are the more usual EU legislation for health and safety issues. They do not have direct applicability but put an onus on Member States to incorporate their contents into national laws within a time scale specified in the directive.

3. Decisions and Recommendations relate to specific matters of local concern and apply directly to the Members States at whom they are directed.

The relationship between Acts, regulations, Orders, ACoPs and guidance notes is illustrated in Figure 1.1.

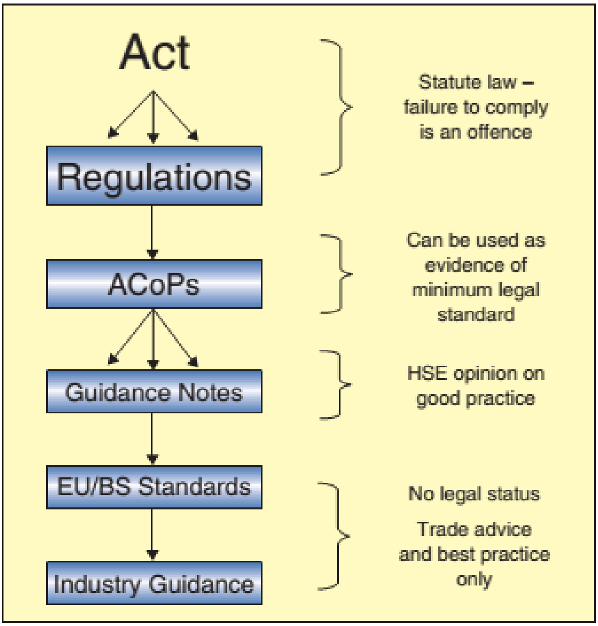


Figure 1.1 – Acts, Regulations, Orders, ACoPs and guidance notes

1.2 Employment legislation

The main purpose of employment legislation is to regulate the relationship between employer and employee and to determine the role and powers of trade union representatives in deciding the terms and conditions under which an employee has to work. It has become practice to include under the wing of 'industrial relations' anything that can affect the way in which an employee has to work, and in this respect safety has an important role to play.

There are some of the ways in which decisions and actions taken for safety reasons can materially affect the employee's working conditions and, conversely, the ways in which employment legislation can affect safety issues. For the safety adviser to be able to perform his duties properly he must be aware of the wider implications of the recommendations he makes, particularly in the field of working conditions.

The law governing industrial relations is extremely complex and covers much more ground than it has been possible to cover in this chapter, but the most important of the statutory provisions have been covered briefly and some of the ways in which their application can affect the employer–employee relationship have been shown.

Main Employer's Rights:

1) a forbidden job which is contra-indicated for health reasons according to the medical certificate;

2) works of increased danger and those which require professional selection are only permitted for employees holding a certificate of psycho-physiological examination;

3) a compulsory state social insurance against industrial accidents and occupational diseases which caused loss of work abilities;

4) working conditions at a workplace, safety of technological processes, machines, mechanisms, equipment and other means of personal protection must be in conformance with the legislation.

Employer's Liabilities:

1) establish special services and appoint officials who shall ensure solving specific labor protection issues;

2) ensure fulfillment of necessary safety precautions in accordance with newly-arisen circumstances;

3) introduce innovative technologies, scientific and technological advances, computer-aided production facilities, ergonomical requirements, positive experience in labor protection;

4) organize labor protection audit, laboratory testing of working conditions;

5) propagate safe work methods and collaboration with labor protection officials.

There are next types of compensations:

1) for work in harmful and severe working conditions:

– additional leave for 3–12 workdays;

– shortened workday down to 24–36 hours per week;

– increased wages;

– pension payments after the age of 45, 50, 55 years;

– additional 10-minute breaks (with warming or cooling depending on the kind of works) after every working hour;

– special nutrition, overalls, etc.

2) for the harm in case of employers' health damage or death:

– main payment is paid by the Social Insurance Fund against Accidents;

– additional payments are paid by employer to victims and their relatives at his own expense under the collective agreement or employment agreement;

– employees who lost their work ability through an accident or occupational disease preserve their job (position) and average wage for the whole period till work ability restoration or till establishing permanent disability;

– if the victim is not able to execute the previous work, he/she shall be offered training and retraining and further employment in accordance with medical recommendations.

Women's Labor Protection

Women's labor may not be used for laborious work, works in dangerous and hazardous conditions, underground works; women's labor in night shift is limited. Women may not be engaged for lifting weights in excess of the established rate.

Employed woman who has two or more children under 15 years or a disabled child, at her request shall be granted an additional unpaid 5-calendar-day leave, days-off excluded.

Juvenile Labor Protection

Juveniles aged 14–15 years are employed only subject to agreement of the guardianship board, parents, police and school administration *(Labor Code of Ukraine, Article 188).* The duration of workday for juveniles aged 14–16 years is 24 hours per week, 16–18-year juveniles – 36 hours per week (part-time). Juveniles are granted a 30-calendar-day summer leave. Juveniles may not work nightshifts nor overtime on days-off. Upon being employed, juveniles shall pass an entry medical examination; till the age of 21 juveniles shall undergo a mandatory annual medical examination.

1.3 Occupational safety management

Main principles of Implementation of Occupational safety management:

– priority of human (employee’s) health and life over the enterprise’s production performance;

– implementation of the accident prevention principle;

– joint discussion of labor safety issues and personal responsibility for decisions and their implications;

– regularity of labor protection management;

– publicity of control and managerial decisions.

Size of occupational safety service is determined according to specialty of enterprise (table 1.1).

OS service participates in:

1) investigation of accidents and occupational diseases;
2) formation of OS fund and its budget allocation;
3) work of OS commission;
4) development of OS instructions;
5) activity of workplaces certification commission.

Table 1.1 – Size of occupational safety service

ENTERPRISES	OS SERVICE
with 51–500 employees	one OS expert trained in engineering
with explosive materials and virulent poisons	two OS experts
with institution of deputy directors	head of OS service is an appointed deputy director regardless of the number of employees

Each company possesses (whether consciously or not, whether documented or not) an overall occupational health and safety management system (OHSMS). This management system is the sum of the management subsystems as well as their interrelationships.

Occupational Health and Safety Assessment Series (OHSAS) Standard and the accompanying OHSAS 18002, Guidelines for the implementation of OHSAS 18001, have been developed in response to customer demand for a recognizable occupational health and safety management system standard against which their management systems can be assessed and certified.

Conventions and Recommendations on occupational safety and health may serve several purposes, acting as (fig. 1.2):

– fundamental principles to guide policies for promotion, action and management;

– general protection measures, for example, guarding of machinery, medical examination of young workers or limiting the weight of loads to be transported by a single worker;

– protection in specific branches of economic activity, such as mining, the building industry, commerce and dock work;

– protection of specific professions (for example, nurses and seafarers) and categories of workers having particular occupational health needs (such as women or young workers);

– protection against specific risks (ionizing radiation, benzene, asbestos);

– prevention of occupational cancer; control of air pollution, noise and vibration in the working environment; measures to ensure safety in the use of chemicals, including the prevention of major industrial accidents;

– organizational measures and procedures relating, for example, to labor inspection or compensation for occupational injuries and diseases.

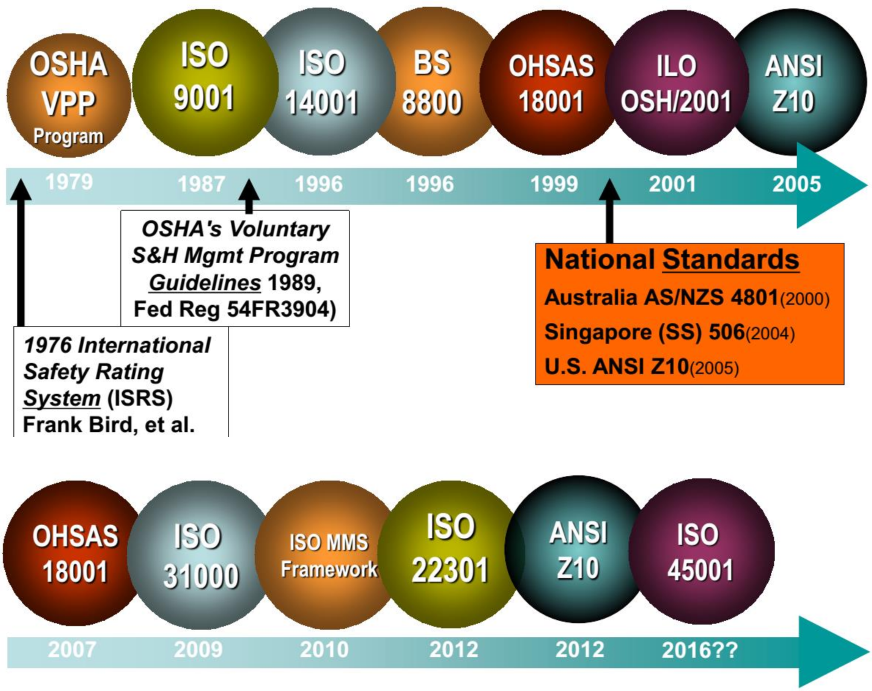


Figure 1.2 – OHSMS Evolution

Key Management System Components:

– Communication/Feedback loops
– Continual Improvement/Learning
– Accountability/Responsibility
– Leadership
– Participation
– Concept of Integration

There is emphasis on continual improvement and systematic elimination of underlying or root causes of deficiencies (fig. 1.3).

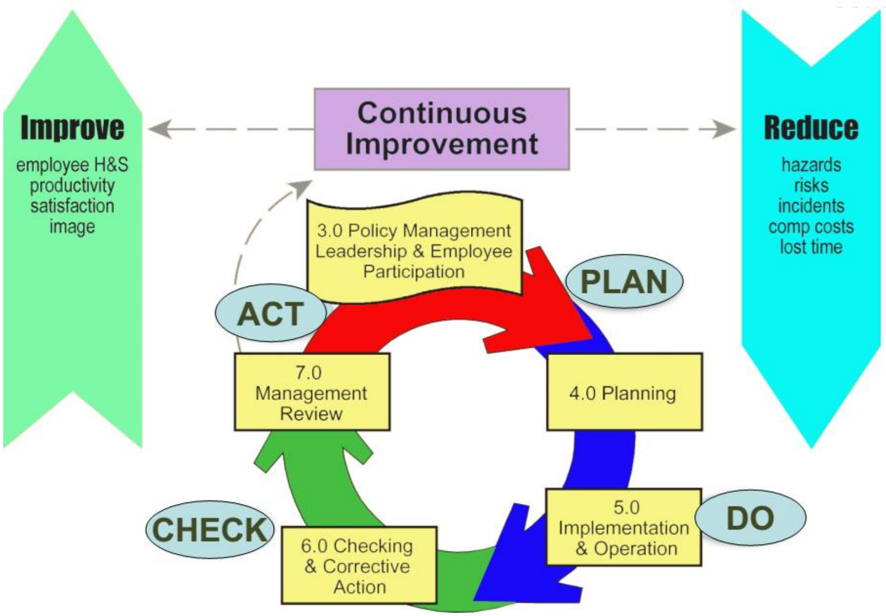


Figure 1.3 – The Z10 OHSMS Model

Plan Do Check Act (PDCA) cycle includes next components.

Plan: identify and analyze the problem: aspects, impacts, legal requirements, objectives, and metrics.

Do: developing and testing a potential solution: for example changes to organizational structure, processes, procedures, documentation, controls.

Check: measure effectiveness of solution and whether it can be improved. Assess through monitoring, evaluation, recordkeeping, audits.

Act: implement the improved solution fully.

All ISO standards follow the philosophy: say it, do it, document it.

Continual improvement is recurring process of enhancing the OH&S management system in order to achieve improvements in overall OH&S performance consistent with the organization's OH&S policy.

Many organizations manage their operations via the application of a system of processes and their interactions, which can be referred to as the "process approach". ISO 9001 promotes the use of the process approach. Since PDCA can be applied to all processes, the two methodologies are considered to be compatible.

The organization shall establish, document, implement, maintain and continually improve an OH&S management system in accordance with the requirements of OHSAS Standard and determine how it will fulfill these requirements. Top management shall define and authorize the organization's OH&S policy and ensure that within the defined scope of its OH&S management system. The organization shall establish, implement and maintain a procedure(s) for the ongoing hazard identification, risk assessment, and determination of necessary controls.

QUESTIONS FOR REVIEW

1. Difference between dangerous and harmful industrial factors.
2. Personal and Collective Protective Equipment.
3. General and special legislative acts on OS in Ukraine.
4. Main Employer's Rights and Liabilities.
5. Work in hazardous and harmful working conditions.
6. Occupational safety management. Key principles.
7. Standards on occupational safety.
8. PDCA cycle: main stages.
9. Continual improvement according to occupational safety.

Topic 2
Prevention of occupational injuries

Main lecture questions:

2.1 Occupational injuries analysis.

2.2 The responsibility of officials for violation of occupational safety legislation.

2.3 The classification of causes of occupational injuries, methods of analysis.

2.4 Investigation and registration of accidents and occupational diseases.

2.5 Prevention of occupational injuries.

2.1 Occupational injuries analysis

Types of injuries depend on impact character:

– mechanical (bruises, fractures);
– thermal (scalds, fire-burns, chilblains);
– chemical (poisoning, chemical burns);
– electrical (electrical burns, electrical signs);
– mental (shock, fright).

Table 2.1 – Types of occupational injuries

Injury (trauma)	**Occupational Accident**	**Occupational disease**
↓	↓	↓
damage to anatomic integrity of the human body or its functions caused by harmful industrial factors	*unexpected event happening to a person through an unforeseeable coincidence (health damage or death)*	*pathological condition caused by long-term work in harmful working conditions*

Work ability loss is depending on consequences servility:

– temporary;

– permanent-temporary;
– permanent.

There are next coefficients for occupational accidents evaluation: injury frequency coefficient, injury severity coefficient, number of man-days of disability.

The injury frequency coefficient K_f may be determined according to the formula:

$$K_f = \frac{N}{P} \cdot 1000, \tag{2.1}$$

where K_f is the injury frequency coefficient;
N is the amount of occupational accidents, pcs;
P is the average number of workers, humans.

The injury severity coefficient K_s may be determined according to the formula:

$$K_s = \frac{D}{N}, \tag{2.2}$$

where K_s is the injury severity coefficient;
D is the loss of work ability, days;
N is the amount of occupational accidents, pcs.

The number of man-days of disability K_d may be determined according to the formula:

$$K_d = \frac{D}{P}, \tag{2.3}$$

where K_d is the number of man-days of disability;
D is the loss of work ability, days;
P is the average number of workers, humans.

2.2 The responsibility of officials for violation of occupational safety legislation

There are four types of responsibility of officials for violation of the legislation on labor protection:

1) Disciplinary responsibility is in cases where guilt is violated rules and regulations for safety. Violation does not lead to serious consequences and could result in reprimand or release.

2) Administrative responsibility is imposed on perpetrators fines. The right to impose fines using the State Committee of Ukraine for occupational safety, fire authorities and health surveillance and their regional branches and other government agencies control.

3) Criminal responsibility occurs when irregularities may cause or have caused accidents to people or any other consequences. Criminal liability can carry only guilty parties, which because of their official position or by special order obliged to provide safe and healthy working conditions.

4) Material responsibility of guilty officials for violation of safety rules occurs when the result of severe violations of the company will be required to pay certain sums of money to the victim of an accident or the social insurance to compensate for these payments.

2.3 The classification of causes of occupational injuries, methods of analysis

In general, we can distinguish 4 groups of causes of occupational injuries:

1. Technical reasons (failure of machinery, lack of fencing).
2. Institutional (lack of organization of work, workplace, lack of instruction, supervision).
3. Sanitation (working environment factors).
4. Psychophysiological (personal): fatigue, lack of discipline, trouble to work, alcohol.

In order to prevent accidents and occupational diseases which have occurred in the production, it is necessary to study and analyze. There are such methods of analysis:

1) statistical;
2) monographic;
3) topography;
4) group;
5) economic.

Statistical method is based on the study of materials registration and accounting accidents, collected in a long time (a year, half a year). The further systematization of their professions, work experience, gender, age, technical factors, the nature of injuries, and the similarity of the circumstances of others is carried out. We construct the dependence of injuries from these factors, which are then used in preventive work. This method is the most common.

Monographic method is descriptive, characterized by the fact that the hazardous or harmful working conditions are detailed examination of individual jobs, workshops, machines, installations. Study accidents, which took place on this site in the past year, investigated the nature of the process; the presence of alarm systems, protective clothing, working environment conditions, that is, the case is studied comprehensively.

Topographical method is when events are portrayed graphically on the plan of the enterprise as symbols in their place of origin. Thus, the basis of its analysis of the places, where there are accidents in. This method is the most obvious, but the reasons are not noted.

Group method reveals the structure of the overall performance and identifies the main groups of reasons that led to injuries; it also sets out the main directions of spending money on prevention of injuries (a kind of statistical).

Economic method is to determine the economic impact of occupational injuries, as well as in the evaluation of cost-effectiveness, to prevent accidents in order to optimize the distribution of funds for labor protection measures.

We can notice a new direction along with traditional methods:

a) a systematic approach to solving the safety problems (use complex methods of research);

b) the method of scientific prediction of safety;

c) automated system of operational accounting and prevention of occupational injuries.

2.4 Investigation and registration of accidents and occupational diseases

There are following types of accidents according to the result of investigation: injuries, occupational diseases and acute poisoning, heat stroke, burns, frostbite, drowning, electric shock and lightning damage due to accidents, fires, natural disasters, contact with animals and insects if they occurred (time and place):

a) *while performing job duties* (including a business trip), and actions in favor of the company even without the authorization of the owner;

b) *at the workplace*, on the premises or at another workplace, given the set break;

c) *on the time required for remediation* of the means of production, protection, clothes before and after work, as well as facilities for personal hygiene;

d) *while traveling to or from work in transport companies*, as well as personal vehicles used for the benefit of the company with the permission of the owner;

e) *during the accident*, as well as during the elimination at production facilities;

f) *during working hours* when moving on foot or by public transport with an employee whose work is connected with the movement of objects between services.

For each accident, that cause result of lose working ability for 1 day or more, and it became necessary to transfer the victim to another easier work for at least 1 day, the form N1 is drawn.

The fact of suicide, natural death or injury during the crime, the act does not consist N1 forms and accident isn't considered as being associated with the production.

The owner of the company, received information about the accident is required to establish a commission to investigate it:

a) specialist of the Department of Labor (Chair);

b) the head of the department where there was accident;

c) the chairman of the trade union organization of which is the victim;

d) in the case of a possible disability of the victim as representatives of relevant working executive management of the Social Insurance Fund.

The owner of the company for 1 day is required to approve the 6 copies N1 act form and send them to:

1) the victim;

2) the head of department;

3) state inspection for supervision of works;

4) trade union organization;

5) the Department of Labor;

6) the work of the executive management of the Fund.

