ENVIRONMENTAL ISSUES IN VALUATION

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MODULE-1

ENVIRONMENTAL ISSUES AND POLLUTION

As stated in Professional Standards (PS2) of the Royal Institution of Chartered Surveyors' (RICS) Valuation Global Standards 2017, if the valuer does not have the required level of expertise to deal with some aspect of the valuation assignment properly, then he/she should decide what assistance is needed. With the express agreement of the client where appropriate, the valuer should then commission, assemble and interpret relevant information from other professionals, such as specialist valuers, environmental surveyors, accountants and lawyers.

However, para 10.7 of General Standards IVS 105 (Valuation Approaches and Methods) of International Valuation Standards 2017 stipulates that regardless of the source of the inputs and assumptions used in a valuation, a ***valuer must*** perform appropriate analysis to evaluate those inputs and assumptions and their appropriateness for the *valuation purpose*.

Asset Standard IVS 300 – Plant and Equipment (under IVS 2017) illustrates environment-related factors that may need to be considered for valuation of plant and machinery.

Asset Standard IVS 400 – Real Property Interests (under IVS 2017) requires that the responsibility for identification of actual or potential environmental risks should be stated in the Scope of Work (refer IVS 101) and Investigations and Compliance (refer IVS 102). Else if the client agrees, a typical special assumption that 'the property is free from contamination or other environmental risks' should be incorporated in the valuation report only for certain purposes.

Valuation Practice Guidance Application VPGA 8 - Valuation of Real Property Interests of RICS (2017) discusses environmental matters in three parts : (a) Natural environmental constraints, (b) Non-natural constraints, and (c) Sustainability. As the valuers may not have specialised knowledge and experience required to comment on environmental factors, it may be appropriate to recommend that an advice of environmental expert be obtained when the potential presence of these factors can be established in the course of a valuation inspection through normal enquiries or by local knowledge.

Judicious juxtaposition of the above guidelines of the RICS and IVS 2017 implies that though valuers themselves need not be environmental experts, it is imperative for the valuers to have fundamental knowledge about environmental issues and to scrutinize the data provided by environmental experts prior to their application for valuation of such affected properties.

1.0 INTRODUCTION

Environment means water, air and land and the interrelationship that exists as between and amongst these media (water, air and land) and human beings, other living beings including micro-organisms and property. Humans continuously interact with the environment and alter the environment by various activities like:

- Rapid Industrialization;
- Urbanization;
- Population explosion; and
- Modern life styles.

But the interaction results into environmental pollution. Thus, environmental pollution means alteration of the composition of the environment which will have deleterious effect on human health or quality of life.

Environmental pollution also means “the presence of any pollutant in the environment which imparts adverse effect on the marketability of an asset.”

Environmental pollutant may be defined as “Any solid, liquid, gaseous or other substance present in such concentration which may be or tend to be injurious to the environment giving rise to adverse effect on the marketability of asset.”
Whenever the quality of environment is deteriorated due to presence of any foreign matter, environmental pollution is said to have occurred. The ‘foreign matter’ is a “pollutant”. A pollutant can be a substance which when enters in the environment either purposefully or through some act of nature, it significantly changes the composition of the environment and shows adverse effect on human health.

Contamination is defined as alteration of physical, chemical and/or biological characteristics of the environment which may not necessarily create deleterious effect due to lesser concentration but contaminant(s) in higher concentration become pollutants that may ultimately lead to degradation or deterioration of the value of assets.

Thus, there can be a contaminated environment without it being polluted but there cannot be a polluted environment without it being contaminated.
Environmental quality standards have been established focusing on humans as opposed to the ecosystem at large. Such standards are extremely difficult to specify.

1.1. TYPES OF ENVIRONMENTAL POLLUTION

Environmental pollution can be broadly classified based on any given compartment or region of the environment which they negatively impact, contributing to the multiple causes of pollution. The various components of environment are air, water, noise and land, and correspondingly the environmental pollution is classified as air pollution, water pollution, noise pollution and land (and soil) pollution. Some of the pollutants include gases, metals and their salts, agro-chemicals including pesticides, biomedical waste, heat, vibration and plastic.

Every type of pollution (air, water, noise, land, industrial, soil, light, thermal, etc.) has its own distinguishing causes and environmental effects. Understanding pollution and its various causes can help address the various concerns linked to environmental degradation and destruction, and the dangers it brings to human health.

Air Pollution

Any deleterious change in the composition of the clean atmospheric air is known as air pollution.

Air pollution means presence of one or more contaminants in the atmosphere such that the contaminant's concentration, characteristics and exposure is injurious to public health or welfare.

According to the definitions under Section 2(b) of the Air (Prevention and Control of Pollution) Act-1981, 'air pollution' means the presence in the atmosphere of any air pollutant. Under Section 2(a) of the Act, 'air pollutant' means any solid, liquid or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment.

The sources of anthropogenic air pollution are (i) Stationary sources like mining and quarrying, refineries and chemical factories, power plants, industrial facilities, sewage and waste treatment, (ii) Community sources like heating of homes and buildings, laundry services, (iii) Mobile sources like diesel and gasoline-powered automobiles, trains, marine vehicles, aeroplanes, and (iv) Indoor sources like tobacco smoking, combustion emissions, asbestos and Volatile Organic Compounds (VOCs).

Thus, air contaminants include suspended particulate matter (dusts, fumes, mists, and smokes), gaseous pollutants (gases and vapours), odours, radio-active materials, noxious chemicals or any other material in the outdoor atmosphere.

Out of the various air contaminants, the **Criteria Air Pollutants** are the only air pollutants with national ambient air quality standards that define allowable concentrations of these substances in **ambient air**. The criteria air pollutants are six common air pollutants defined by the United States Environment Protection Agency (USEPA) and World Health Organization (W.H.O) as these pollutants are found causing harm to health, environment and damage to property thereby affecting adversely the property valuation. These criteria air pollutants also prescribed by the Central Pollution Control Board (CPCB) of India include Carbon Monoxide (CO), Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2), Particulate Matter (PM10), Lead (Pb) and ground level Ozone (O3). The National Air Quality Standards are given in Table 1 below.

