CHAPTER 3

THEORETICAL ANALYSIS
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3.1 INDUSTRIAL WORK ENVIRONMENT AND ITS IMPACT ON THE ORGANIZATION.

The main operations of the manufacturing process in industries include making, altering, ornamenting, finishing, packing, oiling, washing, cleaning, breaking up, repairing, treating, adopting any article or substance with a view to use, sale, transport, deliver, dispose, generate, transform or transmit power etc. by employing electrical or any other form of energy. These industries while carrying out business employ man-power, machines, equipments & tools, materials, and other facilities.

As stated in the previous chapters, the industrial Accidents/Incidents are undesirable events that result in physical harm to the employees, or damage to the property or both, which is usually the result of a contact with a source of energy in kinetic, electrical, chemical thermal, ionizing or non-ionizing radiation etc., above the threshold level of the body or structure or both arising out of industrial work environment. As per the Indian Factories Act, every occupier shall ensure so far as is reasonably practicable, the health, safety and welfare of all the workers while they are at work in the factory i.e. any occupier who creates the risk of health, safety and welfare at work to his employees, should be responsible to remove or minimize such risk created by him. Besides, the owner/occupier of a factory is equally concerned about the productivity improvement of his own organization. As seen, the total factor productivity of an organization is the ratio of total output to the sum of all integrated inputs expended in turning out the said total output. The productivity index also can be computed by taking the ratio of effectiveness over
efficiency. i.e. how well a set of results is accomplished reflects the effectiveness, whereas the ratio of actual output attained to the standard output expected, reflects efficiency. As per the Industrial Engineering norms, the standard output is defined as, the output produced per unit time by an employee having normal physique & health, qualified, well trained, working at a normal pace, working in a normal working conditions by employing standard input resources while producing the said standard output. The management professionals have agreed through the years that the omissions and commissions that cause loss producing events/down grading incidents in the business world are complex in nature. The accidents/incidents are caused, they just do not happen and the causes of loss producing events/down grading incidents can be determined and controlled. However micro examination of the factors responsible for industrial accidents/incidents, is necessary to come to such conclusions. The factors to be analysed for the existing process system correction include analysis of industrial work environment for air pollution, noise pollution, industrial lighting, industrial heat, general working condition of machines/equipments & tool and study of human factor etc.

3.2 INDUSTRIAL WORK ENVIRONMENT – CHEMICALS & TOXIC SUBSTANCES AND OTHER AIR POLLUTANTS:

Today's modern industry and commerce produce and distribute a wide range of products and services through sophisticated technology on large scale basis. Comfort has become the demand of the day. The price of maintaining and improving man's standard of living is the increasingly rapid pollution of both work environment and general environment. Many noxious and toxic chemical
substances, both natural and synthetic, are involved in processing raw materials, in manufacturing finished goods. Pollutants are thus direct products or indirect by-products of our technological process. Some of these substances escape inadvertently, some are released indiscriminately, and other are carelessly dumped. Toxic substances are entering into the work environment as well the general environment from diverse sources. Disposal of waste, non-biodegradable material, noxious substances, hazardous chemicals, radio active residues pose a great threat not only to human beings but also to the equilibrium of the ecological system. Pollution knows no boundaries. Pollutants are foreign or extraneous substances, materials, or agents that is present in the air, water or soil, which impairs the quality of work & work performance, material & equipment damage, property damage, contracting with occupational diseases increasing accident proneness, legal implication besides diminishing the life supporting capacity of the environment. Pollutants may be atoms, molecules, or compounds – organic or inorganic, ions or free radicals. They may occur as simple or complex single substances, mixtures, or aggregates. Pollutants may be in particulate or emulsion state. The particulates are dusts, fumes, and mists. Our pulmonary clearance mechanism is not equal to the task of eliminating the barrage of artificial particulates responsible for a number of diseases that occur in occupational work environment. These include black lung of coal mines, granulomatus disease of beryllium workers, pulmonary fibrosis and increased lung cancer risk of asbestos works, byssiosis produced by cotton dust, illness due to metal fumes etc. However oxidant pollutants may age the tissues, free radicals may increase the rate of genetic mutation, accelerate aging and lead to
cancer disease, cardio pulmonary diseases, may produce asthma or may produce asthma like bronchitis.

Dusts are usually fine dry particles of solid material that vary in size, shape, and physio-chemical nature particles in microns of less in diameter, when inhaled, can reach the pulmonary alveoli. Larger particles are removed from respiratory tract but may cause irritation, damage, infection etc.

Fumes are the oxidised particles of metal when it is heated. Mists or fogs are suspensions of fine liquid droplets. The permissible levels of certain chemicals/Toxic substances in the work environment are prescribed in the Indian Factories Act, 1948.