Act H1 forms, with the investigation materials are saved at the company for 45 years.

A special investigation is performed in a case if:

a) group accident (in the same time with two or more employees);

b) accident that led to the death of the victim.

On each accident "a" or "b" employer must immediately notify:

1) the appropriate authority of state supervision of occupational safety;

2) suitable working executive management of the Fund;

3) sanitation center (in the case of acute occupational poisoning or disease);

4) the local authorities;

5) trade union organization of the enterprise;

6) higher trade union body;

7) the prosecutor's office at the location of the enterprises;

8) supreme management body (ministry or other body);

9) state control of health and safety and the Ministry of Healthcare (when two or more people died).

2.5 Prevention of occupational injuries

In the system of injury prevention a special place belongs to the training and instruction of employees on safe working methods. Many years of practice established a uniform system of teaching safe methods of work. The form of this training is varied and fits for purpose.

Introductory briefing is the first phase of training on safe working practices, compulsory for all who get a job (workers, engineers, students during practice time). It is conducted by safety engineer or chief engineer. Typically, this is group instruction for 1.5–2 hours, and if the individual is for 5–4 hours.

Content of introductory briefing:

1. The main statement of the legislation on health and safety.
2. Internal labor regulations and behavior in the enterprise premises in industrial buildings.
3. The route through the territory, the location of buildings, meaning of warning signs, colors, security, sound and light alarm.
4. Brief descriptions of particularly hazardous work and prevention accidents measures (moving cargo cranes, gas-flame treatment of metal).
5. Some specific circumstances and causes of cases that have occurred as a result of violations of safety instructions and production discipline.
6. General rules of electrical concepts, methods for releasing the person who has been exposed to an electric current, and how to provide first aid.
7. Safety requirements of work clothes, shoes and so on.
8. Value of ventilation in industrial premises of arrangement (local ventilation systems).

9. Basic requirements for most workers with hygiene and personal care.

10. Methods and techniques of first aid in accident and need for treatment in the clinic.

11. Procedure for registration and investigation of accident associated with production.

12. Fire safety in existing workshops and in the territory.

The primary briefing at the workplace is held by the head of the department: a master mechanic, etc. individually. Its task is to acquaint the working details:

a) the device hardware on which it will be necessary to work;

b) devices with safety, fencing and personal protective equipment – their purpose and use;

c) the correct and safe organization of the workplace (stacking of raw materials, semi-finished and finished products);

d) with the content of the safety instructions at the workplace (it is handed out);

e) with safe methods of work, the use of which should protect the worker from injury and occupational diseases;

f) hazardous working methods that are prohibited to use.

Repeated (scheduled) briefing is held at least once every 0.5 year, usually once a quarter

Unscheduled briefing is held, usually by a master in the case of changing the type of work or after the accident that occurred.

QUESTIONS FOR REVIEW

1. Types of occupational injuries.
2. Types of responsibility for violation of occupational safety legislation.
3. Circumstances at which an accident is related to the production.
4. Safety briefing types.

Topic 3
Improvement of air quality

Main lecture questions:

3.1 The impact of air pollution on the human body.

3.2 Rationing of harmful substances in the air.

3.3 The microclimate in industrial premises. Measures for improvement of air quality and working conditions.

3.4 Classification of ventilation systems.

3.5 Principles of ventilation system designing.

3.1 The impact of air pollution on the human body

The work environment is an extensive summary of the factors that may affect its quality. In the area of the working environment it is necessary to draw attention not only to the most significant factors, but also to consider the impact of individual elements of a complex environment in which employees operate. Most common elements affecting the work environment are: noise, ventilation, temperature, humidity, light and stress.

Environmental well-being can be defined as state of the environment in which a person subjectively feels best and is capable of maximum performance, whether physical or mental. State of the environment in which human well-being is achieved, depends on several factors. Here belong: air condition, wall temperature, temperature of surrounding objects, clothing, human subjective parameters, intensity of work and other effects.

Classification of dangerous and harmful industrial factors:

– *physical* (increased or decreased temperature, increased level of noise, vibration and radiation (ionizing, laser, EMF, infrared, ultraviolet and luminous radiation), electric current);

– *chemical* (chemical substances) (table 3.1);

– *biological* (bacteria, viruses, fungi);

– *psychophysical* (physical, mental and emotional overstrains, analyzers overexertion, work monotony).

Table 3.1 – Harmful Substances Classification

Substance groups	Signs of poisoning
1. Neuro-paralytic agents – hydrocarbons, alcohols, ammonium	Cause nervous system dysfunction, convulsions, paralysis
2. Irritants – chlorine, nitrogen oxides	Affect the upper and lower respiratory tracts
3. Burning agents and irritants – inorganic acids, alkaline	Affect the skin, causes abscesses and ulcers
4. Enzymatic agents – cyanic acid, arsenic, mercury salts	Changes enzymes' structure and deactivates them
5. Liver poisons – selenium, chlorohydrocarbons	Cause changes in the liver structure
6. Blood poisons – benzene, lead	Inhibit enzymes, affect blood hemoglobin
7. Mutagens – lead and mercury compounds	Causes genetic cell abnormalities
8. Allergens – nickel compounds, pyridine derivatives	Changes the body reactivity
9. Carcinogens – aromatic amines	Cause malignant growth

Hazardous material transporters and laboratory personnel require different equipment than those responsible for clean-up of spills. The type of selected PPE is further dependent on the hazardous material handled (fig. 3.1).

The use of appropriate protective equipment is important in minimizing exposure to hazardous chemicals.

Figure 3.1 – Examples of PPE for chemical handling

Protective equipment may include respirators, eye protection (such as safety goggles and face-shields), gloves and protective clothing (such as lab coats and plastic or rubber aprons), and foot protection (such as rubber boots or plastic shoe covers).

Protective eye and face equipment is required whenever there is a potential risk of injury that can be prevented by such equipment.

Respirators must be used when an employee may be exposed to a harmful level of a hazardous chemical. Written standard operating procedures governing selection and use of respirators must be established.

3.2 Rationing of harmful substances in the air

Permissible level (PL) is a concentration of harmful substances in work area air which within an 8-hour workday and within the whole period of service cannot cause diseases or health abnormalities.

There are next hazard classes of harmful substances:

– extremely hazardous substances: PL < 0.1 mg/m^3

– especially hazardous substances PL = 0.1–1.0 mg/m^3

– moderately hazardous substances PL = 1.0–10.0 mg/m^3

– low-hazard substances PL > 10.0 mg/m^3

Different types of measures are used to protect people from harmful substances.

1) *Technical measures:*

– replacement of toxic substances with non- or less toxic;

– automation, mechanization, application of remote control in order to eliminate the contact of the employee with toxic substances;

– hermetization of the equipment using local and general ventilation.

2) *Sanitation measures:*

– systematic control of toxic substances concentration in the air;

– use of individual protection means;

– keeping scheduled work-rest regimen.

3) *Medical preventive measures*:

– preliminary and periodical medical examinations;
– treatment at health resorts.

Safe storage of chemicals and other hazardous materials begins with the separation, segregation or isolation of incompatible materials. The degree to which this process needs to be done depends upon the laboratory's size, the quantities and types of materials used, the durability of the storage containers and the potential for spills or leakage.

Separation, segregation and isolation are defined by NFPA standards as follows:

Separation – storage within the same fire area but separated by as much space as practicable or by intervening storage from incompatible materials.

Segregation – storage in the same room but physically separated by space from incompatible materials. This usually requires some type of physical barrier such as sills, curbs or safety cabinets.

Isolation – storage away from incompatible materials in separate rooms, vaults or buildings.

There are various types of chemical storage systems. These include storage lockers, cabinets, vaults and pallets. Many models can be purchased with built-in ventilation, fire suppression systems and spill alarms.

The following recommended practices will also aid in ensuring safe storage of chemicals:

1. Fitting of storage shelves with shelf lips on all sides.
2. Use of caged shelving units.
3. Purchase and utilization of commercially available ventilation systems which include ventilated storage cabinets.
4. Use of storage cabinets with self-closing doors.

Storage cabinets should be labeled according to their contents. In addition, storage cabinets should always be labeled with an appropriate hazard warning.

Flammable and combustible liquids storage cabinets should be labeled: FLAMMABLE – KEEP FIRE AWAY. Each container in the cabinet should be labeled.

Some hazardous materials have special symbols associated with them (i. e., radioactive, biohazard, etc.). These symbols must be displayed prominently in the storage area and on the storage containers.

Over toxic substances control methods:

1) express method: colorimetric (change of color); gas analyzers UG-2, GH-4;

2) laboratory method (taking air samples in work area and its physical and chemical laboratory analysis);

3) continuous method (gas analyzers and detectors): FKG-3M for chlorine; "Syrena-2" for ammonium; "Photon" for hydrogen sulfide.

3.3 The microclimate in industrial premises. Measures for improvement of air quality and working conditions

Microclimatic parameters (or conditions) of the work environment also known as thermal-moisture parameters are determined by temperature, relative humidity and airflow. These physical quantities define subjective well-being (comfort) or ill-being (discomfort).

Workplace microclimate separately and altogether is influenced by:

- temperature;
- humidity;
- air velocity;
- thermal radiation (emission).

Temperature. Particular type of working class has got determined the optimal microclimate conditions, depending on body heat production affected by intensity of employee's activity. The total energy expenditure assigns the individual work activities to the working classes: 1a (sitting at work, administration), 1b (standing at work), 1c (such as mechanics work, work in the steel industry), 2 (such as operating machines, work in the building industry), 3 and 4 (intensive and very intensive work) (table 3.2).

Table 3.2 – The optimal and permissible temperature for some working class

Working class	Temperature, °C			
	Optimal temperature		Permissible temperature	
	Warm season	Cold season	Warm season	Cold season
1a	21–25	20–23	20–28	20–26
1b	20–24	18–21	18–26	17–24
1c	18–22	15–19	16–25	13–22
2	16–19	12–17	12–24	10–20
3	The value does not determine			
4				

Range of optimal values of microclimatic conditions in the working environment is set for a warm period (average daily outdoor temperature 13 °C and more) and winter season (decrease of the average daily temperature for two consecutive days below 13 °C). In case of the workplace with long-term nature where it is impossible to provide optimal conditions, the employer is required to ensure compliance with permissible microclimatic conditions. Exceptions are in need of special workplaces where the burden of heat or cold is impossible to be removed due to various technological reasons.

Humidity. Humidity in the working environment is a specific factor. The specificity of the factor is mainly in the fact that, unlike the temperature, this can be subjectively very difficult to perceive and then evaluate. The human body can have an adverse effect on the decrease in humidity at the level of 20 % mainly in winter (due to heating) and the humidity in excess of 60 % in other seasons. The scope of permissible values of relative humidity is in the Table 3.3.

Table 3.3 – Relationship of temperature, humidity and work performance

Temperature	Humidity	Working performance
21 °C	40 %	Very good
	85 %	Good at changing work and rest
	91 %	Reduced, there is a fatigue and depression
26 °C	30 %	Very good
	65 %	Reduced, rapid fatigue
	80 %	Difficult, the need for frequent rest
32 °C	25 %	Very good
	50 %	Strongly reduced performance
	65 %	Work is almost impossible
	81 %	Exhaustive, leads to an increase in body temperature
	90 %	Work threatens health
	100 %	Work is impossible

Air velocity. In practice it is often not possible to keep the airflow and the intensity at a low level to ensure a comfortable working environment. Difficulties were encountered in most cases, particularly for space cooling. Increasing airflow increases the flow of cooling the body and decreases the amount of sweat produced. The velocity of airflow in the place is to create thermal comfort environment of considerable importance. People with sedentary work in confined spaces are more responsive to airflow than the movement in the nature. These should be respected in the work environment. Summary of values for each type of working class is shown in Table 3.4.

Thermal radiation. It describes the heat exchange by radiation between the surface area of space and the human body. It is an effective heat flux shared by radiation.

Microclimatic conditions can be divided into optimal, acceptable and tolerable groups.

Table 3.4 – The value of permissible velocity of airflow and humidity

Working class	Permissible velocity of airflow, ms^{-1}		Permissible humidity, %	
	Warm season	Cold season	Warm season	Cold season
1a	≤ 0.25	≤ 0.20	30–70	30–70
1b	≤ 0.30	≤ 0.25	30–70	30–70
1c	≤ 0.30	≤ 0.30	30–70	30–70
2	0.1–0.3	≤ 0.30	30–70	30–70
3	The value does not determine			
4				

Adverse meteorological conditions may cause overheating or supercooling of the body.

MC Normalization Methods:

– improvement of technological processes and equipment (removal of intensive heating);

– the rational placement of equipment;

– automation and remote control over technological processes;

– rational heating, ventilation and air-conditioning;

– rationalization of work and rest schedule; the use of equipment: heat insulation and shields;

– rational heating, ventilation and air-conditioning: air and water showers in hot workshops; radiation heating of permanent workplaces; draught protection – closing windows and doors, air and air-thermal curtain installation on doors and gates.

Rationalization of work and rest schedule: shift shortening; additional breaks.

3.4 Classification of ventilation systems

Adequate area ventilation is important in areas where hazardous materials are stored. Without ventilation, vapors may accumulate above safe exposure levels. Ventilation is especially important in areas where flammable and combustible materials are stored.

Ventilation is very important when storing solvents. Vapors from flammable and combustible liquids are heavier than air and therefore accumulate at floor level or other low-lying areas. Always ensure that ventilation is initiated at or near floor level and that all possible dead air spaces are ventilated. The degree of required ventilation depends on the type (class) and quantity of flammable or combustible liquids stored. NFPA 30-1984 standards specify ventilation requirements for storage rooms located within a plant or attached to the plant building. Flammable liquids should not be stored or handled in a building that has a basement or pit into which flammable vapors may seep unless the area is provided with ventilation to prevent accumulation of vapors. The ventilation system should be separate from other air handling systems and the location of air intakes and exhausts should be carefully evaluated. More stringent ventilation requirements are generally applied to storage areas where materials are dispensed.

If you're handling chemicals without the use of a respirator, it should be done in a well-ventilated area. There are two general types of ventilation (fig. 3.2):

- General Dilution Ventilation (GDV);
- Local Exhaust Ventilation (LEV).

Ventilation is a popular method of reducing employee exposures to airborne contaminants. It is also useful in preventing the accumulation of flammable or explosive concentrations of gases, vapors or dusts. If process modifications or other controls do not lower contaminated levels to acceptable concentration, ventilation is often a good choice.

Dilution Ventilation – dilution occurs when contaminants released into the workroom mix with air flowing through the room. Either natural or mechanically-induced air movement can be used to dilute contaminants.

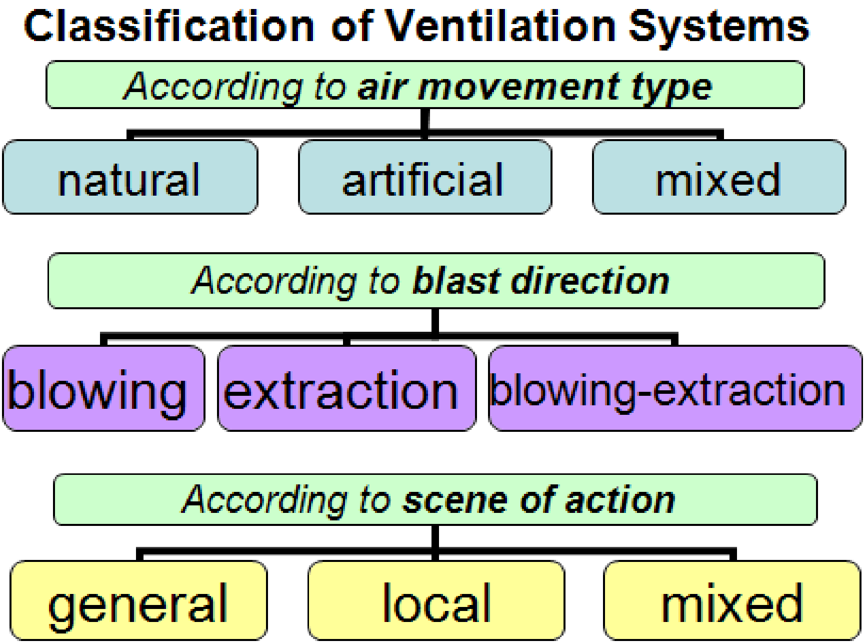


Figure 3.2 – Classification of ventilation systems

Dilution ventilation is used in situations meeting the following criteria:

– small quantities of contaminants released into the workroom at fairly uniform rates;

– sufficient distance from the worker (or source of ignition for fire/explosion hazards to the contaminant source to allow dilution to safe levels;

– contaminants of low toxicity or fire hazard;

– no air cleaning device needed to collect contaminants before the exhaust air is discharged into the community environment;

– no corrosion or other problems from the diluted contaminants in the workroom air.

The major disadvantages of dilution ventilation are that large volumes of dilution air may be needed, and that employee exposures are difficult to control near the contaminant source where dilution has not yet occurred.

Dilution ventilation is also called **general ventilation**. However, in many industrial plants the overall heating and cooling system is referred to as the general ventilation system so the term dilution will be used for contaminant control systems to avoid confusion.

Local Exhaust Ventilation – local exhaust systems capture or contain contaminants at their source before they escape into the workroom environment. A typical system consists of one or more hoods, ducts, an air cleaner if needed, and a fan. The big advantage of local exhaust systems is that they remove contaminants rather than just dilute them.

Even with local exhaust some airborne contaminants may still be in the workroom air due to uncontrolled sources or less than 100 percent collection efficiency at the hoods. A second major advantage of local exhaust is that these systems require less airflow than dilution ventilation systems in the same applications. The total airflow is important for plants that are heated or cooled since heating and air conditioning costs are an important operating expense.

Dilution, not Removal – it is easy to picture moving through the work area in a straight path from the air inlet to exhaust fan, almost as if traveling inside an invisible duct, to whisk contaminants out of the workroom. Some of it passes through the zone of contaminant release and dilutes the contaminants to a lower concentration. The dilution continues as the material moves farther from the process until the contaminated air is removed by the exhaust fan. Depending on the location of the air inlet and exhaust fan, and the total airflow through the room, a considerable time period may elapse after the process stops before all contaminants are removed from the room. Dilution occurs from natural ventilation as well as mechanical systems that use fans or other air-moving devices.

Natural Ventilation – natural ventilation is air movement within a work area due to wind, temperature differences between the exterior and interior of a building, or other factors where no mechanical air mover is used (fig. 3.3).

Even moderate winds can move large volumes of air through open doors or windows. A 15 mph wind blowing directly at a window with an open area of 36 ft^2 can move about 25 000 ft^3/min through the window if the air can escape from the building through another opening.