Table 1 : National Ambient Air Quality Standards for Criteria Air Pollutants

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (notified by Central Government)
Sulphur Dioxide (SO_2), µg/m^3	Annual* 24 hours**	50 80	20 80
Nitrogen Dioxide (NO_2), µg/m^3	Annual* 24 hours**	40 80	30 80
Particulate Matter (size less than 10 µm) or PM_{10}, µg/m^3	Annual* 24 hours**	60 100	60 100
Ozone (O_3), µg/m^3	8 hours* 1 hour**	100 180	100 180
Lead (Pb) , µg/m^3	Annual* 24 hours**	0.50 1.0	0.50 1.0
Carbon Monoxide (CO), mg/m^3	8 hours* 1 hour**	02 04	02 04

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Source: National Ambient Air Quality Standards, Central Pollution Control Board Notification in the Gazette of India, Extraordinary, New Delhi, 18thNovember 2009.

The valuers are concerned due to damage caused to the property by increasing levels of air pollutants. The property essentially consists of variety of elements including buildings made of masonry and concrete, ceramics and glass used for decorative finishes, paints used to adorn wall surfaces, curtains and other furnishes made from fabrics. On account of air pollution, the frequency of painting of the property increases leading to an additional cost and reducing the value of such property. The determination of damage by air pollution and its impact on valuation of the assets is extremely complex.

1.1.1. WATER POLLUTION

When the level of pollutants in water is more than their prescribed standards, water is said to be polluted. Under Section 2(e) of the Water (Prevention and Control of Pollution) Act-1974, 'water pollution' means such contamination of water or such alteration of physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or any other liquid, gaseous or solid substance into water(whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or aquatic organisms.

The main pollutants in water include various chemical compounds (organic and inorganic), oils and grease, silt, heated water from thermal power plants, fertilizers and pesticides, pathogens present in the domestic wastewater and gases dissolved in rain water.

The water supplies from natural and anthropogenic sources are contaminated by sewage, storm water, direct discharge of effluents from industries, pesticides brought through agricultural runoff, runoff from the solid waste disposal sites, corrosion of material used in distribution of water including plumbing systems, oil spills, development of algae in rivers due to presence of nutrients and sunlight, application of certain chemical agents such as chlorine and aluminium in water treatment processes, discharge of toxic substances, discharge / dumping of waste materials into water bodies, sediments from soil erosion, surface runoff from contaminated land and leaching from landfill sites.

Pollutants from the solid wastes dissolve in rain water and ultimately get mixed with underground water through percolation in the soil system (referred to as ground water pollution). Groundwater contamination by contact with toxins contained in the ground is a serious concern as this water may flow downstream and thus carry contamination to considerable distances.
All the pollutants have adverse impact for human, animal or plant life. The impact depends upon the type of the pollutants and their concentration.

Valuer always takes into consideration the source of the water supply and the water quality characteristics while determining the value of the real estate. Valuers have to make a broad assessment of the water resource, potential assessment of treatment of water for the individual estate or assessment of quality of water supplied by municipal transmission for the given estate.

Thermal Pollution

Thermal pollution occurs when water bodies are degraded in terms of altering their temperatures. It commonly happens when people or industries undertake activities that suddenly decrease or increase the temperature of a natural water body which may include lakes, rivers, oceans or ponds.
Thermal pollution is a huge menace and is mainly influenced by power plants and industrial manufacturers that use water as a coolant. Urban stormwater runoff from parking lots and roads also discharges water of elevated temperatures into adjacent water bodies.

When water is either used as a coolant, discharged from stormwater runoff at elevated temperatures, or released from reservoirs with unnaturally cold temperatures, it changes the natural temperature of water bodies. Therefore, thermal pollution is one aspect of the wider subject of water pollution. The alterations of natural water resource temperatures can have dire consequences on aquatic life and the local ecosystems.

1.1.2. NOISE POLLUTION

Noise pollution is an environmental phenomenon but a non-physical contamination as it does not directly affect the various media like air-water-land. Noise is undesired sound and an unwanted disturbance. Transmission of noise which is capable of producing physiological impact in an individual is defined as noise pollution. Noise pollution may interface with various activities of humans like work, recreation, communication and rest/sleep. It may create annoyance and stress.

On account of urbanization, the demand of transport facilities has increased. Due to the power-driven vehicles and jet aircrafts, the problem of noise has become substantially serious. At some locations, noise levels are much above the acceptable level. 'Hearing loss' is becoming frequent phenomenon in many of urban centres of our nation.

Valuation of property is dictated by its location. For illustration, an apartment located close to a cricket stadium or a school will be valued less than properties not affected by the noise emanating from these facilities. This is because too much noise adding to the nuisance value will have a negative impact on pricing.

1.1.3. LAND POLLUTION

Land pollution is the destruction or decline in quality of the earth's land surfaces in term of use, landscape and ability to support life forms. Many times, it is directly and indirectly caused by human activities and abuse of land resources. Land pollution takes place when waste and garbage is not disposed off in the right manner and as such, introduces toxins and chemicals on land.
Land pollution can be broadly classified as:

- Contamination of land due to uncontrolled storage & disposal/dumping of solid and hazardous chemicals/wastes onto soils in the form of herbicides, fertilizers, pesticides, or any other form of the consumer by-products. e.g. the past use of site for storing chemicals might have resulted in contamination of soils and groundwater with arsenic and organo-chlorine compounds.
- Alteration of land due to land uses like deforestation, farming, mining, developmental works like transport and communication.

Acid rain, construction sites, solid waste, mineral exploitation, agricultural chemicals and deforestation are the primary causes of land pollution.

<u>Contaminated Sites</u>

Environment Protection Policy of Australian Capital Territory Government (2000) has discussed land contamination as under:

Land contamination can arise from a range of commercial, industrial, or agricultural land uses and activities, particularly when the land use has involved hazardous materials. These substances if not managed properly may threaten human health or the environment or may affect the current or future land use.