3.3 INDUSTRIAL WORK ENVIRONMENT – NOISE POLLUTION:

In a man-machine system the man and the machine are considered as a unit. The effectiveness of this man-machine system in influenced by its immediate environment. So, in any work system man-machine-environment (MME) is treated as an integrated unit. In factories work is done mostly by machines. Although large portion of the energy is converted in to work, a part of this energy is released as sound. The sound is a wave motion which occurs when a sound source sets the nearest particles of medium in to motion. The noise is nothing but any undesirable or unwanted sound. The human ear responds to intensity of sound between 0-140 dB(A) and a frequency range of about 20 Hz to 20,000 Hz with a maximum sensitivity at about 3000 Hz. At high frequency, close to the source, the noise annoys more compared to low frequency noise. Noise can cause damage to the ear resulting in hearing loss, affects the communication, can cause annoyance, can
cause mental fatigue, manifestation of nausea, headache, tinnitus, pain, dizziness, all of them amount to irritation/annoyance to the worker, reduced efficiency working in that work environment resulting in to business down grading performance, increasing accident proneness. The noise induced hearing loss is irreversible and is a notified occupational disease under the Indian Factories Act, 1948. The different permissible levels are prescribed in the Act for both continuous noise and impulsive or impact noise.

3.4 INDUSTRIAL WORK ENVIRONMENT – FACTORY LIGHTING

A well designed lighting scheme in the work place increases organization’s productivity, reduces industrial accidents, reduces rejection in the quality of work related output. Besides the normal vision, the visibility or the ease of seeing objects depend on many interrelated factors such as:

- Size of the object, larger the size more the visibility. Lesser the illumination more the eyestrain, mental fatigue, causing head-ache.

- The amount of light falling on the object i.e. excess light/illumination levels also cause glare which makes the task difficult to perform.

- The contrast between the object and the surroundings. It will be easier to identify black spot on a white background rather than dark backgrounds. Light colours on the surroundings are suggested at work places where high concentration work is involved that reduces mental fatigue considerably.

- Glare can some times blind the operator for a few seconds. The glare also can lead to severe industrial accidents due to the partial/total failure of the vision temporarily. Highly polished surfaces, unscreened light source, all intensive
reflected rays etc. lead to the excess of glare. In every part of the factory where workers are working or passing through, there shall be provision and maintenance of sufficient and suitable lighting, natural or artificial or both. All the glazed windows and sky-lights used for the lighting of the work-rooms shall be kept clean on both the inner and outer surfaces and to be free from obstructions. The glare either directly from a source of light or by reflection from a smooth or polished surface should be prevented. The formation of shadows to such an extent as to cause eye strain or the risk of accident to the worker also to be prevented. As per the provisions of the Indian Factories Act 1948, the minimum intensity of illumination for different areas and work-rooms range from 20 to 1000 LUX.

3.5 INDUSTRIAL WORK ENVIRONMENT – INDUSTRIAL HEAT STRESS:
The problems of heat stress are very common in many manufacturing industries such as Iron & Steel mills, Glass and ceramic units, Forge and foundry shops, Bricks and Tiles factories, thermo electric Plants, cement industries, coke ovens etc. There are many other work places where artificial hot climates are created for some process requirement. Whenever a worker is exposed to heat conditions, there is a resulting stress and strain induced in the worker due to physiological reactions such as excess sweat productions, increased heart rate, higher core temperature etc. Prolonged exposure to excessively high temperature is a serious health hazard to an individual. The high heat stress disturbs the thermal equilibrium of the human body and consequently produces many adverse physiological reactions in side the body. The condition becomes very alarming when high degree of industrial heat
combines with metabolic heat arising out of heavy physical work performed by the workers. Working under such conditions not only produces undue strain and fatigue to the workmen but also results in gradual decline in efficiency and productivity of the workmen. This also may result in increased accident proneness among the workers. The heat stress is the load of heat that must be dissipated by the body, if it is to remain in thermal equilibrium. It is represented by the sum of the metabolic rate and the gain or loss of heat by convections, radiation or the evaporation of sweat. These factors are governed by the temperature, humidity and air movement in addition to the temperature of the surrounding work environment. It is important to evaluate the degree of heat stress imposed on the workers in order to determine whether it is within the safe limits or not and to ascertain the need for improvement if any, by adopting suitable control measures.