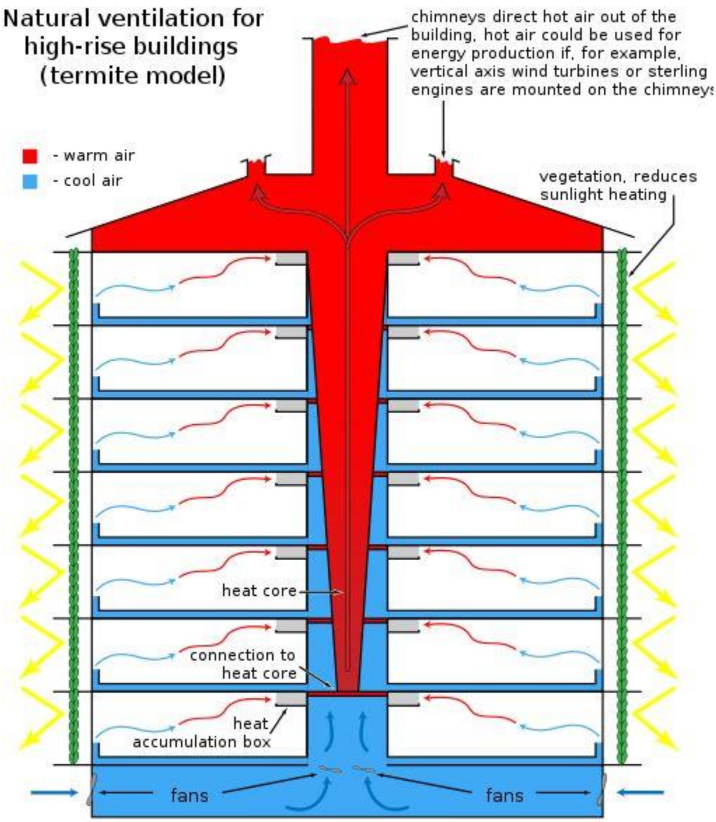


Figure 3.3 – Model of natural ventilation system

This may be enough dilution airflow if the wind is reliable or if production can be scheduled to coincide with favorable winds as long as the building is not shielded from the wind by trees, hills or other structures. The problem is that in many parts of the country this large dilution air volume must be heated in winter, and fuel is expensive.

Air movement due to temperature differences may be more useful than motion caused by wind. Hot processes heat the surrounding air and the rising column of warm air will carry contaminants upward. Roof ventilators allow the escape of the warm air and contaminants. As long as a worker does not have to lean over the heated process and breathe the rising contaminated air, this type of natural ventilation may be adequate. A good sample of replacement air for the building is needed, especially during winter when doors and windows may be closed to minimize drafts.

Evaluating Dilution Ventilation – deciding whether dilution ventilations is a good choice depends on several factors:

– the air volume needed to dilute the contaminants to safe levels may be excessive if large quantities of contaminants are released;

– sufficient dilution must occur before workers inhale contaminated air. If employees work close to the contaminant source, the dilution airflow may have to be increased to reduce concentrations to safe levels before the air reaches the employee's breathing zones. This can be a real problem in manual gluing or surface-coating operations where workers bend over the work and breathe solvent vapors;

– with dilution ventilation for fire protection the dilution must occur before the contaminants reach a source of ignition;

– only low fire hazard or low toxicity materials should be considered for control by dilution ventilation.

Although there is no firm toxicity classification system, the American Conference of Governmental Industrial Hygienists uses guidelines based on the Threshold Limit Values (TLVs) assigned to chemical substances as an indication of safe occupational exposure levels. Table 3.5 provides a summary of these guidelines.

Table 3.5 – Toxicity guidelines for dilution ventilation

Toxicity class	**TLV Range, ppm**
Slightly toxic	> 500
Moderately toxic	100–500
Highly toxic	< 100

The rate of contaminant release or evolution should be reasonably constant to avoid the need for high airflow rates to provide adequate dilution periods of peak contaminant release.

3.5 Principles of ventilation system designing

Ventilation system design is information generally shown in the same manner as any other mechanical system that is on a PFD and P&ID (fig. 3.4).

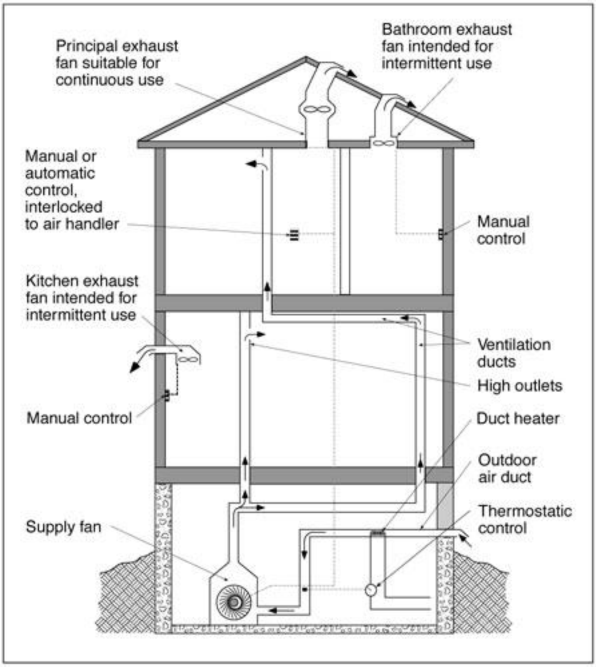


Figure 3.4 – Ventilation system design

Other design data such as the air flow calculations, psychometric calculations and equipment sizing calculations generally are found in design reports or other backup documents.

Basic Ventilation System Requirements

1. The creation of standardized meteorological conditions in the working area.
2. To completely remove harmful gases, steams, dust and aerosols from the working area or dissolve them to BL.
3. Not to bring polluted air from the outside or from adjacent workplaces.
4. Not to create draughts and rapid cooling at workplaces.
5. To be easily accessible for control and repair during operation.
6. Not to create additional difficulties (noise, vibration) during operation.

QUESTIONS FOR REVIEW

1. Influence and prophylaxis of high and low temperature of the environment on the human organism.
2. The rules for measuring air temperature indoors.
3. Influence of high and low temperature with high humidity on the human organism.
4. Prophylaxis of low and high humidity affects on the human organism.
5. The types of air humidity.
6. The method of measuring absolute and relative air humidity.
7. Low and high atmospheric pressure, its influence on the human organism.
8. The method of measurement of atmospheric pressure. Devices for its measurement.
9. Physiological and hygienic significance of air movement.

Topic 4
Industrial lighting

Main lecture questions:

4.1 Importance of Industrial Illumination.
4.2 Basic Light Engineering Notions.
4.3 Natural Illumination.
4.4 Artificial Illumination.
4.5 Artificial Illumination Sources.
4.6 Designing of Artificial Illumination Systems.

4.1 Importance of Industrial Illumination

Light is an important stimulator of not only eyesight but the entire organism as well. For a human being day and night, light and darkness determine biorhythm, periods of vivacity and sleep. Thus, lack of illumination or its excess cause a reduction in central nervous system excitation and, naturally, reduce the intensity of all vital processes.

It is common knowledge that 90 % of all information is perceived visually, thus its quality absolutely depends on illumination. Rational illumination is an important factor in general industrial culture.

The lighting condition of industrial area plays an important role in occupational injury prevention. Foreign researchers have established that more than 20 % of occupational accidents are result of poor illumination.

Depending on the peculiarities of human eyesight, the following illumination requirements have been established for industrial buildings:

– illumination must be sufficient on the working surface so that depending on its reflection factor there is sufficient brightness for distinction;

– working surfaces must be illuminated evenly;

– the contrast of illuminated surfaces must be sufficient for the distinction of details;

– sources of light and the reflected working surface must not be blinding;

– illumination has to ensure labor safety.

4.2 Basic Light Engineering Notions

The illumination of industrial buildings is characterized by quantitative and qualitative parameters (fig. 4.1).

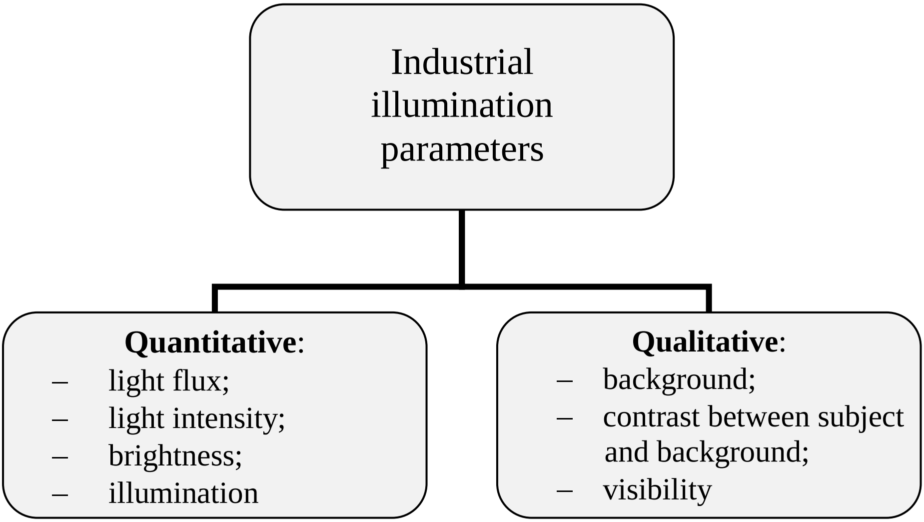


Figure 4.1 – Parameters of the industrial illumination

Light flux (F) is the intensity of light that is evaluated by human eyesight in accordance with light sensation. Unit of light flux measurement is lumen.

Light intensity (I) is a magnitude defined by the ratio between light flux (F) and solid angle (W) within which light flux is equally allocated:

$$I = F/W, \text{ cd (candela).} \quad (4.1)$$

Brightness (B) is the ratio of light intensity that is emanating from surface element into proper direction to shining surface area:

$$B = \frac{I}{S} \cdot \cos\alpha \text{, nit,} \qquad (4.2)$$

where I is light intensity emanating from surface into proper direction, cd;

S is surface area, m^2;

α is angle between normal of surface element S and direction to which the brightness is determined.

Illumination (E) is the ratio of light flux (F) that falls on surface element to surface area of this element (S):

$$E = \frac{F}{S} \text{, lx (lux).} \qquad (4.3)$$

Background is the surface adjacent to the object of distinction on which it is observed.

Background is considered in next way: light when $p > 0.4$, medium when $p > 0.2–0.4$ and dark when $p < 0.2$.

Contrast between subject and background is characterized by the balance of the brightness of the observed object (dot, line and sign) and background.

$$K = \frac{B_o - B_f}{B_f}, \qquad (4.4)$$

where B_0 and B_f are brightness of object and background, nit. Contrast is defined as: big when $k > 0.5$, medium when $k = 0.2–0.5$ and small when $k < 0.2$.

Basic Illumination Hygienic Requirements consist of:

- optimal brightness of the workplace;
- uniformity of illumination;

– absence of sharp difference between the brightness of working surface and that of the environment;

– absence of lighting source dazzle.

4.3 Natural Illumination

One of the main issues of work is to ensure sustainable lighting production facilities and jobs.

Industrial lighting, properly designed and implemented, resolves the following issues:

– improving the conditions of visual work;

– reducing fatigue of workers;

– improving productivity and quality of products;

– positive effect on the working environment, which, in turn, has a positive psychological impact on workers;

– increasing labor safety and reducing injuries in the workplace.

The premises with the constant presence of people must have, as a rule, natural lighting. It is allowed to design premises without natural lighting in certain cases. These conditions are determined in state building codes for designing buildings and structures, regulations on building design of structures of some industries approved in the prescribed manner. Premises in the basement floors of buildings can also have no natural lighting.

Natural lighting is divided into the side, top and combined (top and side). Characterization of natural lighting at workplace in absolute value is impossible due to its change with time depending on the time of day, time of year and cloudiness. Therefore, it is taken to normalize the relative value that is natural lighting coefficient (*NLC*). *NLC* is the ratio of the illumination at a point inside the room E_{in} to simultaneous illumination outside of the room E_{out}, which is created by the light of the open sky, %, i. e.

$$NLC = \frac{E_{in}}{E_{out}} \cdot 100 \quad \%. \tag{4.5}$$

Normalized value of natural lighting coefficient (*NLC*) for the fourth light zone of Ukraine e_{IV} is defined in % by the formula:

$$e_{IV} = e_{nIII} \cdot m \cdot c, \qquad (4.6)$$

where e_{nIII} is normalized value of NLC for third light zone. There is following value for side illumination for most of administrative and managerial areas with III level of work (high accuracy): e_{nIII} = 1.5 %;

m is a light climate coefficient (for Ukraine *m* = 0.9);

c is a sun coefficient. For Sumy latitude *c* is within 0.75–1.0.

The following factors affect brightness level in conditions of natural illumination: light climate, square and direction of light openings, degree of glass cleanness, wall and ceiling color depth of the room.

4.4 Artificial Illumination

There are next types of artificial illumination:

a) general – even and uneven;
b) combined – consists of general and local;
c) local – concentrates light flux at workplaces.

Local illumination is forbidden to use since it creates the danger of industrial injuries or occupational diseases.

Artificial illumination is divided into working, emergency, evacuation, security and telltale light according to purpose.

Working illumination facilitates the industrial process, people movement, transport movement and is necessary in all industrial buildings.

Emergency illumination ensures work continuation when switching on working illumination can cause explosion, fire or poisoning. The minimal illumination of working surfaces under emergency illumination has to be 5 % of working illumination, but no less than 2 lx.

Evacuation illumination is to ensure people evacuation from the building when there is an emergency shutdown of working illumination. The minimal illumination is 0.5 lx indoors and no less than 0.2 lx in open areas.

All the buildings must have natural illumination. Illumination norm depends on optical work whose accuracy is defined by the smallest object of distinction.

It is advisable to use combined illumination during different kinds of works: lamps of local illumination create high illumination of the working surface and lamps of general illumination even brightness in the field of vision (table 4.1).

Table 4.1 – Standards of artificial lighting

Area	E, lx
Control panels, measuring instruments on equipment and heat dashboards, water level gages	300
Computer room	200
Boiler fronts, smoke exhaust rooms, ventilators, electric rooms	100
Maintenance floor, passageways behind boilers	50
Corridors, ladders	5
Panel rooms	300

Brightness has to be even within the field of vision. Uneven illumination at working place must not be greater than 1.3 and 1.5 in passageways.

Boiler-room is provided with sufficient natural illumination and at night – with electric lighting.

Apart from working illumination boiler-rooms must have emergency lighting with independent power feed.

4.5 Artificial Illumination Sources

There are different types of lamps as sources of artificial illumination depending on light extraction element (fig. 4.2).

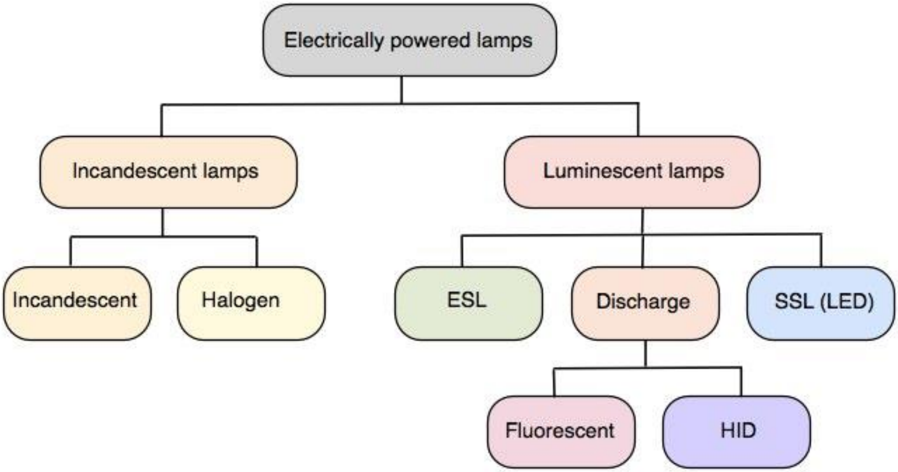


Figure 4.2 – Illustration of different types of lamps

Incandescent, discharge and LED lamps are widespread as artificial illumination sources.

Incandescent lamps are characterized by simple construction and production, low price, easy exploitation, wide voltage and power ranges (fig. 4.3).

There are next drawbacks of incandescent lamps:

– high brightness (dazzle effect);

– low light efficiency (7–20 lm/W);

– relatively low operation life (to 2.5 thousand hours);

– yellow–red rays domination comparatively with natural light;

– high reheat temperature (to 140 °C that makes them fire hazardous).

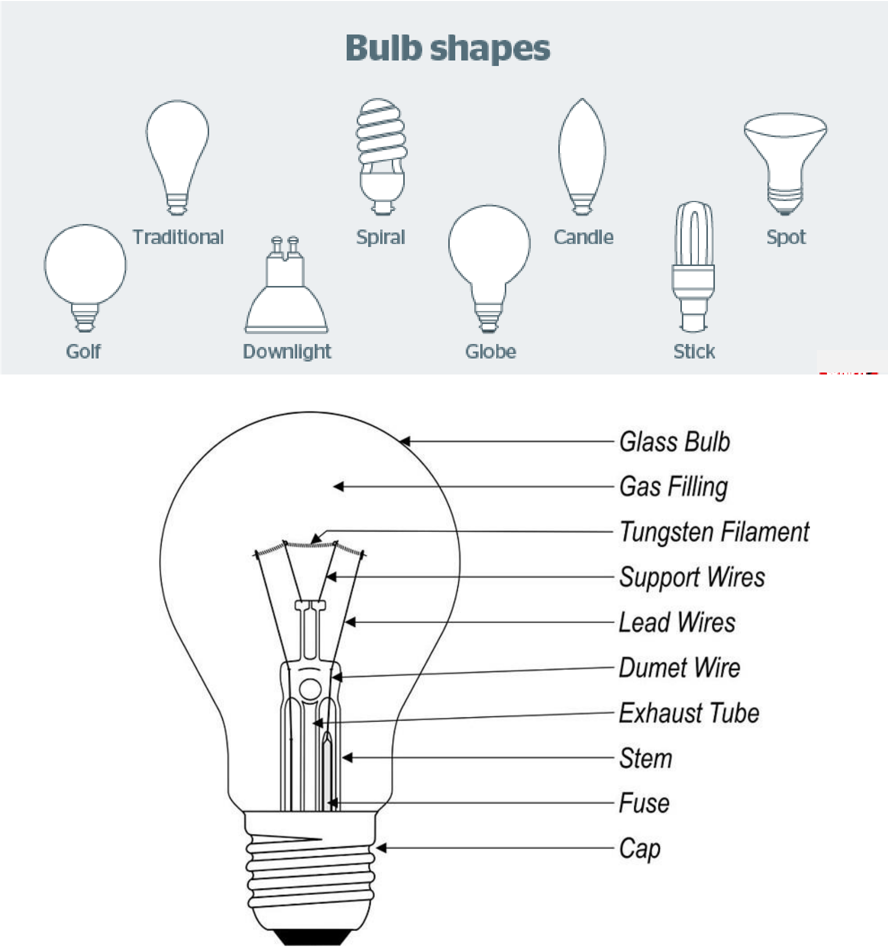


Figure 4.3 – Shapes of bulb incandescent lamp

Incandescent lamps are usually used for local illumination and for areas where personnel stay temporarily.