The activities which have potential to adversely impact on human health and the environment are many. Some of them are given below:

- commercial incineration of wastes (including medical, chemical and municipal wastes)
- commercial landfills
- sewage and industrial effluent treatment plants
- petroleum storage tanks
- electricity generation
- commercial use of chemicals
- preservation of timber

It is therefore necessary to ensure an integrated approach considering public health, planning, occupational health and safety, hazardous and toxic waste management for addressing contamination.

The U.K. Environment Act states that:

"Contaminated land is any land which appears to the local authority in whose area it is situated to be in such a condition by reason of substance in, on or under the land that:

(a) significant harm is being caused
Or
(b) there is a significant possibility of such harm
Or

(c) pollution of controlled waters is being caused
Or
(d) is likely to be caused"

The question therefore is "What is significant?" In other words, what level of contamination is acceptable and at what point is it unacceptable? An explanation by the Department of Environment on the basis of harm caused, is as under:

- Chronic or acute toxic effect, i.e. serious injury or death to humans
- Irreversible or other adverse change in functioning of an ecological system
- Substantial damage to or failure of building
- Disease or other physical damage or death of livestock or crops kept, reared or grown on the land in question or adjacent land such that there is a substantial loss in their value.

Thus the effect of contamination on human heath, certain protected ecological systems, property in the form of crops-livestock-buildings-plant &machinery and controlled waters must be considered.

The principal causes of contamination of land include:

(1) uncontrolled disposal of industrial, solid and hazardous wastes on land
(2) uncontrolled burning of solid waste on land
(3) improper storing either temporarily or permanently of toxic substances/wastes, discarded chemicals, industrial reject materials
(4) deposition of stack emissions and toxic substances during transfer via atmosphere
(5) soil pollution caused by industrial effluents running uncontrolled over the land.

1.2 ENVIRONMENTAL DEGRADATION AND STEPS TO RESTORE ENVIRONMENTAL DAMAGE

Our environment is deteriorating for the last two centuries and almost every part of the planet has been touched by it in one way or the other. Environmental pollution refers to the degradation of quality and quantity of natural resources. The primary cause of environmental degradation is human disturbance.

The industrial revolution of 19th century mechanized the production and manufacturing of goods and introduced the use of machinery and other heavy equipments-which in turn, used fuels as source of energy, which deteriorate the environment. The modern technological progress is actually the root cause of the environmental deterioration.

1.2.1 CAUSES OF ENVIRONMENTAL DEGRADATION

Different kinds of human activities are the main reasons of environmental degradation. These have led to environment changes that have become harmful to all living beings. The waste products, smoke emitted by vehicles and industries increase the amount of poisonous gases in the air. Unplanned urbanization and industrialization help to increase pollution of the sources of water and have also caused air and sound pollution.

Environmental changes are based on many factors including:

- Urbanization
- Industrialization
- Over-population
- Economic growth
- Deforestation
- Intensification of agriculture
- Increase in energy use
- Increase in transportation.

1.2.2 STEPS TO RESTORE ENVIRONMENTAL DEGRADATION

The degradation has adverse impacts on humans, plants, animals and micro-organisms. To cope up with the critical situation, we need to make optimum use and management of resources, sustainable development, adoption of green concept and above all community participation in all developmental activities.

1. **Reform Current Systems : Reformation of the current system with more strict laws towards environmental pollution and degradation must be implemented.**

2. **Promote Green Jobs : Lift people out of poverty and reduce environmental impact at the same time.**

3. **Televise Real-Time Debates and Discussions Among Environmental Experts and Representatives from Other Sectors :** Millions of people are working to solve various environmental crises. They should be heard and others should learn more about the issues from them. TV and internet videos can help reach a wide audience and get people involved. To get the most out of it, these forums would need to be live, unscripted and open to people of diverse backgrounds and opinions.

4. **Abandon 'Cap and Trade' System :** The global cap and trade system sets limits on carbon emissions for businesses around the world. It is set up so that the worst polluters can buy "pollution credits" from those who stay under the limit and pollute less. Supporters argue that this not only sets realistic goals to decrease pollution, but economically incentivizes businesses to pollute less. It may sound like a good idea, but there are serious negative consequences to cap and trade.

Another way to deal with pollution would be to hold polluters criminally liable through the justice system for violation of other's property. We each own our lungs and air pollution violates those boundaries. Sufficient penalties make polluting prohibitive so it is phased out and the real costs of healthy goods will become apparent.

5. **Account for Externalized Costs :** Humans rely on nature for their survival. We are threatening all life on this planet without accounting for our impact along the way and tracking how well forests are regenerating, other species are surviving, and water systems are maintaining themselves.

6. **Label Genetically Modified Foods :** There is currently no way to know if your food is genetically-modified despite the fact that there are significant environmental and health hazards associated with GMO's (Genetically Modified Organisms).

7. **Promote Renewable Energy and "New Energy" Technology :** The burning of fossil fuels is polluting the air, fueling war and global conflict, and breeding dependence on oil-rich countries. But efficient, sustainable alternatives exist that can revolutionize the energy industry. Exciting innovations in the solar and wind industries have been emerging in recent years – prices are more competitive; energy generation is more efficient; and adoption is more common worldwide.
   Some of such established strategies include:
   - **Decrease our reliance on oil** and use it to make the transition to renewable alternatives.
   - **Employ alternative energy sources** including wind and solar to power a large portion of the world.
   - **Stop suppressing and further develop "New Energy" resonant technology devices** to make clean, abundant power accessible everywhere.

8. **Phase out, stop or shifting environmentally harmful subsidies: Government should develop strategy for removal of subsidies that are directly or indirectly causing harm to the environment.**

Each year the world's taxpayers provide billions of dollars in subsidies for environmentally destructive activities, such as fossil fuel burning, over-pumping aquifers, clear-cutting forests, and overfishing. This essentially implies that the world is spending lot of money annually to subsidize its own destruction.