Heat balance:

The heat stress on the human body results from two types of heat load i.e. (1) External Heat (Environmental Heat) and (2) Internal body heat (Metabolic Heat). The environmental heat load results from conduction/convection, and radiation. The metabolic heat is generated due to intra-cellular oxidative process taking place inside human body, resulting from physical activity. The metabolic heat load must be dissipated through conduction/convection/radiation depending on the environmental condition. In addition, the heat can be dissipated by the body through evaporation and cooling of the sweat over skin of the body. The evaporation of one litre of sweat removes 580 kcal heat from the body as well as from the surroundings. The Heat balance equation is thus represented as

\[ M \pm C \pm R - E = \pm S \]
Where,

- \( M = \) Metabolic heat, depending on the amount of physical activity involved,
- \( C = \) Convective heat gain or loss depending on ambient air temperature and air movement,
- \( R = \) Radiant heat, depending on mean radiant temperature of hot equipment or process heat
- \( E = \) Evaporation heat loss, depending on the rate of sweating, humidity, ambient air temperature, vapour pressure on the surface of the skin based on air movement
- \( S = \) Amount of heat gain or loss by the body.

When there is perfect heat balance, then there is no storage of heat i.e. \( S = 0 \). Then, the above Heat balance equation is represented as,

\[
M \pm C \pm R = E
\]

This means that the heat generated internally as well as heat received from the external environment could be dissipated solely by evaporation of sweat. More perspiration by the human body induces more stress on the physical condition of the body.

**Factors responsible for Heat Balances:**

a) Climatic Factors: The environmental factors determine as to how, and as to what extent, the metabolic heat can be lost to the outside environment, or to what extent the body would gain heat from the surroundings. The climatic factors include
- i) Air temperature
- ii) Humidity
- iii) Air movement
- iv) Radiant heat.

b) Non-climatic Factors: The non-climatic factors would include
- i) The rate of work
- ii) Acclimatization by an individual
As a result of the body's inability to cope up with excess heat load, heat illness may occur. The heat stroke is a state of thermoregulatory failure and is the most serious of the heat illness, which is characterized by hot, dry skin, rapidly rising body temperature, collapse, loss of consciousness, and convulsions. When the deep body temperatures approaches 41°C (106°F) and beyond for long the danger of heat stroke is imminent and may be fatal. The heat exhaustion is less severe heat illness, which is characterized by clammy moist skin, weakness or extreme fatigue, nausea, head-ache, low blood pressure with a weak pulse. Without prompt treatment, it may result in fatal. This heat exhaustion occurs in persons when the total blood volume has been reduced due to dehydration or among the individuals who have a low level of cardiovascular fitness. The heat cramps, another category of heat illness are characterized by painful spasms in one or more skeletal muscles. The heat cramps primarily occur in persons who sweat profusely in heat condition without replacing salt losses. Proper control measures are necessary to protect workmen from heat stress.

3.6 PHYSICAL FATIGUE FACTOR DUE TO IMPROPER WORK ENVIRONMENT

Uncontrolled work environment such as presence of noxious and toxic chemical substances in the work environment beyond threshold limits, excess noise pollution beyond permissible levels, improper lighting/glare in the work place, industrial heat imbalance, unsafe conditions prevailing due to improper machines, equipments,
tools etc, shall subject any industrial worker to extra fatigue situation, there by increasing the risk of accident proneness, reduced work performance efficiency, low quality out put, deteriorated health due to occupational diseases/prolonged illness etc. which obviously contribute to the factor of business down grading efficiency.

**Phenomenon associated with Fatigue**

Fatigue in industry workers refer to i) Feeling tiredness ii) Physiological changes in the human body (the nerves and the muscles fail to respond as fast as is in normal conditions because of chemical changes in the body resulting from work) and iii) Diminished capacity of doing work. The physiological point of view, the human body may be thought of a machine which consumes fuel and gives out useful energy. The physical work exerted either continuously or in excess than capacity shall affect the bodily circulating system, muscular system, nervous system, respiratory system, digestive system etc leading to mental fatigue/physical fatigue, behavioral change. Fatigue is the result of accumulation of waste products in the muscle and in the blood stream which reduces the capacity of muscle to act. Lactic acid is the waste product generated from glycogen (energy source) when the muscles contract (i.e. work done). This lactic acid tend to resist the continued activity of the muscle. During the recovery phase of muscular action, oxygen is used to change most of the lactic acid back to glycogen, thus enabling the muscles to continue moving. The supply of oxygen and temperature affect the speed of recovery.
Effect of physical environment on the workers

The physiological cost of doing work is affected by the environmental factors such as temperature, humidity, air movement and air borne contaminants/air pollution. The individual worker has certain energy requirement just to maintain his body functioning. When he does physical work, his energy requirements naturally increase. If the resting environment and the working environment are changed (for example if the temperature is increased from 70°F to 90°F), then the energy cost increases at both resting level and at the work level. The change in the heart rate appears to be the best means of measuring the effects of such work environmental factors.