Gas-discharge lamps emanate optical range light resulting from an electric discharge in rare gas and metal steam environment as well as luminescence.

Advantages:

– economy, light efficiency 40–100 lm/W;
– operation life up to 10 thousand hours;
– any spectrum guarantee;

– reheat temperature – 30–60 °C.

Drawbacks:

– light flux pulsation that can cause stroboscopic effect and the optical effect of moving objects;

– complicated switching system;

– relatively expensive;

– a significant period between switching on and striking.

Gas-discharge lamps can be of high (fluorescent) or low pressure (fig. 4.4).

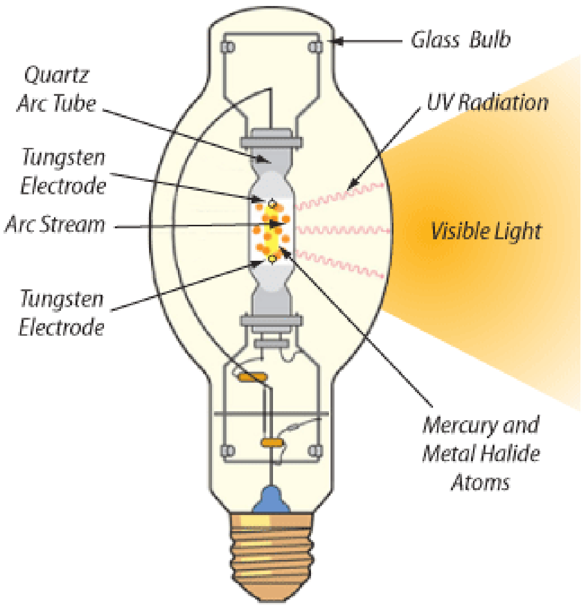


Figure 4.4 – High-intensity discharge lamp

Fluorescent lighting is used for doghouse and industrial building illumination (fig. 4.5). However, they cannot be used in conditions of low temperature. Gas-discharge lamps of high pressure are used if there is a need of high light efficiency, light source compactness and stability despite adverse environment conditions.

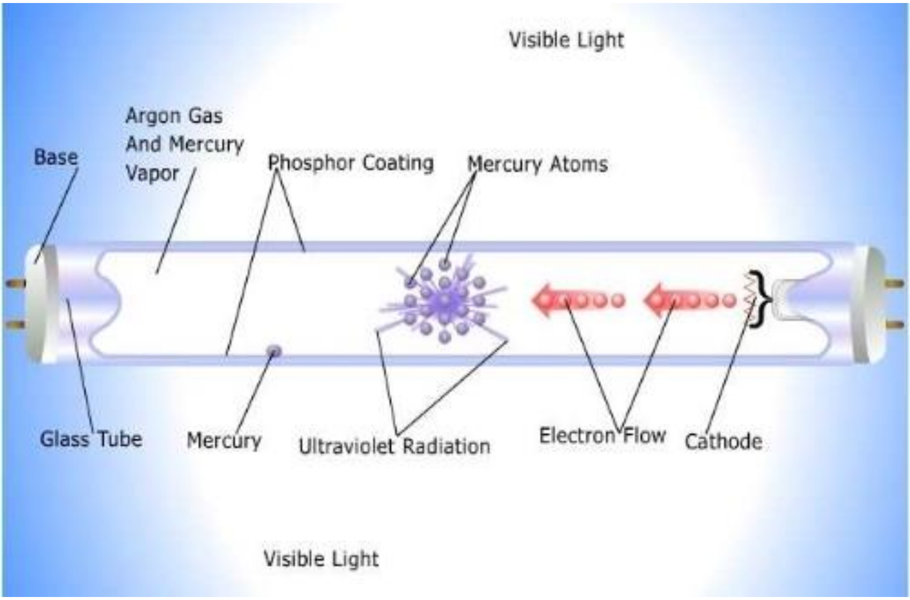


Figure 4.5 – Fluorescent light bulb diagram

In order to avoid the dazzle effect, the bulb is placed into the fitting that prevents excessive brightness of the source and protects it from the effect of fire- and explosion-hazardous and reactive environment, mechanical failures, dust, dirt and atmospheric precipitates.

Depending on construction, there are the following types of lamps: open (the bulb is not separated from the environment), protected (the bulb is separated with a shell that is no barrier for free air penetration), closed (the shell protects the lamp from large dust particles), dust-tight lamps, water proof lamps, explosion-hazardous lamps, lamps of improved reliability against explosion.

Lamps can be of general and local illumination. The system of general or combined illumination is designed for all industrial buildings. Working surface illumination represented by lamps of general illumination in the system of combined illumination must be no less than 10 % of normal for combined, but not lower than 150 lx at gas-discharge lamps and 50 lx at incandescent lamps.

Figure 4.6 – Comparison of different types of lamps

4.6 Designing Artificial Illumination Systems

Design involves:
- choice of the system of illumination;
- type of lighting source;
- lamp type;
- choice of location of lighting devices;
- calculations;
- definition of lamp and bulb power.

A system of general or combined illumination is designed for all industrial buildings. The lighting of the working area by lamps of general lighting in the system of combined lighting has to be no less than 10 % of combined lightning standard but not lower than 150 lx for gas-discharge lamps and 50 lx for incandescent lamps.

From the economic point of view luminous tube lamps of LB type are the best as they have the highest light efficiency. The minimal height from the floor at which the lamps are to be installed is 2.6 m for a 4-bulb lamp and 3.2 for lamps with 4 and more bulbs.

The selection of a lamp depends on workplace characteristics. For buildings whose walls and ceiling have low reflecting capacity, lamps of direct effect are used. For buildings whose walls and ceiling have high reflecting capacity, lamps mainly of direct effect are used.

In administrative and office buildings, lamps of diffused illumination are common. Lamps must have a proper protection level from conditions of the environment where they are fixed.

Operation of Lighting Devices

Windows have to be cleaned at least two times a year if dust level is rather low and at least four times if emission of dust is high. The frequency of lamp cleaning is 4–12 times a year (depending on dust level).

The level of illumination of controlled places must be checked regularly at least once a year.

QUESTIONS FOR REVIEW

1. Basic lighting concepts and definitions.
2. Classification of industrial lighting.
3. What instruments can measure the amount of light in the room? What is working principle?
4. On what indicators does the choice of normalized value of artificial lighting in the workplace depend on?
5. What is the stroboscopic effect of using HID lamps? Enumerate steps how it can be reduced.
6. What are the main methods for calculating artificial lighting? Write a formula for one of the above methods.
7. What are the advantages and disadvantages of existing sources of artificial lighting?

Topic 5
Protection against noise, infrasound and ultrasound

Main lecture questions:

5.1 Characteristics of noise.
5.2 Effects of noise on humans.
5.3 Protective measures against noise.
5.4 Ultrasound. Infrasound.

5.1 Characteristics of noise

Industrial noise is a sound or a combination of sounds that are displeasing to a human.

There are next basic parameters of the noise:

1. *The amplitude of the oscillation* is the maximum deviation from the initial position of the particles of the environment that conduct sound.

2. *Sound pressure* is a variable pressure that occurs in addition to the atmospheric pressure in the environment through which the sound waves are spread.

3. *The speed of sound* is the distance at which the wave process can spread in one second.

4. *Wavelength* is the distance between two adjacent condensation or liquefaction in the sound wave.

5. *The power of sound (intensity)* is the amount of energy that passes in the result of sound spread through an area of $1m^2$ per unit of time.

6. *The frequency content of noise* is a collection of sounds frequencies contained in it.

Interference is the process of imposition of the sound waves of the same frequency.

Diffraction is the process of sound waves rounding of the finite size obstacles.

Resonance is the process of a sharp amplitude increase due to the coincidence of the sound frequency with the natural frequency of oscillation.

7. *Sound volume or noise*. Unit volume is fon.

Only at frequency of 1000 Hz units in dB match with units in fon.

8. *Sound power of the sound source* P is the total amount of sound energy radiated by a source of noise into the environment per unit of time.

Hearing threshold (auditory threshold) is the minimum amount of sound energy that a person perceives as sound. The hearing threshold is $I_o = 10^{-12}$ W/m^2. Sound pressure corresponding to this value is equal to $P_o = 2 \cdot 10^{-5}$ N/m^2.

Pain threshold is sound energy at which the sound already causes painful sensations. It corresponds to the strength of $I = 10^2$ W/m^2, and a sound pressure $P = 20$ N/m^2.

Bel (B) is the logarithm of the ratio of the actual sound parameter to accepted limit value in acoustics.

$$L_p = \lg(\frac{p_{act}}{p_{\lim}}), \qquad (5.1)$$

where L_p – sound pressure level;

p_{act} – the actual value of sound pressure;

p_{lim} – the limited value of sound pressure.

The whole range from auditory to pain threshold is concluded in the 14 B or 140 dB.

Sound is usually measured with microphones responding proportionally to the sound pressure. The power in a sound wave goes as the square of the pressure. (Similarly, electrical power goes as the square of the voltage.) The log of the square of x is just 2 log x, so this introduces a factor of 2 when we convert to decibels for pressures. Sound pressure levels in decibels are caused by some common sources (table 5.1).

Table 5.1 – Situation examples of sound pressure level

Example	Sound pressure level, dB
The explosion of the atomic bomb (fatal threshold)	200
The clock process	30
Quiet conversation	30
Normal working conditions for our classrooms	60
Loud music	110
The turning machine	100

5.2 Effects of noise on human body

Some undesirable effects of the noise on human health:

– specific damage of hearing organs;
– psychiatric disorders;
– neurosis;
– hypertension;
– function disorders of gastrointestinal tract;
– cardiovascular system disorders.

Noise disease is an occupational disease associated with a combination of occupational hearing loss and disorders of the central nervous system and the cardiovascular system in workers in noisy environments.

As well as permanent and temporary hearing loss, noise-related conditions include: tinnitus (ringing in the ears), which can be painful and may lead to sleep disturbance; acoustic trauma; perforated eardrum; and hyperacusis (which can develop after sudden exposure to high sound levels and the sufferer may then find certain sounds uncomfortably or even painfully loud). Exposure to noise has been linked to heart disease and high blood pressure, especially in pregnant workers, and noise may affect the hearing of the unborn child. Noise plus exposure to solvents has a synergistic effect, causing greater noise-induced hearing loss than exposure to noise alone.

Exposure to noise reduces our ability to hear higher frequencies and so interferes in our ability to hear human speech clearly, resulting in noise-induced hearing loss (which differs from age-induced hearing loss). The inability to hear what is being said, to use a telephone or take part in conversation in social situations can lead to social exclusion and additional health risks.

Noise at work can cause other problems such as disturbance, interference with communications, difficulties with concentration, fatigue, tension and irritability – all of which may also cause stress.

An emerging problem is voice loss due to the necessity to speak in noisy environments and may affect, for example, teachers, lecturers and call center workers.

5.3 Protective measures against noise

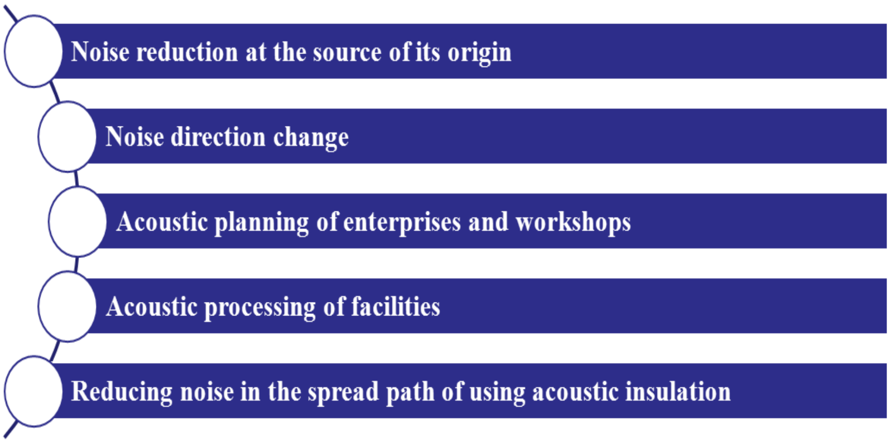
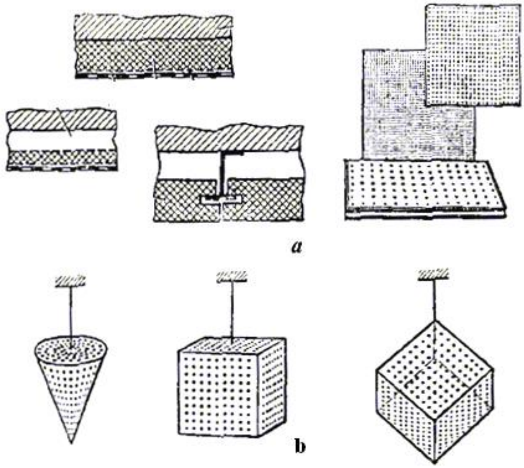


Figure 5.1 – Protective measures against noise occurrence

There are next types of facing materials: fiber; basalt fiber; mineral wool (fig. 5.2).

The choice of sound-absorbing materials and structures depends on the noise spectrum and the type of room.



a – sound-absorbing facing; b – artificial sound absorbers
Figure 5.2 – Acoustic treatment of premises

The local methods of noise control at the factories, such as insulating covers, screens, cabins, are used.

Noisy workshops should be concentrated in the hinterland, far from other manufactures, and protected by area of tree and shrub plantings.

Individual protection means:

a) *antiphons* as headphones and liners, mixtures of fibers of organic cotton and germicidal ultra-thin polymer fibers (reduce noise by 15–30 dB);

b) *helmets* – under the influence of the noise levels > 120 dB.

5.4 Ultrasound. Infrasound

The sources of the ultrasonic vibrations work in the frequency range of 16 to 80 kHz (fig. 5.3).

Ultrasound can be generated by a variety of industrial processes: cleaning, drilling, welding plastics, mixing. Their influence is observed at the distance of 25–50 m.

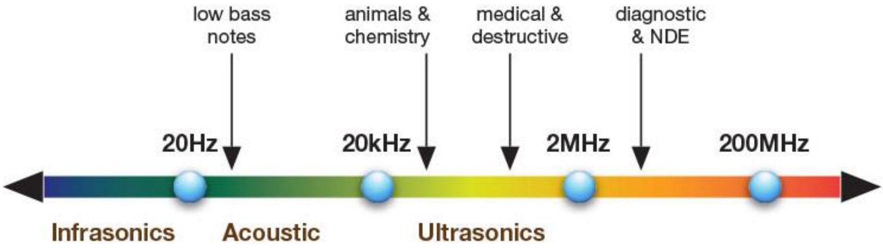


Figure 5.3 – Ultrasonic range diagram

Ultrasound causes the functional disturbances of the nervous system, headache, change of blood pressure and blood properties, the loss of the auditory sensitiveness and fatigue.

Admissible levels (AL) of the ultrasound:

1) AL in the places of contact of the parts of body of the operator with the working machine parts must not exceed 110 dB.

2) In case of the total effect of the ultrasound:

– from 1 to 4 hours during one shift the normative value can be increased by 6 dB;

– under its effect from 0.25 hour to 1 hour – by 12 dB;

– from 5 to 15 min – by 18 dB;

– from 1 to 5 min – by 24 dB.

Protective methods from ultrasound:

– sound-proofing;

– protective shields (shelter materials are steel, duralumin, acrylic resin, cloth laminate added to the acoustical absorbents);

– the use of the booths of remote control;

– vibration isolation (vibration isolation coverage, rubber mittens, carpets).

Infrasound is a mechanical vibration of the resilient environment with frequency of 20 Hz and less.

Infrasound can be generated by natural events: thunder, winds, volcanic activity, large waterfalls, impact of ocean waves, earthquakes. Also it can be generated by man-made events: high powered aircraft, rocket propulsion systems, explosions, sonic booms, bridge vibrations, ships, air compressors, washing machines, air heating and cooling systems, automobiles, trucks, watercraft and rail traffic.

The infrasound effect on a human at the level of 100–120 dB especially at 6–8 Hz frequency can cause:

- unpleasant feeling;
- hearing impairment;
- nausea;
- dizziness;
- disturbances of the vestibular apparatus.

At the upper end of the audio range, hearing sensitivity decreases at the rate of approximately 100 dB/octave, compared to 10–20 dB/octave for low audio and infrasonic frequencies. Most HPDs (hearing protection device) provide relatively good attenuation at high frequencies υ.

Ways of protection:

- reduction of the infrasound level in its origin;
- removal of the infrasound causes;
- medical prophylaxis;
- increase of frequency of mechanism rotation;
- increase in construction inflexibility;
- mufflers installation of the resonance type, resonance and chamber.

QUESTIONS FOR REVIEW

1. Hearing and pain threshold. Value of intensity and sound pressure.
2. Noise disease. Causes, symptoms, consequences.
3. Acoustic treatment of premises.
4. Individual protection means against noise.
5. Difference between ultrasound and infrasound by effect on human health.

Topic 6
Protection against industrial vibration

Main lecture questions:

6.1 Physical characteristics and classification of vibration.

6.2 Effects of vibration on the human body.

6.3 Common protective methods against harmful effects of vibration.

6.1 Physical characteristics and classification of vibration

At low frequencies (3–100 Hz) with large amplitude (0.5–0.003 mm) a human perceives oscillation as a ***vibration***.

According to the presence 6 degrees of freeness in the simplest single-mass systems vibration is generally implemented in six ways (fig. 6.1).

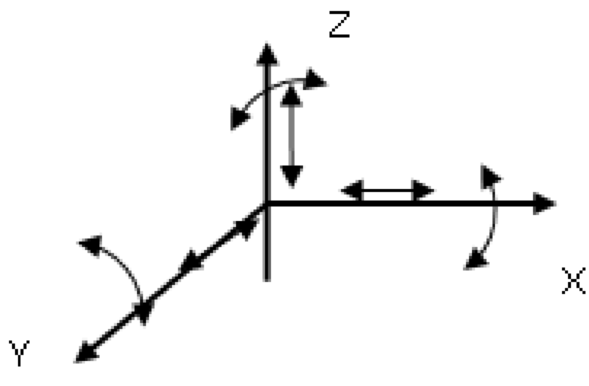


Figure 6.1 – Forms of vibrations implementation

Vibration is a movement of point or mechanical system in which there is an increase or decrease alternately in time value of at least one coordinate.