One way to correct the situation is **tax shifting** - raising taxes on activities that harm the environment so that their prices begin to reflect their true cost and offsetting this with a reduction in income taxes. A complementary way to achieve this goal is subsidy shifting.

A world facing economically disruptive climate change can no longer justify subsidies to expand the burning of coal and oil. Shifting these subsidies to the development of climate-benign energy sources such as wind, solar, biomass, and geothermal power will help stabilize the earth's climate. Shifting subsidies from road construction to rail construction could increase mobility in many situations while reducing carbon emissions.

In a troubled world economy where many governments are facing fiscal deficits, the tax and subsidy shifts can help balance the books, create additional jobs, and save the economy's eco-supports. Tax and subsidy shifting promise greater energy efficiency, cuts in carbon emissions, and reductions in environmental destruction.

9. **Trusts – A Tool to Manage the Commons :** Land or resources belonging to or affecting the whole of a community are generally referred to as the 'commons'. One compelling way to deal with management of the commons is to create trusts that are designed to protect natural resources for present and future generations. This is already being done in many countries with considerable success. e.g. the Pacific Forest Trust, the Marin Agricultural Land Trust, the Oregon Water Trust.

10. **Set up Systems for Voluntary Co-operation :** The environment varies so much from place to place that it doesn't make sense to have sweeping national solutions to environmental crises. Rather, people should have a say within their community about how to deal with local environmental issues.

1.3 REVIEW YOUR UNDERSTANDING

1. Water pollution means
   A. Level of pollutant is more than the prescribed standard
   B. Contamination of water
   C. Alteration of physical, chemical or biological properties of water
   D. All the above

2. Environmental pollution means
   A. Presence of any pollutant in environment which causes adverse impact on human health and ecosystem
   B. Alteration of characteristics leading to degradation of quality of environment
   C. Presence of pollutants in any form but in such concentration which may tend to be injurious to environment giving rise to adverse effect on marketability of assets
   D. All of the above

3. Air pollution means
   A. Level of pollutant is more than the prescribed standard
   B. Contamination of water
   C. Alteration of physical chemical or biological properties of water
   D. None of the above

4. In which type of contaminant, Noise Pollution is categorized?
   A. Hazardous and toxic material
   B. Industrial wastewater
   C. Physical contamination
   D. Non–physical contamination

5. State the principal causes of contamination of land.

MODULE-2

OUTLINE OF ENVIRONMENTAL LEGISLATIONS

2.0. INTRODUCTION

Even before India's independence in 1947, several environmental legislations existed but the real impetus for bringing about a well-developed framework came only after the UN Conference on the Human Environment (Stockholm, 1972). The UN Conference on Human Environment at Stockholm in 1972 influenced the need for integrated legal mechanism to conserve the natural resources, protect the environment and ensure healthy human life. Under the influence of this Stockholm Declaration, the National Council for Environmental Policy and Planning within the Department of Science and Technology was set up in 1972. This Council later evolved into a full-fledged Ministry of Environment and Forests (MoEF) in 1985 which today is the apex administrative body in the country for regulating and ensuring environmental protection.

Climate change was also an agenda in the ministry (MoEF) but it was explicitly made a priority in 2014 and the ministry was renamed as Ministry of Environment, Forest and Climate Change (MOEFCC) in May 2014.

After the Stockholm Conference, constitutional sanction was given to environmental concerns in 1976 through the 42nd Amendment, which incorporated them into the Directive Principles of State Policy and Fundamental Rights and Duties.

Constitutional Provisions related to Environment
Article 21 – Right to pollution free environment
Article 48A - imposes a duty on the State to protect and improve the environment, and to safeguard the forests and wild life of the country.
Article 51A(g) - imposes duty on every citizen to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.

Since the 1970s, an extensive network of environmental legislation has grown in the country. The MoEF and the pollution control boards (CPCB i.e. Central Pollution Control Board and SPCBs i.e. State Pollution Control Boards) together form the regulatory and administrative core of the sector.

The major legislative measures brought about in India for protection of environment and human health can be broadly grouped into the following categories:

(i) Water
(ii) Air
(iii) General (Environment Protection)
(iv) Forest and Wildlife
(v) Industrial Health and Safety.

Some of the major legislations emphasised in this study material include:

1. The Water (Prevention and Control of Pollution) Act, 1974
2. The Water (Prevention and Control of Pollution) Cess Act, 1977
3. The Air (Prevention and Control of Pollution) Act, 1981
4. The Environment (Protection) Act, 1986.

The Water Act provides for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water. Apart from the Water Act which deals with the prevention & control of water pollution and the Air Act which is concerned with the prevention-control-abatement of air pollution, the Environment (Protection) Act-1986 was enacted to be a comprehensive legislation for the protection and improvement of environment and for matters connected therewith. The scope and definition of 'Environment' was expanded to include water, air and land and the interrelationship which exists among and between water, air and land, and human beings, other living creatures, plants, microorganisms and property. The Environment Protection Act also provides for handling of hazardous substances. Under this Act, the statutory powers are mostly conferred on the Central Government. However, the Central Government is vested with the power of delegating the powers under the provisions of the Act to an Authority constituted or to the Authorities to be specified with the residuary power retained in them.

The Water (Prevention and Control of Pollution) Cess Act, 1977 was passed by Parliament to provide for the levy and collection of cess on water consumed by persons with a view to augment the resources of the CPCB and the State Pollution Control Boards. This Act by giving 70% rebate to the scheduled industries encourages the industries to take up serious measures to control pollution in accordance with the conditions laid down under the Water Act, 1974.

This financial incentive is in addition to the already existing financial incentives given to the industries under the Income Tax Act as well as subsidies on clean manufacturing technology and pollution control given by certain State Governments. These incentives vary across States depending on their respective industrial policies. Earlier, service tax exemption was given on services provided by way of construction, erection, installation, commissioning, completion, fitting out, repair, maintenance, renovation or alteration of pollution control or effluent treatment plant *except when located in a factory*.