The causes of vibration can be:

1) unbalanced forceful actions (gears, crank mechanism in engines and compressors);

2) unbalanced elements that rotate: uneven product distribution in the mills, centrifuges, separators, rotating. Non-symmetrical wear causes beating. Imbalance is due to casting defects, non-symmetrical mass distribution, and others;

3) wind resonance (on the cause of up to 50-ies of the last century was not brought to notice).

Types of vibration regarding the influence on a person:

a) local (brings into oscillation motion only separate parts of the body);

b) general (causes shaking of a person).

Types of general vibration regarding the sources of its origin:

– transporting (during the motion of the machines);

– transporting and technological (during the work of the machines which execute technological operations in the stationary position or move on the specially prepared surfaces);

– technological (during the work of the stationary machines or transmitted to the working places that do not have any sources of vibration).

Vibration is characterized by absolute parameters:

1) amplitude of displacement (X), m, is the magnitude of the rejection that fluctuates from the equilibrium position;

2) amplitude of speed (V), m/s;

3) amplitude of acceleration (A), m/s^2;

4) the period of oscillation (T), s.

5) frequency (f), Hz.

6.2 Effects of vibration on the human body

Vibration influence on a human depends on:

– the vibration parameters;

– the direction of its action;

– places of its impact;

– the individual characteristics of a person.

Diseases caused by systematic influence of general vibration:

– vibration illness (serious disorder of the physical health, usually caused by the vibration effect onto the CNS);

– migraine;
– dizziness;
– bad sleep;
– lessening of work efficiency;
– bad feel;
– poor cardiac health.

Rate vibration of 10.4 m/s is physiologically caught by a person as the threshold of perception. Vibration with the speed of 1 m/s causes pain.

General vibration causes the shaking of the whole body. Local vibration attracts the oscillating movement of the body parts.

To local vibration are exposed workers, who work with different types of hand-held power tool (for cleaning welds, fettling of castings, riveting, etc.).

Effect of general vibration on the human body occurs in different ways, depending on its frequency.

Harmful influence of local vibration is as follows: spasms of the vessels which begin from the finger phalanxes, and spread over the hand, forearm and engulf the heart vessels.

General vibration with a frequency of 0.7 Hz (shaking), although unpleasant, but does not lead to disease. In this case, the human body and its individual organs move as a single unit without experiencing mutual displacements. The consequence of this vibration is the so-called “sea” disease that occurs due to disruption of the normal activities of the human vestibular apparatus.

Various internal organs and body parts (e. g., head and heart) can be conventionally regarded as oscillatory systems with a specific concentrated mass, as there is a spring connecting muscles, bones, and connective tissues. This system has a number of resonances whose frequencies also depend on the worker’s body position (“standing” or “sitting”).

The resonance at frequencies of 4–6 Hz corresponds to the oscillations of the shoulder girdle and hips; at frequencies of 25–30 Hz – head over your shoulders (sitting position).

For most of the internal organs natural frequencies are in the range of 6–9 Hz.

Fluctuations jobs with these resonance frequencies are very dangerous because they can even cause mechanical damage and rupture of these bodies. Systematic action of general vibration in a resonant or near resonant frequency may cause occupational disease such as vibration disease.

Vibration disease is a professional disease, the main etiological factor of which is industrial vibration. There are the following concomitant occupational factors of risk as the favourable background for the development of the disease: noise, super cooling, significant muscle tension of shoulder, forced position of body.

It leads to the degeneration of biological tissues:

a) muscle atrophy;

b) loss of elasticity of blood vessels (become brittle, resulting in disturbed blood supply);

c) loss of mobility of the tendons (spinal deformity);

d) loss of sensitivity of nerve endings, increased fragility of hair and nails.

Local vibration acts somewhat differently in the human body:

a) vascular spasms, that start with the terminal phalanges, are extended to the entire palm, forearm and cover the vessels of the heart;

b) there is deterioration in limb blood supply.

At the same time there is an impact on the nerves, muscle and bone tissue. This action is expressed in such forms:

c) in violation of the sensitivity of the skin;

d) in the ossification of the tendons and muscles;

e) pain and salt deposits in the joints of hands.

In the end, the deformation and decrease in joint mobility.

Especially harmful vibrations are with the frequency equal to the frequency of: the body and its organs (6–9 Hz); hands (30–80 Hz).

Methods of hygienical estimation of vibration:

– frequency (spectral) analysis of its parameters;

– integral estimation of the spectrum of the frequency parameters, that are rationed;

– dose of the vibration.

6.3 Common protective methods against harmful effects of vibration

The main directions of solving the problem of vibration protection are the automation of production and the introduction of robotics.

Ways of protection against vibration:

1) reduction of vibration in the source of its origin;
2) vibration damper;
3) vibration extinction;
4) vibration isolation.

Reduction of vibration in the source of its origin:

– the replacement of the percussive processes by non-percussive;

– the static and dynamic balancing;

– the replacement of metallic details by plastics with the significant internal friction;

– an application of the resilient insertions and gaskets in the connections;

– the greasing of the connecting and passing machine knots.

Vibration damper is a reduction of the vibration level of the protected object by converting the energy of mechanical vibrations of this system, fluctuates in other types of energy (fig. 6.2).

Figure 6.2 – Vibration damper

Increasing energy losses in the system can be by:

1) using vibration absorbents with the significant internal friction (plastics, soft rubbers, mastics, thick felt);

2) using materials with greater internal friction allows lowering vibration in the range of mean and high frequencies between 8–10 dB.

Vibration extinction is the reduction of vibration level of machines and aggregates by placing it onto the vibration isolation bases.

Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibrations (rubber, spring and combined) (fig. 6.3).

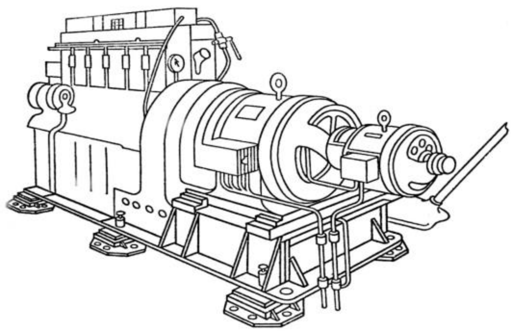
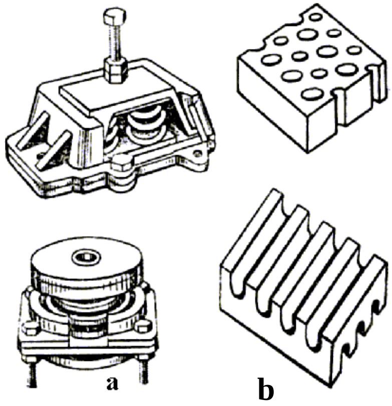


Figure 6.3 – System with the vibration isolation

1. Vibration isolation between the stationary equipment and the foundation by means of rubber gaskets, springs, rubber and metal shock absorbers (fig. 6.4).

Spring insulators in comparison with rubber have a number of advantages: they can be used for isolation of both low and high frequencies; they retain the constancy of elastic properties in time longer, resist the effects of oils and heat, relatively small. But they can skip high frequency vibrations, as the spring material (steel) has small internal losses. Therefore, in this case it is recommended to install spring vibration isolators on gaskets made from elastic materials such as rubber (combined cushioning).



a – springs; b – rubber vibroinsulator
Figure 6.4 – Vibration isolated supports (shock absorbers)

2. Acoustic joints of the foundations of buildings (emptiness is left on the foundation of the building).

3. Basement vibration insulation from the ground.

4. Elastic inserts between the load-bearing elements of buildings and structures (the fans are separated by an elastic insert from the air ducts).

5. When working with a hand-operated mechanized tool, personal protective equipment is used against vibration.

Personal protective equipment includes:

a) anti-vibration gloves;

b) anti-vibration pads or plates, which are secured by fastening to the handle;

c) special shoes on a high elastic sole.

To prevent vibration disease for workers with vibrating equipment it is recommended to carry out a set of preventive measures:

1) water treatment;

2) massage;

3) physical therapy;

4) vitaminization (Vitamins B_1, B_{12}, B_6, PP).

Periodic medical examinations are realized not rarer than once in 12 months with participation of internist, neurologist, otolaryngologist. At the inspection it is necessary to realize capillaroscopy, measuring of skin temperature, cold test, to explore vibration, pain sensitiveness, if necessary radiography of hands, spine.

When working with vibrating equipment a duty cycle processing operation not related to vibration is included. If this is not possible, it is necessary to provide for 10–15 minute breaks after every hour of operation.

It is noted that the adverse effects of exposure to vibration are enhanced in cold conditions. Therefore, in the wintertime it is necessary to provide workers with warm mittens.

QUESTIONS FOR REVIEW

1. Causes and types of vibration.
2. General and local vibration.
3. Vibration disease. Causes, symptoms, consequences.
4. Ways of protection against vibration.
5. Vibration damper. Vibration extinction. Vibration isolation.

Topic 7
Protection from exposure of ionizing radiation

Main lecture questions:

7.1 Characteristics of ionizing radiation.

7.2 The biological effect of ionizing radiation.

7.3 General principles of protection against ionizing radiation.

7.1 Characteristics of ionizing radiation

Ionizing radiation (IR) can damage living tissue in the human body. It strips away electrons from atoms breaks some chemical bonds.

Ionizing radiation is used in:

a) medicine;

b) industry (instruments for material thickness measuring, moisture meters, level signaling, various signaling devices), defectoscopy;

c) biology (plant breeding);

d) agriculture (seed radiation before sowing, etc.);

e) sterilizing products.

Spontaneous decay of radioactive materials produces radiation. It may be the result of an accident of Power Nuclear Plants and other objects.

Radiation may be ionizing and non-ionizing. The main types of ionizing radiation are:

1. Corpuscular radiation (α-, β-rays, neutron radiation).

2. Electromagnetic radiation (γ-, x-ray, cosmic radiation).

Alpha and beta, gamma and X-rays particles are the most common forms of ionizing radiations. Radioactive iodine is a beta particle released during nuclear plant accidents. The amount of energy the radiations can deposit in a given space varies with each type. Radiations also differ in the power to penetrate. Inside the body the alpha particle will deposit all its energy in a very small volume of tissue while gamma radiation will spread energy over a much larger volume (fig. 7.1).

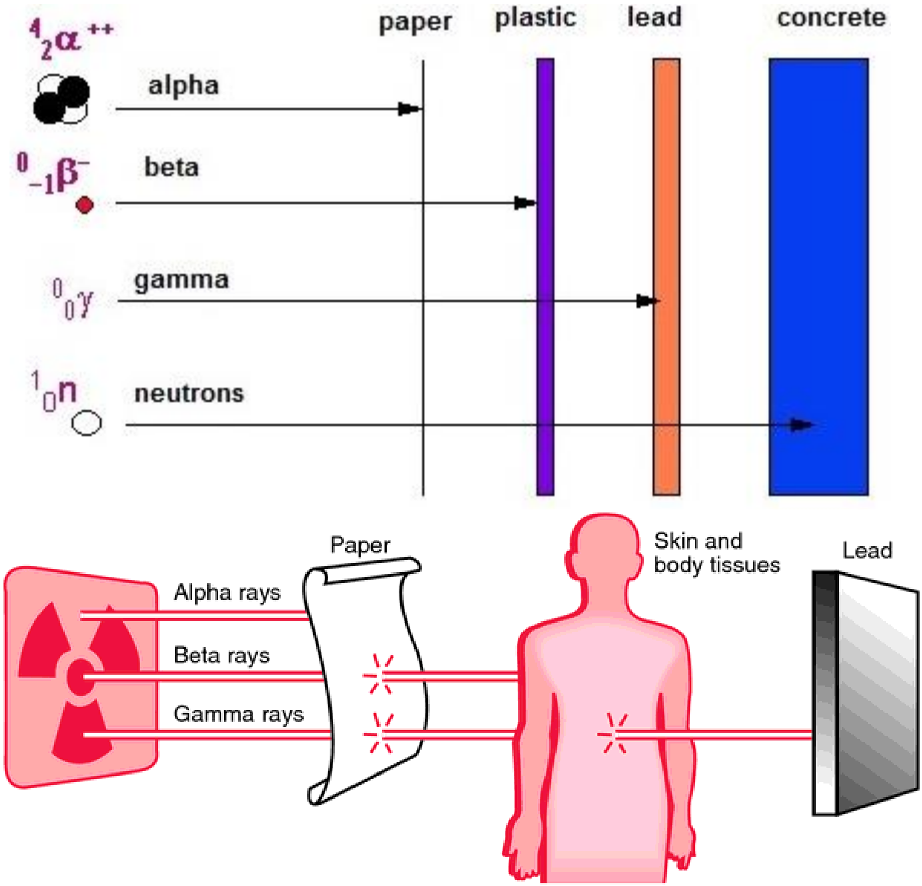


Figure 7.1 – Comparison of main types of ionizing radiation

The boundary between ionizing and non-ionizing electromagnetic radiation that occurs in the ultraviolet is not sharply defined, since different molecules and atoms ionize at different energies. Conventional definition places the boundary at a photon energy between 10 eV and 33 eV in the ultraviolet.

7.2 The biological effect of ionizing radiation

The allowed exposures from specific radioactive sources to the public are limited to 100 mrem. Medical X-rays generally deliver less than 10 mrem. All kinds of ionizing radiations produce health effects. The damages incurred by different kinds of tissue vary with the type of radiation to which the person is exposed and the means of exposure. Non-ionizing radiations do not affect at molecular levels. They may cause electrical shocks and burns. Prolonged exposure to microwaves radiation, which is non-ionizing, may cause cataracts.

The biological effect of ionizing radiation on human health is divided into two types: direct and indirect. Direct exposure to radiation and radiation emitters (radionuclides) can affect the whole body while inhalation or ingestion affects tissues inside the body.

The body attempts to repair the damage caused by the radiation. However, at times the damage is so severe and widespread that repair is impossible. Radiations can damage the process of normal cell division leading to cancers (fig. 7.2).

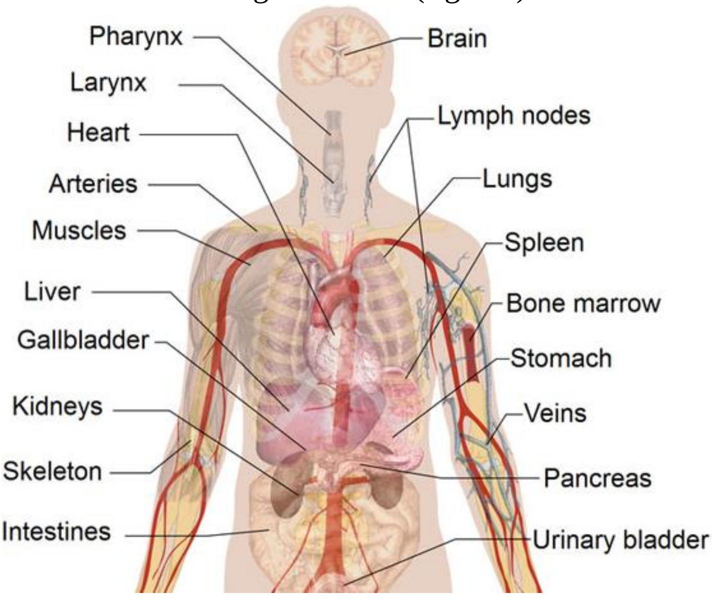


Figure 7.2 – Ionizing radiation effect on human body

Indirect effect is ionization of water molecules, which is part of the biological tissue (70–80 % of the human body consists of water) (fig. 7.3).

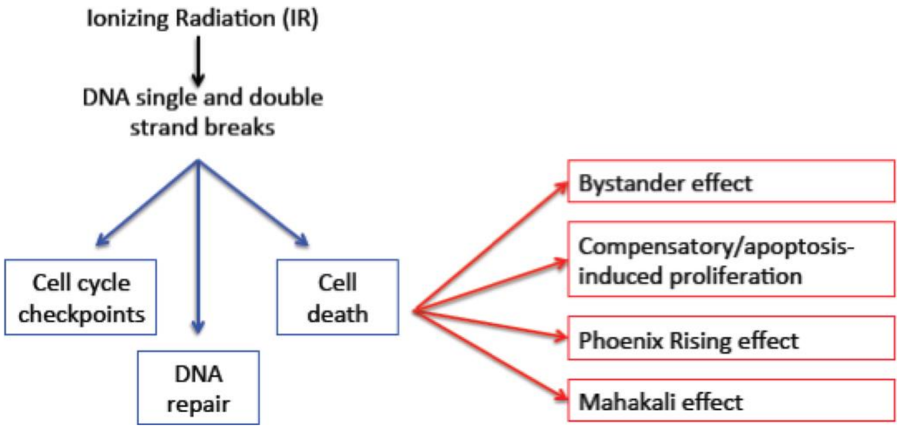


Figure 7.3 – Ionizing radiation effect on DNA

The thyroid gland is one of the most radiation-sensitive parts of the body, especially in babies and children. Most nuclear accidents release radioactive iodine into the atmosphere. This is absorbed by the body. Absorption of too much radioactive iodine can cause thyroid cancer to develop several years after exposure.

Biological effect of IR depends on:

a) the dose of radiation. For example:
   0–25 Rem – tangible violations are absent;
   25–50 Rem – possible changes in the blood;
   80–120 Rem – change of blood cells (initial signs of radiation sickness);
   up to 120 Rem – working infringement;
   250–450 Rem – disability;
   300 Rem – the death, 50 % of the damage;
   600 Rem – 100 % of the death;

b) the IR type, because different types of IR have different penetrating potential;

c) the age (children are more susceptible);

d) the sensitivity of the organism to IR.

For example, a lethal dose:
– for mice is 500 Rem;
– for rabbits is 1 200 Rem;
– for frogs is 5 000 Rem;
– for bedbugs is 10 000 Rem.

7.3 General principles of protection against ionizing radiation

The current radiation protection standards are based on three general principles:

1. Justification of a practice, i. e. no practice involving exposures to radiation should be adopted unless it provides sufficient benefit to offset the detrimental effects of radiation.

2. Protection should be optimized in relation to the magnitude of doses, number of people exposed and also to optimize it for all social and economic strata of patients.

3. Dose limitation, on the other hand, deals with the idea of establishing annual dose limits for occupational exposures, public exposures, and exposures to the embryo and fetus.

The international radiation symbol (also known as the trefoil) first appeared in 1946, at the University of California, Berkeley Radiation Laboratory. The sign is commonly referred to as a radioactivity warning sign, but it is actually a warning sign of ionizing radiation.

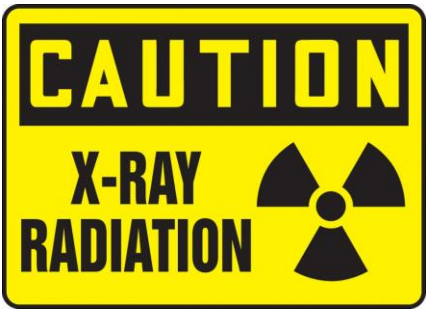


Figure 7.4 – Warning signs of radiation hazards

Optimization of protection and the ALARA Principle. Optimization of protection can be achieved by optimizing the procedure to administer a radiation dose which is *as low as reasonably achievable* (ALARA), so as to derive maximum diagnostic information with minimum discomfort to the patient. ALARA and Optimization of Radiation Protection (ORP) are concepts of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection (NCRP). The history of the ALARA concept is traced back to the Manhattan project of World War-II that radiation exposures be kept at lowest possible level. This means that all radiation exposures to patients and personnel are to be kept as low as possible while still obtaining the accurate diagnostic information needed from the procedure. ALARA recognizes that there will always be some radiation exposure to patients involved in radiological procedures using ionizing radiation, but it also recognizes that these exposures can be minimized.

Judicious choice of investigations can significantly avoid not only radiation exposures but also increase both the diagnostic accuracy and working efficiency of a radiology department. These include substituting non-ionizing methods of examination in place of examinations involving ionizing radiation wherever possible; e. g. a combination of Ultrasound (US) and radio-nuclide study in place of Intravenous Urography (IVU), where US provides adequate structural information and radio-nuclide study provides the functional information. Evaluation of the lymph node status in the abdomen in various clinical conditions by US in place of repeated Computed Tomography (CT) and use of Colour Doppler flow imaging in place of diagnostic angiography are two other simple methods to reduce radiation exposure to patients.

The greatest risk to the fetus of chromosomal abnormalities and subsequent mental retardation is between 8 and 15 weeks of pregnancy and examinations involving radiation to the fetus should be avoided during this period. For examinations which may involve rather heavy doses of radiation such as Barium enemas, pelvic or abdominal CT, the examination should be carried out during the first 10 days of the menstrual cycle to avoid irradiating any possible pregnancy. Some of the methods to reduce radiation exposure, which show the maximum benefits of radiation protection and cause minimum extra costs, are also the simplest. These include avoiding repeat exposures by employing proper exposure factors, and maintaining a proper record of films so that repeat examinations can be avoided wherever possible. In our opinion “optimization of protection” can be achieved by “optimization of the radiological procedure” so as to reduce radiation exposures to the minimum levels. This optimization is possible by good quality assurance and quality control. Factors which can contribute to dose reduction and quality assurance are: using high frequency three phase generator equipment, using high KV technique and low mAs, using the shortest exposure time, beam collimation and using proper beam filtration. The other factors which contribute to optimization of procedure are using a X-ray table top which allows high beam transmission, antiscatter grids, high speed films with rare earth screens, optimal film processing and largest possible *source to image receptor distance* (SID). High frequency generators help in generating high KV for use in the “high KV and low mAs technique”. The high KV beam has higher energy photons, which undergo a lesser degree of beam attenuation and greater penetration of the beam through the patient. Therefore the tissue deposition of photons is reduced, which reduces the radiation dose to the patient.

Tube current or mA determines the quantity of the photons (in contradistinction to KV which determines the energy of photons) which also contribute to the patient dose. Increased exposure time also contributes to an increased patient dose. Since patient exposure is determined by exposure rate and time, the use of high frequency generators which generate high KV beam will decrease the mAs required to produce diagnostically adequate X-rays and hence reduce radiation dose to the patient.

Beam filtration causes lower energy photons to be absorbed by the filters thus increase the mean energy of the beam and its penetration power and hence decrease the patient dose. Beam collimation determines the size and shape of the beam. Field of view (FOV) which is the size of the irradiated area, directly affects the patient dose. Beam collimators control the FOV in such way, that only the diagnostically important area is irradiated. A good alignment between the field of the collimator and the radiation beam, reduces the possibility of beam cut off and beam overlap, thus reduces the chances of diagnostically inadequate exposures and prevents repeat exposures. The table top should be one which allows a high beam transmission which increases the quantity of diagnostically important photons reaching the film. A carbon fibre material is generally used for a high transmission table top. Antiscatter grids reduce scattered radiation reaching the film thus improving the quality of the resulting the radiograph and reducing chances of repeat exposures. Although antiscatter grids require slightly higher exposures and somewhat increased radiation dose to the patient, their advantage in producing improved quality of radiographs outweighs this minor risk of increased radiation dose to the patient. Appropriate SID also has an important role in radiation protection, which is discussed in the subsequent section.

Correct exposure factors and technical considerations have a significant contribution towards patient shielding for CT examinations as well. For a CT examination of the skull, correct gantry angulation and beam collimation significantly reduce radiation dose to the orbits, despite the proximity of these organs to the x-ray beam, whereas the converse is true if correct technical considerations are not adhered to.

QUESTIONS FOR REVIEW

1. Main types of ionizing radiation.
2. Difference between corpuscular and electromagnetic radiation.
3. Ionizing radiation effect on DNA.
4. What factors does biological effect of IR depend on?
5. Warning signs of radiation hazards.
6. Optimization of protection against ionizing radiation.

Topic 8
Protection from exposure of electromagnetic fields

Main lecture questions:

8.1 Characterization and classification of electromagnetic fields (EMF).

8.2 Effect of EMF on human health.

8.3 Guidelines for limiting EMF exposure.

8.4 Protective measures against EMF.

8.1 Characterization and classification of electromagnetic fields (EMF)

Whereas electric fields are associated only with the presence of electric charge, magnetic fields are the result of the physical movement of electric charge (electric current). An electric field, **E**, exerts forces on an electric charge and is expressed in volt per meter (V m^{-1}).

Similarly, magnetic fields can exert physical forces on electric charges, but only when such charges are in motion. Electric and magnetic fields have both magnitude and direction (i. e., they are vectors). A magnetic field can be specified in two ways – as magnetic flux density, **B**, expressed in tesla (T), or as magnetic field strength, **H**, expressed in ampere per meter (A m^{-1}). The two quantities are related by the expression:

$$B = \mu H , \qquad (8.1)$$

where μ is the constant of proportionality (the magnetic permeability); in a vacuum and in air, as well as in non-magnetic (including biological) materials, μ has the value $4\pi \cdot 10^{-7}$ when expressed in henry per meter (H m^{-1}). Thus, in describing a magnetic field for protection purposes, only one of the quantities **B** or **H** needs to be specified.

The electromagnetic spectrum is divided into following sub-section according to frequency (f) range: radio frequency (RF)

(100 kHz < f ≤ 300 GHz), intermediate frequency (IF) (300 Hz < f ≤ ≤ 100 kHz), extremely low frequency (ELF) (0< f ≤ 300 Hz), and static (0 Hz) (only static magnetic fields are considered in this opinion) (fig. 8.1). There is a separate section for environmental effects.

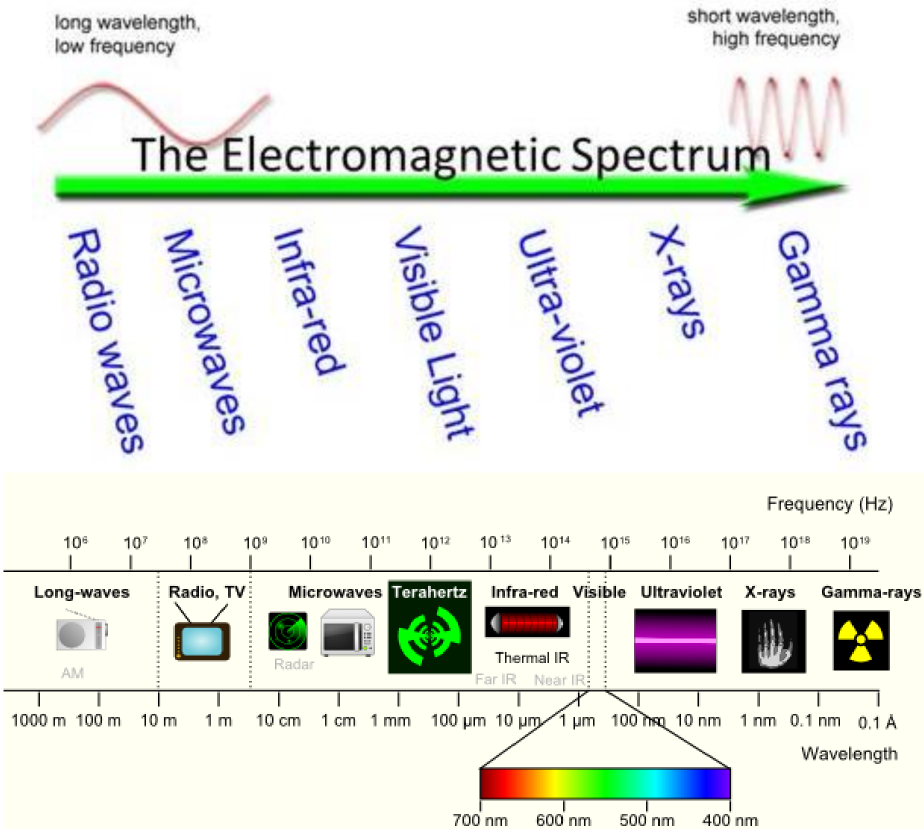


Figure 8.1 – Electromagnetic spectrum

In the far-field region, the plane-wave model is a good approximation of the electromagnetic field propagation.

The characteristics of a plane wave are:

a) the wave fronts have a planar geometry;

b) the **E** and **H** vectors and the direction of propagation are mutually perpendicular;

c) the phase of the **E** and **H** fields is the same;

d) the quotient of the amplitude of E/H is constant throughout space. In free space, the ratio of their amplitudes E/H = 377 ohm, which is the characteristic impedance of free space;

e) power density, **S**, i. e., the power per unit area normal to the direction of propagation, is related to the electric and magnetic fields by the expression:

$$S = EH = E^2 / 377 = 377 H^2 . \tag{8.2}$$

Table 8.1 – Typical sources of electromagnetic fields

Frequency range	Frequencies	Some examples of exposure sources
Static	0 Hz	VDU (video displays); MRI and other diagnostic/scientific instrumentation; Industrial electrolysis; Welding devices
ELF	0–300 Hz	Powerlines; domestic distribution lines, domestic appliances; electric engines in cars, train and tramway; welding devices
IF	300 Hz – 100 kHz	VDU; anti theft devices in shops, hands free access control systems, card readers and metal detectors; MRI; welding devices
RF	100 kHz – 300 GHz	Mobile telephony; broadcasting and TV; microwave oven; radar, portable and stationary radio transceivers, personal mobile radio; MRI

Over the course of the past decade, numerous electromagnetic field sources have become the focus of health concerns, including power lines, microwave ovens, computer and TV screens, security devices, radars and most recently mobile phones and their base stations (table 8.1).

8.2 Effect of EMF on human health

It is well recognized that there are established biophysical mechanisms that can lead to health effects as a consequence of exposure to sufficiently strong fields. For frequencies up to, say, 100 kHz the mechanism is stimulation of nerve and muscle cells due to induced currents and, for higher frequencies, tissue heating is the main mechanism. These mechanisms lead to acute effects (fig. 8.2).

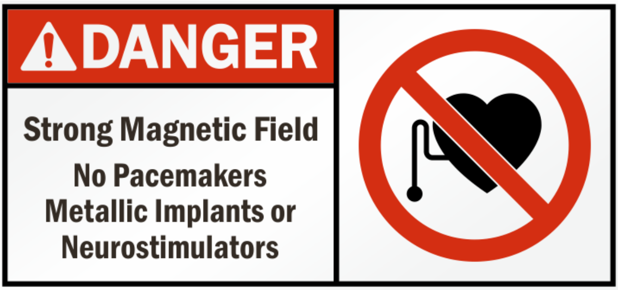


Figure 8.2 – Electromagnetic field warning sign

Low-frequency electric fields influence the human body just as they influence any other material made up of charged particles. When electric fields act on conductive materials, they influence the distribution of electric charges at their surface. They cause current to flow through the body to the ground. Low-frequency magnetic fields induce circulating currents within the human body. The strength of these currents depends on the intensity of the outside magnetic field. If sufficiently large, these currents could cause stimulation of nerves and muscles or affect other biological processes.

Both electric and magnetic fields induce voltages and currents in the body but even directly beneath a high voltage transmission line, the induced currents are very small compared to thresholds for producing shock and other electrical effects.

Heating is the main biological effect of the electromagnetic fields of radiofrequency fields. In microwave ovens this fact is employed to warm up food. The levels of radiofrequency fields to which people are normally exposed are very much lower than those needed to produce significant heating. Scientists are also investigating the possibility that effects below the threshold level for body heating occur as a result of long-term exposure.

Effects on general health. Some members of the public have attributed a diffuse collection of symptoms to low levels of exposure to electromagnetic fields at home. Reported symptoms include headaches, anxiety, suicide and depression, nausea, fatigue and loss of libido. To date, scientific evidence does not support a link between these symptoms and exposure to electromagnetic fields. At least some of these health problems may be caused by noise or other factors in the environment or by anxiety related to the presence of new technologies.

Effects on pregnancy outcome. Many different sources and exposures to electromagnetic fields in the living and working environment, including computer screens, water beds and electric blankets, radiofrequency welding machines, diathermy equipment and radar, have been evaluated by the WHO and other organizations. The overall weight of evidence shows that exposure to fields at typical environmental levels does not increase the risk of any adverse outcome such as spontaneous abortions, malformations, low birth weight, and congenital diseases.

Cataracts. General eye irritation and cataracts have sometimes been reported in workers exposed to high levels of radiofrequency and microwave radiation, but animal studies do not support the idea that such forms of eye damage can be produced at levels that are not thermally hazardous. There is no evidence that these effects occur at levels experienced by the general public.

Electromagnetic fields and cancer. Despite many studies, the evidence for any effect remains highly controversial. However, it is clear that if electromagnetic fields do have an effect on cancer, then any increase in risk will be extremely small. A number of epidemiological studies suggest small increases in risk of childhood leukemia with exposure to low frequency magnetic fields in the home. However, scientists have not generally concluded that these results indicate a cause-effect relation between exposure to the fields and disease (as opposed to artifacts in the study or effects unrelated to field exposure). In part, this conclusion has been reached because animal and laboratory studies fail to demonstrate any reproducible effects that are consistent with the hypothesis that fields cause or promote cancer. Large-scale studies are currently underway in several countries and may help resolve these issues.

Electromagnetic hypersensitivity and depression. Some individuals report "hypersensitivity" to electric or magnetic fields. They ask whether aches and pains, headaches, depression, lethargy, sleeping disorders, and even convulsions and epileptic seizures could be associated with electromagnetic field exposure.

There is little scientific evidence to support the idea of electromagnetic hypersensitivity. Recent Scandinavian studies found that individuals do not show consistent reactions under properly controlled conditions of electromagnetic field exposure. Nor is there any accepted biological mechanism to explain hypersensitivity. Research on this subject is difficult because many other subjective responses may be involved, apart from direct effects of fields themselves.

8.3 Guidelines for limiting EMF exposure

There is insufficient information on the biological and health effects of EMF exposure of human populations and experimental animals to provide a rigorous basis for establishing safety factors over the whole frequency range and for all frequency modulations. In addition, some of the uncertainty regarding the appropriate safety factor derives from a lack of knowledge regarding the appropriate dosimetry. Existing exposure guidelines, such as those issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), protect against these effects. The current issue is the possibility that health effects occur at exposure levels below those where the established mechanisms play a role and in particular as effects of long term exposure at low level.

The following general variables were considered in the development of safety factors for high-frequency fields:

a) effects of EMF exposure under severe environmental conditions (high temperature, etc.) and/or high activity levels;

b) the potentially higher thermal sensitivity in certain population groups, such as the frail and/or elderly, infants and young children, and people with diseases or taking medications that compromise thermal tolerance.

The following additional factors were taken into account in deriving reference levels for high-frequency fields:

a) differences in absorption of electromagnetic energy by individuals of different sizes and different orientations relative to the field;

b) reflection, focusing, and scattering of the incident field, which can result in enhanced localized absorption of high-frequency energy.

Different scientific bases were used in the development of basic exposure restrictions for various frequency ranges:

a) between 1 Hz and 10 MHz, basic restrictions are provided on current density to prevent effects on nervous system functions;

b) between 100 kHz and 10 GHz, basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localized tissue heating; in the 100 kHz – 10 MHz range, restrictions are provided on both current density and SAR;

c) between 10 and 300 GHz, basic restrictions are provided on power density to prevent excessive heating in tissue at or near the body surface.

8.4 Protective measures against EMF

Measures for the protection of workers include engineering and administrative controls, personal protection programs, and medical surveillance. Appropriate protective measures must be implemented when exposure in the workplace results in the basic restrictions being exceeded. As a first step, engineering controls should be undertaken wherever possible to reduce device emissions of fields to acceptable levels. Such controls include good safety design and, where necessary, the use of interlocks or similar health protection mechanisms.

Administrative controls, such as limitations on access and the use of audible and visible warnings, should be used in conjunction with engineering controls. The equipment emitting EMF must be placed in working areas dedicated to the sole use of that equipment and at an appropriate distance from other working areas where the personnel stands for extended periods of time. Moreover, in order to prevent indirect effects, interferential problems and undue exposure, it is of basic importance to avoid that metallic objects of any kind and electrical equipment are placed next to EMF sources, except if an appropriate previous technical assessment has been performed.

In general, the distance between the installation area of the equipment, which we will define as the restricted access area with relation to the risk of EMF exposure, and the other working areas, which are free access areas, depends on the technical features of the equipment and should be estimated by the person who is in charge of risk assessment.

In application of the optimization principle, it will be appropriate to aim, where possible, at obtaining that the exposure to electromagnetic fields in the areas dedicated to prolonged stay of the non-professionally exposed personnel is below the maximum limits established in the current regulations for the general public.

The work areas where the exposure values can be higher than the reference levels for the general public established in the European recommendation 1999/519/EC, should be delimited by using electromagnetic fields alerting signs, which have to be compliant to the current regulations for warning signs (fig. 8.3).

Personal protection measures, such as protective clothing, though useful in certain circumstances, should be regarded as a last resort to ensure the safety of the worker; priority should be given to engineering and administrative controls wherever possible. Furthermore, when such items as insulated gloves are used to protect individuals from high-frequency shock and burns, the basic restrictions must not be exceeded, since the insulation protects only against indirect effects of the fields.