2.1 THE WATER(PREVENTION AND CONTROL OF POLLUTION) ACT, 1974

This Act provides for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water. For carrying out above objects, the Act contemplates the constitution of Central Pollution Control Board (CPCB) at the National level and State Pollution Control Boards at State level. The CPCB apart from functioning as a coordinating national level body, also acts as a State Board in respect of the Union Territories. These have since been constituted. This Water Act defines water pollution and prescribes penalties besides establishing administrative machinery like CPCB and SPCB. The Boards are given comprehensive powers to advise, coordinate and provide technical assistance in the prevention &control and abatement of water pollution. These Boards are entrusted with the task of monitoring the state of water pollution in the country and laying down standards of permissible level of pollution.

Any person who wants to locate an industry has to check whether the area in which he wants to locate an industry is in the areas declared under Section 19 of the Water Act or not. In the absence of any notification excluding that area, the Water Act applies throughout the State and therefore the proponent has to conform to the provisions of the Act. In so far as the Union Territory of Delhi is concerned, there is no such exclusion and therefore the Water Act can be enforced in the whole of the Union Territory of Delhi.

Further, under the amended Section 25 of the Water Act read with Section 26, unlike the non-amended sections, it requires previous consent of the State Board to establish or to take any steps to establish any industry. The Boards control sewage and industrial effluent discharges by approving, rejecting or conditioning (like the location, construction and use of the outlets as well as nature and composition of new discharges) the application seeking consent to discharge.

The State Board must maintain and make public a register containing particulars of Consent Order. The Act empowers a State Board, upon 30 days of notice to a polluter, to execute any work required under a consent order which has not been executed. The Board may recover the expenses for such work from the polluter. The students are advised to read Section 25 of the Act. This Act prohibits dumping of poisonous, noxious or polluting matter into the streams and wells, as well as any activity which impedes the flow of the water of a stream. The boards are authorized to take action against polluters by imposing conditions aimed at discouraging pollution and can prosecute the polluter.

It is the duty of valuer to ensure that the occupier of the industry has fulfilled all the obligations under this Act before he makes any transaction of buying or selling of the industrial property under your advice.

This Act was amended in 1988.

2.1.1 THE WATER(PREVENTION AND CONTROL OF POLLUTION) RULES 1975 and **Amendment Rules 2011** regulate the qualifications and other terms & conditions of the service of the members of the Central Pollution Control Board.

2.1.2 THE WATER(PREVENTION AND CONTROL OF POLLUTION) CESS ACT 1977 provides for the levy and collection of cess or fees on water consuming industries and local authorities. This cess is collected with a view to augment the resources of the Central Board and the State Boards for the prevention and control of water pollution constituted under the Water Act, 1974. The Act was last amended in 2003.

2.1.3 THE WATER(PREVENTION AND CONTROL OF POLLUTION) CESS RULES 1978 contains the standard definitions and indicate the kind of and location of meters that every consumer of water is required to affix.

2.2 THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT, 1981

This Act provides for the prevention, control and abatement of air pollution in the nation. This Act mainly regulates and control emissions from automobiles and industrial plants. Under the Air Act, all industries operating within designated air pollution control areas must obtain consent from the State Boards.

The States are required to prescribe emission standards for industry and automobiles after consulting the Central Board as regards the ambient air quality standards. The Central Board for the prevention and control of water pollution is also authorized to implement and enforce the Air Act as well. This body lays down standards for the quality of the air.

Under Section 19, the Central Board is given powers mainly to coordinate the activities of State Boards. Section 19 of the Act contemplates declaration of air pollution control areas. The State Government may, after consultation with the State Board, by notification in the Official Gazette declare any such area for the purposes of the Act. For example, the entire Union Territory of Delhi having been so declared, is in air pollution control area for the purposes of this Act. The Board may prohibit the use of any fuel other than approved fuel in the area causing air pollution.

Under Section 21 of the Air Act, only with the previous consent of the State Board a person shall establish or operate any industrial plant in air pollution control area.

Under Section 22 of the Air Act, any person carrying on any industry or operating any industrial plant in any air pollution control area is prohibited from discharging or causing or permitting to be discharged the emission of any air pollutants in excess of the standards laid down by the State Board.

Further, no person shall, without the consent of the State Board, operate an industrial plant involving industries specified in schedule in air pollution control area.

Under Chapter VI of the Act, the penalties in case of failure in complying with the directions issued under Section 21 or Section 22, is imprisonment for a term which shall not be less than one year and six months but which may extend to six years and with fine, and in case the failure continues, with an additional fine which may extend to five thousand rupees for every day during which such failure continues even after the conviction for the first such failure.

2.2.1 THE AIR (PREVENTION AND CONTROL OF POLLUTION) RULES, 1982 define the procedures of the meetings of the Boards and the powers entrusted to them.

2.2.2 THE AIR (PREVENTION AND CONTROL OF POLLUTION) AMENDMENT ACT, 1987 empowers the central and state pollution control boards to meet with grave emergencies of air pollution.

2.3 THE ENVIRONMENT (PROTECTION) ACT, 1986

This Act passed by Parliament on 23rd May, 1986 authorizes the central government to protect and improve environmental quality, control and reduce pollution from all sources, and prohibit or restrict the setting and/or operation of any industrial facility on environmental grounds. It also provides for taking appropriate steps for the protection and improvement of human environment, the decisions of which were taken at the United Nations Conference on the Human Environment held at Stockholm in June 1972 in which India also participated. This Act further aims at implementing the decision aforesaid in so far as they relate to protection and improvement of environment and the prevention of hazards to human beings, other living creatures, plants and property.

Section 3(2)(v) confers powers on the Central Government to restrict the area in which any industry, operation or process or class of industries, operations or processes shall not be carried out or shall be carried out subject to certain safeguards. By virtue of this Act, the Central Government is empowered to take all needful actions for prevention, control and abatement of environmental pollution. The powers include coordination of actions by states, planning and execution of nationwide programmes and laying down environmental quality standards. The Central Government is also empowered to make rules which may provide for the prohibition and restrictions on the location of industries and carrying on the processes and operations in the different areas.

Section 8 of the Act clearly provides that no person shall handle or cause to handle any hazardous substance except in accordance with such procedure and after complying with such safeguards as may be prescribed.

This Act also includes the power of handling hazardous substances, prevention of environmental accidents, research, inspection of polluting units, establishment of laboratories, dissemination of information etc. A complete set of administration procedure and organization structures are also envisaged under the Act.

Penalty for each contravention of the provision of this Act is imprisonment for a term which may extend to five years or with a fine which may extend to one lakh rupees or with both, and in case the failure or contravention continues, with additional fine which may extend to five thousand rupees for every day during which such failure or contravention continues after the conviction for the first such failure or contravention. If the failure or contravention continues beyond a period of one year after the date of conviction, the offenders shall be punishable with imprisonment for a term which may extend to seven years.
This Act was last amended in 1991.

2.3.1 THE ENVIRONMENT (PROTECTION) RULES, 1986 and subsequent amendments lay down the procedures for setting standards of emission or discharge of environmental pollutants. The Rules prescribe the parameters for the Central Government, under which it can issue orders of prohibition and restrictions on the location and operation of industries in different areas. The Rules lay down the procedure for taking samples, serving notice, submitting samples for analysis and laboratory reports. The functions of the laboratories are also described under the Rules along with the qualifications of the concerned analysts.

2.3.2 HAZARDOUS WASTE (MANAGEMENT AND HANDLING) RULES, 1989 are framed with the objective to control the generation, collection, treatment, import, storage, and handling of hazardous waste.
Some of the other Rules for hazardous substances management notified by MOEF / MOEFCC include:

- The Chemical Accidents (Emergency Planning, Preparedness and Response) Rules 1996 and Amendment Rules 2015
- The Rules for Manufacture, Use, Import, Export and Storage of Hazardous Micro-organism, Genetically Engineered Organisms or Cells, 1989 (amended 2010)
- Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989 (and Amendment Rules 2000)
- The Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016
- The Bio-Medical Waste (Management and Handling) Rules, 1998 and (Amendment) Rules, 2003
- Plastic Waste (Management & Handling) Rules, 2011
- Several other Rules notified by the MoEF (*refer* www.moef.nic.in)

2.3.3 THE PUBLIC LIABILITY INSURANCE ACT, 1991 (amended 1992) and **The Public Liability Insurance Rules, 1991** (amended 1993) - The main objective of these legislations is to provide for damages to victims of an accident which occurs as a result of handling any hazardous substance. The Act applies to all owners associated with the production or handling of any hazardous chemicals.

2.3.4 THE BIOMEDICAL WASTE (MANAGEMENT AND HANDLING) RULES, 1998 is a legal binding on the health care institutions to streamline the process of proper handling of hospital waste such as segregation, disposal, collection, and treatment.

2.3.5 THE SOLID WASTE MANAGEMENT RULES, 2016 apply to every urban local body, outgrowths in urban agglomerations, census towns, notified areas, notified industrial townships, areas under the control of Indian Railways, airports, airbases, ports and harbours, defence establishments, special economic zones, State and Central government organisations, places of pilgrims, religious and historical importance as may be notified by respective State government from time to time and to every domestic, institutional, commercial and any other non residential solid waste generator situated in the areas **except** industrial waste, hazardous waste, hazardous chemicals, bio medical wastes, e-waste, lead acid batteries and radio-active waste, that are covered under separate rules framed under the Environment (Protection) Act, 1986.

These rules lay down the duties of waste generators and authorities and the frequency of review of implementation of these Rules at various levels.

2.3.6 THE CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT RULES, 2016

The rules shall apply to every waste resulting from construction, re-modeling, repair and demolition of any civil structure of individual or organisation or authority who generates construction and demolition waste such as building materials, debris, rubble.

Every waste generator shall prima-facie be responsible for collection, segregation of concrete, soil and others and storage of construction and demolition waste generated.

Local authority shall be responsible for proper management of construction and demolition waste within its jurisdiction including placing appropriate containers for collection of waste, removal at regular intervals, transportation to appropriate sites for processing and disposal.

2.3.7 THE NOISE POLLUTION (REGULATION AND CONTROL) AMENDMENT RULES, 2002 lay down such terms and conditions as are necessary to reduce noise pollution, permit use of loud speakers or public address systems during night hours on or during any cultural or religious festive occasion.

2.3.8 WETLAND (CONSERVATION AND MANAGEMENT) RULES, 2010 are notified to ensure better management, conservation and prevention of degradation of existing wetlands.

The **Wetlands (Conservation and Management) Amendment Rules, 2016** decentralise wetlands management by giving states powers to not only identify and notify wetlands within their jurisdictions but also keep a watch on prohibited activities.

2.3.9 MISCELLANEOUS NOTIFICATIONS

- The Ozone Depleting Substances (Regulation and Control) Rules, 2000
- Noise Pollution (Regulation and Control) Rules, 2000 as amended till 2010
- Coastal Regulation Zone notifications
- Environmental Clearance and Environmental Impact Assessment notifications (1994 to 2016)
- Environment Standards - industry specific (*refer* www.moef.nic.in)

2.4 THE NATIONAL GREEN TRIBUNAL ACT, 2010

This Act provides for the establishment of National Green Tribunal (NGT) for effective and expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matters.

Both the National Environment Tribunal Act 1995 and the National Environment Appellate Authority Act 1997 were repealed by the enactment of the NGT Act in 2010.

As per the provisions of the NGT Act 2010, the National Environment Appellate Authority (NEAA) established under the NEAA Act 1997 stands dissolved and the cases pending before the NEAA stand transferred to the NGT.

2.5 FOREST AND WILDLIFE

2.5.1 THE INDIAN FOREST ACT 1927

It is one of the many surviving colonial statutes. It was enacted to ‘consolidate the previous laws relating to forests that were passed before the 1920s, the transit of forest produce, and the duty leviable on timber and other forest produce’.