Beyond This Point you are entering an area where RF Emissions *may exceed* the FCC General Population Exposure Limits
Follow all posted signs and site guidelines for working in an RF environment

Beyond This Point you are entering a controlled area where RF Emissions *may exceed* the FCC Occupational Exposure Limits
Obey all posted signs and site guidelines for working in an RF environment

Beyond This Point you are entering a controlled area where RF Emissions *exceed* the FCC Controlled Exposure Limits
Failure to obey all posted signs and site guidelines could result in serious injury

Figure 8.3 – Electromagnetic fields safety signs

With the exception of protective clothing and other personal protection, the same measures can be applied to the general public whenever there is a possibility that the general public reference levels might be exceeded.

It is also essential to establish and implement rules that will prevent:

a) interference with medical electronic equipment and devices (including cardiac pacemakers);

b) detonation of electro-explosive devices (detonators);

c) fires and explosions resulting from ignition of flammable materials by sparks caused by induced fields, contact currents, or spark discharges.

QUESTIONS FOR REVIEW

1. Physical parameters of electromagnetic fields.
2. Electromagnetic spectrum.
3. Main sources of electromagnetic fields.

4. Electromagnetic field warning sign.
5. Effects on general health, pregnancy outcome of EMF.
6. Electromagnetic fields and cancer.
7. Safety factors for high-frequency fields.
8. Personal protection measures against EMF.

Topic 9
Electrical safety

Main lecture questions:

9.1 Effects of electric current on the human body.
9.2 The danger of static electricity.
9.3 Protection against electrical hazards.
9.4 Carrying out work in the electrical network.

9.1 Effects of electric current on the human body

Electrical safety is a system of organizational and technical measures and tools that protect people from harmful and dangerous current electric arc, electromagnetic field and static electricity.

Electric current that passes through the body, causes thermal, electrolytic, biological and mechanical action.

Thermal effect of electric current causes skin burns, heating to a high temperature of blood vessels, nerves, heart, brain and other organs that are on the current path, and causes them serious functional disorders.

Electrolytic effect of electric current appears in the electrolysis (decomposition) fluids, including blood.

Biological effect of electric current appears in the stimulation and excitement of living tissues, resulting in the observed convulsive muscle contractions that can lead to respiratory arrest, the breakdown of tissues and organs, dislocation of limbs, spasms of the vocal cords.

Mechanical effect of electric current is evident in tissue separation and isolation even in parts of the body.

People are injured when they become part of the electrical circuit. Humans are more conductive than the earth (the ground we stand on) which means if there is no other easy path, electricity will try to flow through our bodies.

There are four main types of injuries: electrocution (fatal), electric shock, burns, and falls. These injuries can happen in various ways:

– direct contact with exposed energized conductors or circuit parts. When electrical current travels through our bodies, it can interfere with the normal electrical signals between the brain and our muscles (e. g., heart may stop beating properly, breathing may stop, or muscles may spasm);

– when the electricity arcs (jumps, or “arcs”) from an exposed energized conductor or circuit part (e. g., overhead power lines) through a gas (such as air) to a person who is grounded (that would provide an alternative route to the ground for the electrical current).

Thermal burns including burns from heat generated by an electric arc, and flame burns from materials that catch on fire from heating or ignition by electrical currents or an electric arc flash. Contact burns from being shocked can burn internal tissues while leaving only very small injuries on the outside of the skin.

There are IV degrees of thermal burns:

I – redness of the skin;

II – formation of vesicles;

III – necrosis of the entire thickness of the skin;

IV – carbonization of tissue, burn to the bone.

Thermal burns from the heat are radiated from an electric arc flash. Ultraviolet (UV) and infrared (IR) light emitted from the arc flash can also cause damage to the eyes.

An arc blast can include a potential pressure wave released from an arc flash. This wave can cause physical injuries, collapse your lungs, or create noise that can damage hearing.

Muscle contractions, or a startle reaction, can cause a person to fall from a ladder, scaffold or aerial bucket. The fall can cause serious injuries.

Electric shock is a kind of reaction of the human organism to the action of an electric current.

Increasing levels of current above the “let-go” threshold causes loss of muscular control, irregular heart rhythm, and finally, cardiac arrest (fig. 9.1).

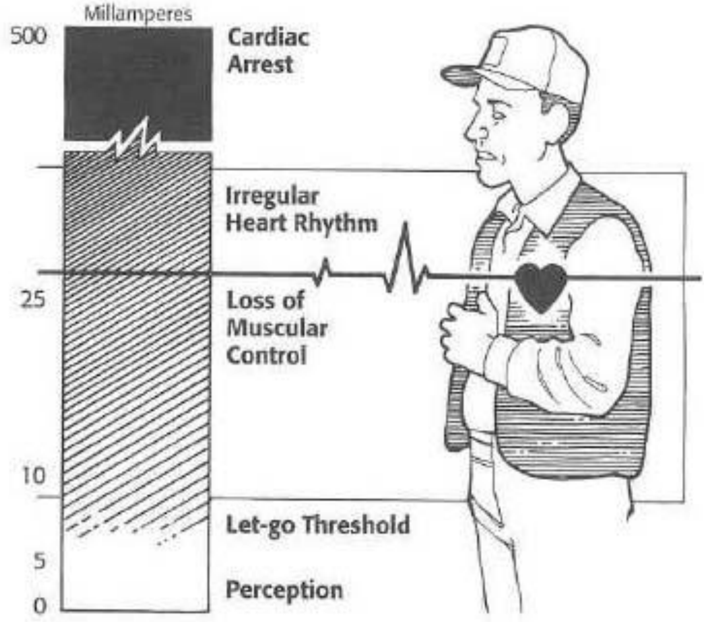


Figure 9.1 – Electrical shock

There are 4 degrees of electric shock:

1. Convulsive muscle contractions without loss of consciousness (without prejudice to the heartbeat and breathing).

2. Convulsive muscle contractions with loss of consciousness, but without prejudice to breathing and heartbeat (first aid is lead to memory using water, ammonia).

3. Loss of consciousness and irregular heartbeat or breathing (First Aid is cardiopulmonary resuscitation – CPR).

4. Clinical death is intermittent transition state from life to death, which occurs after the cessation of the heart and lungs.

Causes of death from electric current during electric shock:

1) cardiac arrest;

2) cessation of breathing (respiratory paralysis) is usually due to the direct action of the current on the chest muscles that are involved in the process of respiration;

3) electric shock is a kind of severe neuro-reflex reaction in response to excessive irritation hazard, which is accompanied by a profound disorder of blood circulation, respiration, and metabolism.

The main factors that determine the outcome of human injury hazard:

1. *The value of current.* By virtue of possible damage to a human, currents are divided into tangible, catching and fibrillated. Tangible current is an electric current that passes through when the body is felt irritated.

2. *The duration of current flow.* The higher the duration, the greater the likelihood of severe or fatal.

3. *The current way.* If the current path finds vital organs – heart, lungs, brain – the risk of injury is very high, since current acts directly on these organs.

4. *The impact of frequency and type of current*. Since the resistance of the human body has a capacitive component, increasing the frequency of the applied voltage is accompanied by the decrease in the impedance of the body and increase of the current that passes through a person.

5. *The individual properties.* Healthy and physically strong people are easier to endure electric shocks than sick and weak.

6. *The factor of attention.* Factor of attention increases resistance of the body. 85 % of electric shock factor occurs in the absence of attention.

9.2 The danger of static electricity

Nearly all electric charge in the universe is carried by protons and electrons. Protons are said to have a charge of +1 electron unit, while electrons have a charge of −1, although these signs are completely arbitrary. Because protons are generally confined to atomic nuclei, which are in turn imbedded inside atoms, they are not nearly as free to move as are electrons. Therefore, when we talk about electric current, we nearly always mean the flow of electrons, and when we talk about static electricity, we generally mean an imbalance between negative and positive charges in objects (fig. 9.2).

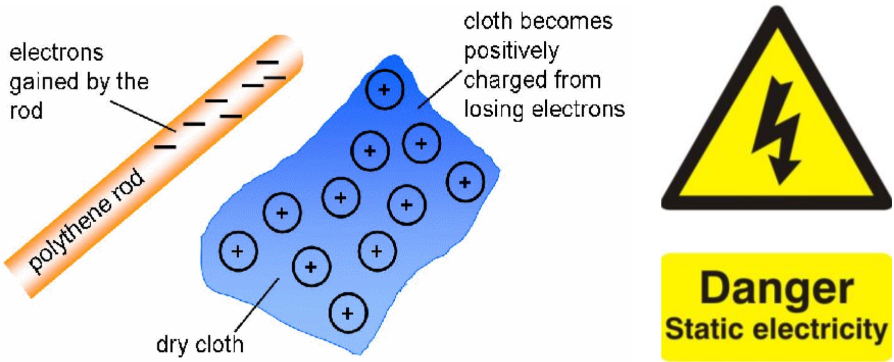


Figure 9.2 – Static electricity

Static electricity also can cause a shock, though in a different way and generally not as potentially severe as the type of shock described previously. Static electricity can build up on the surface of an object and, under the right conditions, can discharge to a person, causing a shock. The most familiar example of this is when a person reaches for a door knob or other metal object on a cold, relatively dry day and receives a shock. However, static electricity also can cause shocks or can just discharge to an object with much more serious consequences, as when friction causes a high level of static electricity to build up at a specific spot on an object. This can happen simply through handling plastic pipes and materials or during normal operation of rubberized drive or machine belts found in many worksites. In these cases, for example, static electricity can potentially discharge when sufficient amounts of flammable or combustible substances are located nearby and cause an explosion. Grounding or other measures may be necessary to prevent this static electricity buildup and the results.

9.3 Protection against electrical hazards

Most electrical accidents result from one of the following three factors:

- unsafe equipment or installation;
- unsafe environment;
- unsafe work practices.

Some ways to prevent these accidents are through the use of insulation, guarding, grounding, electrical protective devices, and safe work practices.

Insulators such as glass, mica, rubber, or plastic used to coat metals and other conductors help stop or reduce the flow of electrical current. This helps prevent shock, fires, and short circuits. To be effective, the insulation must be suitable for the voltage used and conditions such as temperature and other environmental factors like moisture, oil, gasoline, corrosive fumes, or other substances that could cause the insulator to fail.

Guarding involves locating or enclosing electric equipment to make sure people don't accidentally come into contact with its live parts. Effective guarding requires equipment with exposed parts operating at 50 volts or more to be placed where it is accessible only to authorized people qualified to work with it. Recommended locations are a room, vault, or similar enclosure; a balcony, gallery, or elevated platform; or a site elevated 8 feet (2.44 meters) or more above the floor. Sturdy, permanent screens also can serve as effective guards.

Conspicuous signs must be posted at the entrances to electrical rooms and similarly guarded locations to alert people to the electrical hazard and to forbid entry to unauthorized people. Signs may contain the word "Danger", "Warning" or "Caution" and beneath that, appropriate concise wording that alerts people to the hazard or gives an instruction, such as "Danger/High Voltage/Keep Out" (fig. 9.3).

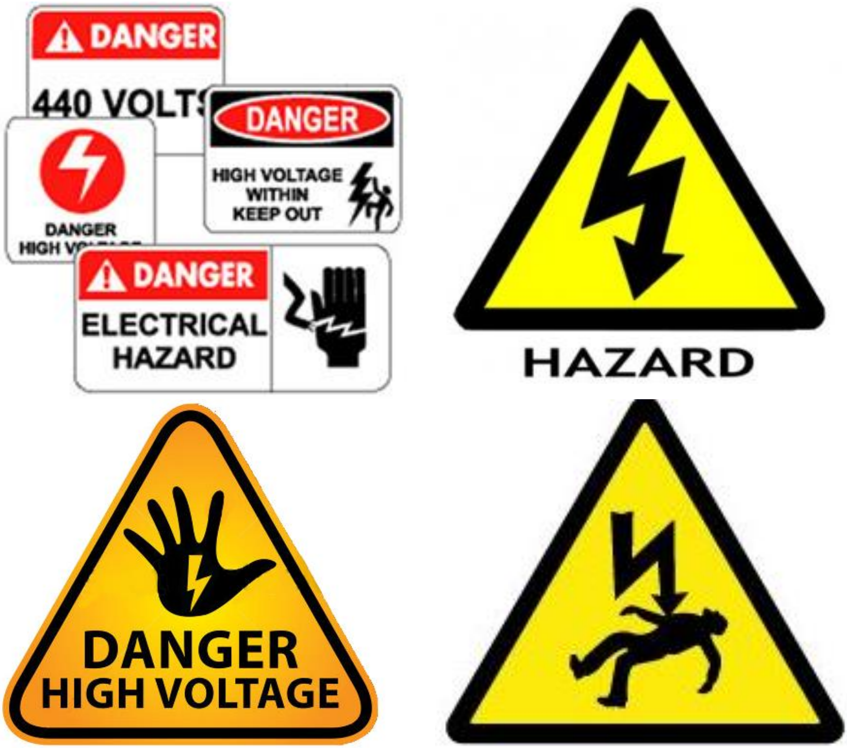


Figure 9.3 – Electrical Safety signs

"Grounding" a tool or electrical system means intentionally creating a low-resistance path that connects to the earth. This prevents the buildup of voltages that could cause an electrical accident. Grounding is normally a secondary protective measure to protect against electric shock. It does not guarantee that you won't get a shock or be injured or killed by an electrical current. It will, however, substantially reduce the risk, especially when used in combination with other safety measures.

A *service* or *system ground* is designed primarily to protect machines, tools, and insulation against damage. One wire, called the "neutral" or "grounded" conductor, is grounded. In an ordinary low-voltage circuit, the white or gray wire is grounded at the generator or transformer and at the building's service entrance.

An *equipment ground* helps protect the equipment operator. It furnishes a second path for the current to pass through from the tool or machine to the ground. This additional ground safeguards the operator if a malfunction causes the tool's metal frame to become energized. The resulting flow of current may activate the circuit protection devices.

Circuit protection devices limit or stop the flow of current automatically in the event of a ground fault, overload, or short circuit in the wiring system. Well-known examples of these devices are fuses, circuit breakers, ground-fault circuit interrupters, and arc-fault circuit interrupters (fig. 9.4).

Figure 9.4 – Circuit protection devices

Fuses and *circuit breakers* open or break the circuit automatically when too much current flows through them. When that happens, fuses melt and circuit breakers trip the circuit open. Fuses and circuit breakers are designed to protect conductors and equipment. They prevent wires and other components from overheating and open the circuit when there is a risk of a ground fault.

Ground-fault circuit interrupters, or GFCIs, are used in wet locations, construction sites, and other high-risk areas. These devices interrupt the flow of electricity within as little as 1/40 of a second to prevent electrocution. GFCIs compare the amount of current going into electric equipment with the amount of current returning from it along the circuit conductors. If the difference exceeds 5 milliamperes, the device automatically shuts off the electric power.

Arc-fault devices provide protection from the effects of arc-faults by recognizing characteristics unique to arcing and by functioning to deenergize the circuit when an arc-fault is detected.

Electrical accidents are largely preventable through safe work practices. Examples of these practices include the following:

– deenergizing electric equipment before inspection or repair;
– keeping electric tools properly maintained;
– exercising caution when working near energized lines;
– using appropriate protective equipment.

Electrical safety-related work practice requirements for general industry are detailed in Subpart S of 29 CFR Part 1910, in Sections 1910.331–1910.335. For construction applications, electrical safety-related work practice requirements are detailed in Subpart K of 29 CFR Part 1926.416 to 1926.417.

Employees who work directly with electricity should use the personal protective equipment required for the jobs they perform. This equipment may include rubber insulating gloves, hoods, sleeves, matting, blankets, line hose, and industrial protective helmets designed to reduce electric shock hazard. All help reduce the risk of electrical accidents.

Appropriate and properly maintained tools help protect workers against electric hazards. It is important to maintain tools regularly because it prevents them from deteriorating and becoming dangerous. Check each tool before using it. If you find a defect, immediately remove it from service and tag it so no one will use it until it has been repaired or replaced. When using a tool to handle energized conductors, check to make sure it is designed and constructed to withstand the voltages and stresses to which it has been exposed.

All employees should be trained to be thoroughly familiar with the safety procedures for their particular jobs. Moreover, good judgment and common sense are integral to preventing electrical accidents. When working on electrical equipment, for example, some basic procedures to follow are to:

– deenergize the equipment;

– use lockout and tag procedures to ensure that the equipment remains deenergized;

– use insulating protective equipment;

– maintain a safe distance from energized parts.

9.4 Carrying out work in the electrical network

Some general safety tips for working with or near electricity. Inspect portable cord-and-plug connected equipment, extension cords, power bars, and electrical fittings for damage or wear before each use. Repair or replace damaged equipment immediately.

Always tape extension cords to walls or floors when necessary. Nails and staples can damage extension cords causing fire and shock hazards.

Use extension cords or equipment that is rated for the level of amperage or wattage that you are using.

Always use the correct size fuse. Replacing a fuse with one of a larger size can cause excessive currents in the wiring and possibly start a fire.

Be aware that unusually warm or hot outlets may be a sign that unsafe wiring conditions exist. Unplug any cords or extension cords to these outlets and do not use until a qualified electrician has checked the wiring.

Always use ladders made with non-conductive side rails (e. g., fiberglass) when working with or near electricity or power lines.

Place halogen lights away from combustible materials such as cloths or curtains. Halogen lamps can become very hot and may be a fire hazard.

Risk of electric shock is greater in areas that are wet or damp. Install Ground Fault Circuit Interrupters (GFCIs) as they will interrupt the electrical circuit before a current sufficient to cause death or serious injury occurs.

Use a portable in-line Ground Fault Circuit Interrupter (GFCI) if you are not certain that the receptacle you are plugging your extension cord into is GFCI protected.

Make sure that exposed receptacle boxes are made of non-conductive materials.

Know where the panel and circuit breakers are located in case of an emergency.

Label all circuit breakers and fuse boxes clearly. Each switch should be positively identified as to which outlet or appliance it is for.

Do not use outlets or cords that have exposed wiring.

Do not use portable cord-and-plug connected power tools with the guards removed.

Do not block access to panels and circuit breakers or fuse boxes.

Do not touch a person or electrical apparatus in the event of an electrical accident. Always disconnect the power source first.

Some tips for working with power tools.

Switch all tools OFF before connecting them to a power supply.

Disconnect and lockout the power supply before completing any maintenance work tasks or making adjustments.

Ensure tools are properly grounded or double-insulated. The grounded equipment must have an approved 3-wire cord with a 3–prong plug. This plug should be plugged in a properly grounded 3–pole outlet.

Test all tools for effective grounding with a continuity tester or a Ground Fault Circuit Interrupter (GFCI) before use.

Do not bypass the on/off switch and operate the tools by connecting and disconnecting the power cord.

Do not use electrical equipment in wet conditions or damp locations unless the equipment is connected to a GFCI.

Do not clean tools with flammable or toxic solvents.

Do not operate tools in an area containing explosive vapours or gases, unless they are intrinsically safe and only if you follow the manufacturer's guidelines.