The Act gave the State Government the power to create Reserved Forests, and the right to use Reserved Forests for Government use alone. It also created Protected Forests, in which the use of resources by local people was controlled. Some forests were to be controlled by the village community, and these were called village Forests. The Act remained in force till the 1980s when it was realized that protecting forests for timber production alone was not acceptable. The other values of protecting the services that forests provide and its valuable assets such as biodiversity began to overshadow the importance of their revenue earnings from timber.

This led to the Forest Conservation Act of 1980 and its amendment 1988.

2.5.2 THE FOREST (CONSERVATION) ACT 1980 and Rules 1981

The principal objective of this Act is protection of and the conservation of the forests. It strictly restricts and regulates the de-reservation of forests or use of forest land for non-forest purposes without the prior approval of Central Government. To this end, the Act lays down the pre-requisites for the diversion of forest land for non-forest purposes.

The Act was amended in 1988 and Rules were amended in 1992.

Forest conservation is the planned management of the forest environment to prevent its exploitation, destruction or neglect. There is a need for conservation of forests as population increases rapidly, resources are constantly exploited, pollution is dramatically increasing with respect to time and damages caused by the development activities are irreversible.

Section 2 of this Act requires the approval of Central Government before a State Government "de-reserves" a reserved forest, uses forest land for non-forest purposes, assigns land to private person or corporation or clears forest land for the purpose of reafforestation. In other words, the Act provides restriction on the de-reservation of forest or use of forest land for non-forest purpose. Here, non-forest purpose means breaking up or clearing of any forest land or portion thereof for cultivation of tea, coffee, spices, rubber, palms, oil bearing plant, horticultural crops or medicinal plants or for any purpose other than reafforestation.

But non-forest purpose does not include any work relating to conservation, development and management of forests and wildlife e.g. establishment of check-posts, fire-lines, construction of fencing, bridges, culverts, dams, pipelines, waterholes, pipelines etc.

An Advisory Committee constituted under section 3 of this Act advises the Government with regard to the grant of approval under Section 2 and any other matter connected with conservation of forests.

Whoever contravenes or abets the contravention of any of the provisions of section 2 of this Act, shall be punishable under Section 3A with simple imprisonment for a period which may extend to fifteen days.

Section 4 empowers the Central Government to make rules for carrying out the provisions of this Act by notification in the official gazette.

2.5.3 THE WILDLIFE (PROTECTION) ACT 1972, Amendment 1993 and Rules 1995 were framed with the objective of effectively protecting the wild life of this country and to control poaching, smuggling and illegal trade in wildlife and its derivatives. The Wild Life (Protection) Amendment Act, 2002 was enacted in January 2003 and punishment and penalty for offences under the Act have been made more stringent.

2.5.4 THE BIOLOGICAL DIVERSITY ACT 2002 and **Biological Diversity Rules 2004** are framed to provide for the conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of the benefits arising out of the use of biological resources and knowledge associated with it.

2.6 INDUSTRIAL SAFETY AND OCCUPATIONAL HEALTH LAWS

The basic aim of the concerned law making and amending authorities is to devise laws which provide safety standards to protect the basic needs of workers and take care of their welfare. Legislation on occupational health and safety has existed in India for several decades. The principal health and safety laws are based on the British Factories Act.

The Factories Act 1948, the Mines Act 1952, The Dock Workers (Safety, Health & Welfare) Act 1986 and The Building & Other Construction Workers (Regulation of Employment and Conditions of Service) Act 1996 are some of the laws which contain provisions regulating the health of workers in an establishment whereas the Employees' State Insurance Act 1948 and the Workmen's Compensation Act 1923 are compensatory in nature.

Some of the other relevant legislations dealing with occupational safety and health (OSH) are:

- Explosives Act, 1884;
- Dangerous Machines (Regulations) Act, 1923;
- Indian Boilers Act, 1923;
- Petroleum Act; 1934;
- Plantation Labour Act, 1951;
- Indian Atomic Energy Act, 1962;
- Insecticides Act, 1968;
- Radiological Protection Rules; 1971;
- Electricity Act, 2002.

2.6.1 THE FACTORIES ACT, 1948

The Factories Act, 1948 (amended in 1987) was enacted with the object of protecting factory workers from subjecting to unduly long hours of bodily strain or manual labour. It lays down that employees should work in healthy and sanitary conditions so far as the manufacturing will allow and that precautions should be taken for their safety and for the prevention of accidents.

The Factories Act, however, is applicable only to factories that employ 10 or more workers; it covers only a small proportion of workers.

The Act defines a 'worker' as any person employed directly or through any agency (including a contractor), whether for remuneration or not in any manufacturing process or in any work incidental to or connected with the manufacturing process. It is required that work performed should be connected with the product which is produced in the manufacturing process.

This Act is enforced by the State Governments through factory inspectors.

2.6.2 THE MINES ACT, 1952

This is an Act to amend and consolidate the law relating to the regulation of labour and safety in mines (coal, metal and oil) and extends to the whole of India.

The significant obligations under the Mines Act and the Mines Rules, 1955 include the formation of safety committees in every mine where more than 100 persons are employed; providing a notification of accidents and the appointment of workmen's inspectors by the manager (one inspector for every 500 miners).
The Act states that adolescents (not completed 15 years) are prohibited from any mining operation; the initial and periodical examination of miners is to be conducted and notice has to be provided for any notifiable diseases.

The Directorate of Mines is empowered to undertake safety and occupational health surveys in the mines and the central government is empowered to appoint a "competent" person for inquiring into the occupational diseases that have been detected.

2.6.3 THE DOCK WORKERS (SAFETY, HEALTH & WELFARE) ACT, 1986

This Act regulates health, safety, welfare and other working conditions of employees in ports and docks with an emphasis on reducing accident rates on ports and docks.

THE DOCK WORKERS (SAFETY, HEALTH & WELFARE) RULES, 1990 apply to all major ports in India as defined in the Major Ports Act, 1963.

2.6.4 THE BUILDING AND OTHER CONSTRUCTION WORKERS (REGULATION OF EMPLOYMENT AND CONDITIONS OF SERVICE) ACT, 1996

This is an Act to regulate the employment and conditions of service of building and other construction workers and to provide for their safety, health and welfare measures and for other matters connected therewith or incidental thereto Section 47 contains penal provisions for contravention of provisions regarding safety measures under the Act.