Every good safety and health program provides measures to control electrical hazards. The measures should be helpful in establishing such a program. The responsibility for this program should be delegated to someone with a complete knowledge of electricity, electrical work practices, and the appropriate OSHA standards for installation and performance. Everyone has the right to work in a safe environment. Safety and health add value to your business and your workplace. Through cooperative efforts, employers and employees can learn to identify and eliminate, or control electrical hazards.

QUESTIONS FOR REVIEW

1. Types of electrical injuries and effects on human health.
2. Degrees of thermal burns and electric shock.
3. Factors that determine the outcome of human injury electrical hazard.
4. Physics of static electricity. Danger.
5. Ways to prevent electrical accidents.
6. Insulation, guarding, grounding, electrical protective devices.
7. Circuit protection devices.
8. General safety tips for working with or near electricity.
9. Tips for working with power tools.

Topic 10
Fire safety

Main lecture questions:

10.1 Processes of burning and explosion.

10.2 Classification of the category of buildings, structures and premises for fire and explosion hazards.

10.3 Fire protection requirements to ensure the forced evacuation from the building.

10.4 Fire extinguishing methods.

10.1 Processes of burning and explosion

Burning is the exothermic reaction of substance oxidization, which is accompanied by flame, luminescence, and smoke.

Four things must be present at the same time in order to produce fire:

– enough oxygen to sustain combustion;

– enough heat to raise the material to its ignition temperature;

– some sort of fuel or combustible material;

– the chemical, exothermic reaction that is fire.

Oxygen, heat, and fuel are frequently referred to as the "fire triangle" (fig. 10.1).

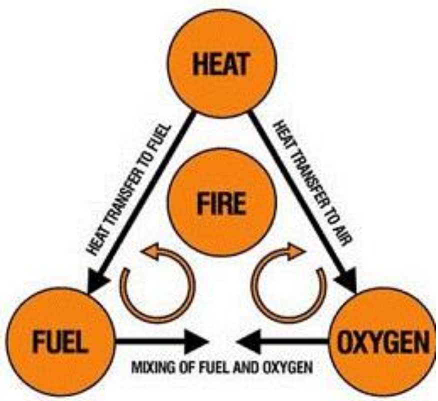


Figure 10.1 – Basic of burning process – fire triangle

Add in the fourth element, the chemical reaction, and you actually have a fire “tetrahedron”. The important thing to remember is: take any of these four things away, and you will not have a fire or the fire will be extinguished.

Burning can be divided into the following processes:

– flash;
– ignition;
– inflammation;
– spontaneous combustion;
– spontaneous ignition.

Flash is a rapid combustion of combustible substance, which is not accompanied by formation of constrained gas.

Combustion is the initial stage of burning under the influence of the inflammation source.

Inflammation is the ignition which is accompanied by flame.

Spontaneous combustion is a phenomenon of the speed acceleration of exothermic reactions, which causes a sudden temperature increase and burning of matters in default of any inflammation source.

Spontaneous ignition is a spontaneous combustion which is accompanied by appearance of flame.

Burning can be accompanied by: *fire and explosion.*

Explosion is a rapid transformation of matter (explosive burning) which is accompanied by the burst of energy and formation of shock wave (speed is of 330 m/s).

Explosion-proof indexes of substances and materials are used for:

– the analysis of the fire danger;
– classification of dangerous freights;
– the choice of category of rooms and buildings pursuant to the requirements of norms of the technological design;
– the purpose of the realization of technical supervision on materials.

Main causes of fires are:

1. Improper heat-producing machine installation – 20 %.

2. Faulty or improper installation of electrical installations and electrical systems – 16 %.

3. Poor training equipment for repairing – 13 %.

4. Auto-ignition materials – 10 %.

5. Violation of production process (especially at the end of the month).

6. Discharge static electricity.

7. Lighting strike.

Indexes of fire explosiveness of substances and materials:

– the combustibility group;
– flash temperature;
– combustion temperature;
– the lower and upper concentration borders of flame distribution;
– the conditions of thermal combustion.

Due to combustibility, matters and materials are divided into three groups:

1. Noncombustible (cannot be burned). Under fire effect or high temperature they do not flash, rot and char.

2. Heavily burnt. Under the fire effect or high temperature they flash, smolder, char and when the ignition source is available they continue to burn, smolder or char.

3. Combustible (can be burnt). Under the fire effect or high temperature they flash, smolder, and char.

Groups of materials according to flash temperature:

– *inflammable liquids* are the ones whose flash temperature does not exceed 45 °C (in closed crucible), and they are able to burn after the removal of the ignition source on their own;
– *flammable liquids* are the ones whose flash temperature is more than 45 °C, and they are able to burn after the removal of the ignition source on their own.

Fire safety signs can be used to identify flammable materials and other fire hazards (fig. 10.2). 'Flammable' signs should be placed alongside any potential ignition points or fuel sources as part of a larger fire safety management plan.

Figure 10.2 – Fire safety warning signs

Groups of compatible preservation of substances and materials:

1. Substances that are apt to the formation of explosive mixtures: potassium nitric acid, potassium chlorate etc.

2. Constrained and fluid gases:

   a) burnt and highly explosive – acetylene, hydrogen, propane;

   b) inert and not put out – argon, nitrogen, helium;

   c) gases which sustain burning – oxygen, compressed and liquidized air.

3. Self-igniting from water and air substances: potassium, sodium, aluminum dust, zincs dust etc.

4. Flammable burnt substances:

   a) liquids – petrol, acetone, alcohol;

   b) solid substances – celluloid, naphthalene.

5. Substances that can cause combustion: bromine, sulphur acid, potassium aluminate.

6. Easily burnt substances – cotton, hay, peat, sulphur, vegetable and animal soot.

10.2 Classification of the category of buildings, structures and premises for fire and explosion hazards

The fire and explosion hazard areas and warehouse purposes, regardless of their functionality are divided into the following categories:

1) high explosive (A);
2) explosive (B);
3) fire risk (B1–B4);
4) a moderate fire risk (D);
5) reduced fire risk (D).

Categories of premises for fire and explosion hazards are based on the premises of the type of flammable substances and materials, their quantity and fire properties, and based on the space-planning decisions and premises characteristics. Definition of the categories of premises should be carried out by sequential testing facilities belonging to the categories of the most dangerous (A) to the least dangerous (D).

The category A includes areas in which there are (treated) flammable gases, flammable liquid with a flash point of more than 28 degrees Celsius in a quantity that can form explosive mixtures steam and gas, in the ignition which develops the design pressure of explosion in the room of more than 5 kPa, and (or) substances and materials that can explode and burn at contact with water, oxygen, or with each other, in a such amount that the design pressure of explosion in the room is more than 5 kPa.

The category B includes areas in which there are (treated) combustible dust or fibers, flammable liquid with a flash point above 28 °C, flammable liquids in such a quantity that can form explosive dust-air or vapor-air mixture, which, when ignited, develop the design pressure of explosion in the room of more than 5 kPa.

The categories B1–B4 are areas in which there are (treated) flammable and nonflammable liquids, solids flammable and nonflammable materials and supplies (including dust and fibers), substances and materials capable of contact with water, oxygen, air, or with each other only to burn, provided that the premises in which they are located (address), are not category A or B.

The assignment of the room to the category B1, B2, B3 or B4 is dependent on the amount and method of placement of fire load in this area and space planning characteristics, as well as the fire properties of materials that make up the fire load.

The category D includes the areas in which there are (treated) non-combustible substances and materials in the hot or molten state, the processing of which is accompanied by radiant heat, sparks and flame, and (or) fuel gases, liquids and solids that are burned or recycled as fuel.

The category D also includes the areas in which there are (treated) combustible media and materials in a cold state. Categories of buildings and structures for fire and explosion hazards are based on the proportion and summed area of the hazard category premises in the building and construction.

The building belongs to the category T in case of all the following conditions: the building is not classified as A, B or C and in total area of the premises in categories A, B, B1, B2, B3 and r is greater than 5 percent of the summed area of all premises. The building does not belong to the category T, if we sum up floor space in categories A, B, B1, B2, B3 and C in the building, which does not exceed 25 percent of the summed area of all within the container premises (but not more than 5 000 square meters) and the spaces of category A, B, B1, B2 and B3 are equipped with automatic fire extinguishing installations.

The building belongs to the category A if it does not apply to category B, C or D. Methods for determining the classification criteria for inclusion of the facilities and warehouse assignment to the categories of fire and explosion hazards are set regulations on fire safety. Categories of buildings, structures and premises and warehouse destination for fire and explosion hazards are specified in the design documentation for capital construction and renovation.

Common fire hazards are:

1) electrical systems that are overloaded, resulting in hot wiring or connections, or failed components;

2) combustible storage areas with insufficient protection;

3) combustibles near equipment that generates heat, flame, or sparks;

4) candles, smoking (cigarettes, cigars, pipes, lighters, etc.), flammable liquids;

5) chimneys of fireplace that are not properly or regularly cleaned; cooking appliances – stoves, ovens;

6) heating appliances – wood burning stoves, furnaces, boilers, portable heaters;

7) electrical wiring in poor condition; batteries; personal ignition sources – matches, lighters;

8) electronic and electrical equipment; exterior cooking equipment – BBQ, campfires.

10.3 Fire protection requirements to ensure the forced evacuation from the building

Fire safety is the set of practices intended to reduce the destruction caused by fire. Fire safety measures include those that are intended to prevent ignition of uncontrolled fire, and those that are used to limit the development and effects of the fire after it starts.

Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building.

The system of fire-prevention is the total of organizational measures and hardware directed to prevention of influence on the people of dangerous fire factors and limitation of material losses.

Fire safety protection is achieved by:

– the proper choice of the necessary degree of fire-resistance of building constructions;

– proper volume design of buildings;

– room and factory location in compliance with the fire safety requirements;

– the installment of the fire-prevention barriers in buildings, ventilation systems, fuel and cable communications;

– the limitation of the effluence and spread of combustible liquids during the fire;

– the off-take installment;

– planning evacuation routes;

– taking measures for successful fire extinguishing.

Measures of preventing fire spread into the house while planning and building industrial enterprises:

– division of houses into fire-prevention compartments by fire-prevention walls or a fire-prevention ceiling;

– division of houses into sections by fire-prevention partitions;

– installment of fire-prevention barriers for the limitation of the fire spread over constructions and combustible materials (ridges, skirting boards, peaks, belts etc.);

– installment of fire-prevention doors and gates;

– installment of fire-prevention breaks between the houses.

Fire Doors. Fire barriers play an integral role in managing a fire by preventing the spread of smoke, toxic gases, and fire itself from one area to another. Fire doors are fundamental to the integrity of fire barriers, because any time there is an open doorway to a compartment; a fire barrier is temporarily broken. To prevent breaks in fire protection, fire doors must be self-closing and be equipped with proper latching devices in order to provide as much resistance as possible to the spread of fire, smoke and toxic gases. Fire exit doors are often held open for the convenience of employees and visitors, creating a significant fire hazard for all building occupants due to the break created in the fire barrier. Doors that are designed to be fire exit doors can be held open, but only if they automatically release when the building fire alarms are activated. Fire doors may only be held open by a device that automatically releases when the fire alarm is activated (such as an electromagnetic hold-open device).

Fire doors are needed:

– where a door has an ‘EXIT’ sign on or around it;

– where a door leads to exit stairwells and horizontal exits;

– where a door leads to a hazardous area such as flammable storage;

– where a door leads to a hallway or from one fully-enclosed room to another.

Hazards to avoid with fire doors:

a) fire doors should never be tied open or held open by devices such as door wedges or blocks;

b) when closed, fire doors should never have their latches taped over. During a fire, hot gases can easily build up enough pressure to cause fire doors to blow open.

Figure 10.3 – Fire action

Fire action signage is essential to clearly communicate to anyone on your premises what action should be taken in the event of a fire. It is a legal requirement that visitors and employees know the fire evacuation procedure in the event of a fire and alarm activation.

10.4 Fire extinguishing methods

There are following methods of fire extinguishing:

a) removal of combustible material on fire or hearth reducing its percentage content;

b) removal of oxidant or reducing its concentration in the combustion zone (reducing the percentage of oxygen in the air to 14–15 % leads to the cessation of burning);

c) lowering the temperature of combustible environment to the point where further combustion is not possible (below the ignition temperature).

The majority of portable fire extinguishers located throughout every University building consists of multi-purpose, dry chemical extinguishers that will be effective on any type of fire you may encounter:

– ordinary combustibles, such as paper, cardboard, cloth and wood;

– energized electrical equipment;

– flammable liquids (except for flammable metals).

If you discover a fire, you must immediately set off the building fire alarm system by activating a manual fire alarm pull station to warn building occupants.

Only attempt to extinguish the fire if it is **very small, not more than 2 feet high.** Keep your escape route behind you. Should you decide to try to extinguish the fire, use the following acronym to help you (fig. 10.4):

P. A. S. S.

Pull safety pin from handle.

Aim at base of fire.

Squeeze the trigger handle.

Sweep from side to side.

Extinguisher types

Extinguisher structure

To operate an extinguisher

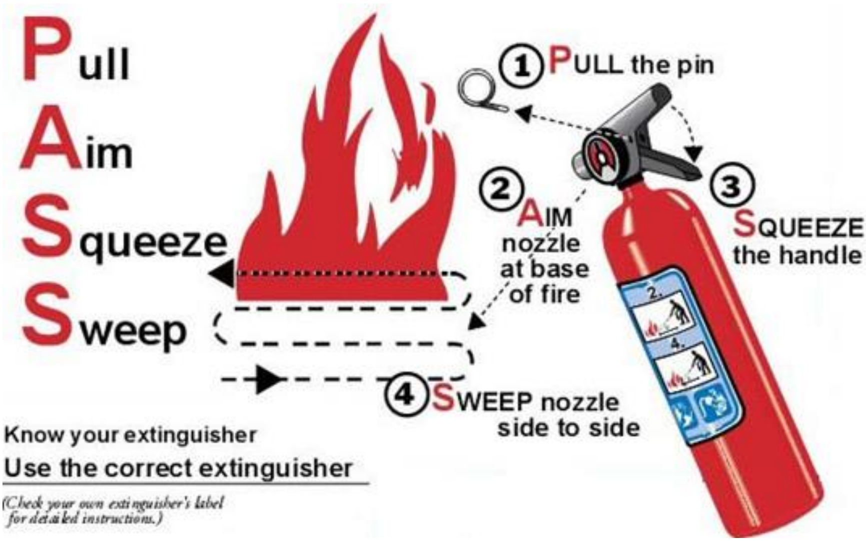


Figure 10.4 – Fire extinguisher

Not all fires are the same. Different fuels create different fires and require different types of fire extinguishing agents.

Class A fires are fires in ordinary combustibles such as wood, paper, cloth, trash, and plastics.

Class B fires are fires in flammable liquids such as gasoline, petroleum oil and paint. Class B fires also include flammable gases such as propane and butane. Class B fires do not include fires involving cooking oils and grease.

Class C fires are fires involving energized electrical equipment such as motors, transformers, and appliances. Remove the power and the Class C fire becomes one of the other classes of fire.

Class D fires are fires in combustible metals such as potassium, sodium, aluminum, and magnesium.

Class K fires are fires in cooking oils and greases such as animals fats and vegetable fats.

Some types of fire extinguishing agents can be used on more than one class of fire. Others have warnings where it would be dangerous for the operator to use a particular fire extinguishing agent.

If you decide not to fight the fire, try to close the door to the fire area, if it is safe to do so. This will help to prevent heat, smoke and toxic gases from entering the egress corridors. Then evacuate the building via the closest exit.

A periodic check of the extinguishers should be performed to ensure:

a) the extinguisher is not being used inappropriately (for example, to prop a door open);

b) the extinguisher pressure gauge needle is in the green zone;

c) there are no visible indications that the extinguisher has been damaged, discharged, or removed from its proper location;

d) that the inspection tag is attached to the fire extinguisher. The inspection tag must be stamped with a month and year indicating the extinguisher was inspected within the past twelve months.

QUESTIONS FOR REVIEW

1. Basic of burning process – fire triangle.
2. Fire safety warning signs. Fire action.
3. Fire extinguishing methods.

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MAIN DEFINITIONS

Acceptable risk – risk that has been reduced to a level that can be tolerated by the organization having regard to its legal obligations and its own OH&S policy.

Accident – an undesired event resulting in death, ill health, injury, damage, environmental loss or other loss.

Accident at work – the result of dangerous industrial factor effect on worker in the performance of job duties or job supervisor.

Audit – systematic, independent and documented process for obtaining "audit evidence" and evaluating it objectively to determine the extent to which "audit criteria" are fulfilled.

Collective Protective Equipment (CPE) – tool designed to protect two or more employees.

Dangerous factor – the industrial factor, the impact of which on the employee under certain conditions can lead to injury or other sudden health deterioration.

Danger zone – a space in which the possible effects on the running of hazardous and (or) harmful factors.

Electrical safety – a system of organizational and technical measures and tools that protect people from harmful and dangerous current electric arc, electromagnetic field and static electricity.

Environmental protection – management arrangements to cover the protection of the environment, including mitigating the effects from fire fighting and other emergency operations from pollution, caused by workplace operations.

False alarm – an unwanted fire signal resulting from a deliberate operation of a fire safety system, the unintentional electrical actuation of a fire safety system, or the actuation of a fire safety system with good intent (believing there to be a fire).

Fire/combustion – a chemical reaction or series of reactions involving the process of oxidization, producing heat, light and smoke. There are two classes of fire: conflagration (where combustion occurs relatively slowly) and detonation (where combustion occurs instantaneously).

Fire safety – the set of practices intended to reduce the destruction caused by fire.

Hazard – a source or situation with the potential to cause harm (death, injury, ill health, damage to property or environment).

Hazard identification – process of recognizing that a hazard exists and defining its characteristics.

Harmful factor – the industrial factor, prolonged exposure to which in certain conditions can lead workers to a disease or a decrease in efficiency.

Ill health – the term ill health includes acute and chronic physical or mental illness which can be caused or made worse by physical, chemical or biological agents, work activity or environment.

Incident – an undesired event that does not result in any harm or loss. Incidents are often referred to as near misses; some organizations refer more accurately to 'incidents' as 'near hits'.

Occupational disease – the result of long term effect of harmful industrial factor.

Occupational health and safety – factors and conditions that can affect the well-being of persons within the workplace, i. e. employees, contractors, temporary workers and visitors.

Personal Protective Equipment (PPE) – tools designed to protect a single employee.

Risk – the combination of the likelihood and severity (consequences) of a hazard causing harm.

Risk assessment – process of evaluating the risk(s) arising from a hazard(s), taking into account the adequacy of any existing controls, and deciding whether or not the risk(s) is acceptable.

Safety – the freedom from unacceptable risk from harm.

Навчальне видання

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