(1) Whoever contravenes the provisions of any rules made under section 40 shall be punishable with imprisonment for a term which may extend to three months, or with fine which may extend to two thousand rupees, or with both, and in the case of a continuing contravention, with an additional fine which may extend to one hundred rupees for every day during which such contravention continues after conviction for the first such contravention.

(2) If any person who has been convicted of any offence punishable under sub-section (1) is again guilty of an offence involving a contravention or failure of compliance of the same provision, he shall be punishable on a subsequent conviction with imprisonment for a term which may extend to six months or with fine which shall not be less than five hundred rupees but which may extend to two thousand rupees or with both:

Provided that for the purposes of this sub-section, no cognizance shall be taken of any conviction made more than two years before the commission of the offence for which the person is subsequently being convicted.

2.6.5 THE WORKMEN'S COMPENSATION ACT, 1923

This Act creates legal obligation on the employer to pay compensation to workmen involved in accidents arising during the course of their employment. The objective of the Workmen's Compensation Act is to make provision for the payment of compensation to a workman only, i.e., to the concerned employee himself in case of his surviving the injury in question and to his dependants in the case of his death.

The prerequisites for payment of compensation to such injured workmen are as follows:

- Personal injury must be caused.
- There must be temporary, total or partial disablement due to an accident, which also includes occupational diseases.

The State Government is to appoint a Commissioner to decide the liability of an employer to pay compensation, the amount and duration of compensation, among other issues. An appeal may lie to the High Court in case the applicant has grievance against the Commissioner's orders.

Compensation is decided on the nature of injury caused. Where the injury from an accident results in the death of the workman, the minimum compensation payable is around Rs.50,000 and the maximum may extend to Rs.3 lacs. In case of permanent total disablement and permanent partial disablement, compensation may extend to Rs.60,000, depending on its nature. Further the amount of compensation is calculated on the wage-group to which the workman belongs and the time-period for which he has worked

2.6.6 THE EMPLOYEES' STATE INSURANCE ACT, 1948

It is a social welfare/security legislation enacted with the object of ameliorating various risks and contingencies sustained by workers while serving in a factory or establishment.

It is designed to provide cash benefit in the case of sickness, maternity and employment injury, payment in the form of pension to the dependents of workers who died of employment injury and medical benefit to workers. It recognizes the contributory principle against such contingencies, provides protection against sickness, replaces lumpsum payments by pension in the case of dependents benefit and places the liability for claims on a statutory organization.

The Act lays down provisions to set up an ESI Corporation, to promote measures to improve health and welfare of insured persons and a Medical Benefit Council to advise the Corporation on medical benefits, certification, etc. The Medical Boards have to ascertain the percentage of disability of injured workers before submitting their report to the Corporation in order to grant compensation to the workers.
Section 39 of the Act makes the employer primarily liable for the payment of contribution on behalf of himself and his employees towards the ESI Fund.

In case of misuse of the contribution by employer, the employee can sue the employer in the Employees' State Insurance Court set up by the respective State Government.

2.7 REVIEW YOUR UNDERSTANDING

1. In which year was the Stockholm Conference held?
   - A. 1992
   - B. 1972
   - C. 2005
   - D. 1872
2. What was the objective of Stockholm Conference?
   - A. Preservation and improvement of natural resources and wildlife
   - B. Preservation and improvement of human environment
   - C. Preservation and improvement of forest and natural environment
   - D. None of the above
3. Which Act, expanded definition of “environment” to include water, air, land and the interrelationship which exists among and between water, air, land and human other living being and property?
   - A. The Water (Prevention and Control of Pollution) Act, 1974
   - B. The Water (Prevention and Control of Pollution) Cess Act, 1977
   - C. The Air (Prevention and Control of Pollution) Act,1981
   - D. The Environment (Protection) Act, 1986
4. Which Act provides for maintaining the wholesomeness of water in the nation?
   - A. The Water (Prevention and Control of Pollution) Act, 1974
   - B. The Water (Prevention and Control of Pollution) Cess Act, 1977
   - C. The Air (Prevention and Control of Pollution) Act,1981
   - D. The Environment (Protection) Act, 1986
5. Which one is said to be non-forest use under Forest Conservation Act?
   - A. Construction of fencing
   - B. Construction of Check post
   - C. Plantation of tea
   - D. Clearing up portion of forest land
6. The penalty imposed for contravention of Forest Conservation Act,1980 is
   - A. Maximum 15 days of simple imprisonment
   - B. Maximum 30 days of simple imprisonment and fine
   - C. Minimum 15 days of simple imprisonment and a fine
   - D. One year simple imprisonment and Rs.10000/- fine

7. The Advisory Committee constituted under Forest Conservation Act advises
   A. State Government on any matter of forest management
   B. As regards approval of government grants
   C. In recruitment of staff for forest resources
   D. All of the above
8. Discuss the provisions of the Forest Conservation Act, 1980

MODULE-3

VALUATION OF ENVIRONMENTALLY AFFECTED PROPERTY

1.0 INTRODUCTION

The objective of studying environmentally affected property is to provide guidance to the valuers in preparing valuation brief when environmental factors may have influence on the asset values.

The environmental factors which are important in asset valuation are those which are potentially detrimental to real property and plant & machinery. These may be on account of environmental factors like gases, heat, radiation, noise, vibration, chemicals, hazardous substances as well as odour impacting air, water, groundwater, soil and having direct or indirect effect on the individual asset. The assets may be important from the aesthetic, archaeological, historical and heritage point of view and may belong to the private sector or to the Government.

3.1 CONTAMINATED PROPERTY

When the buyer is devoid of the property rights i.e. the exclusive rights partly or fully to possess, enjoy, dispose etc. due to contamination, the property is said to be contaminated. In other words the environmental factors play their role in interference of the property rights. They create an indirect restraint in the use of property owned. When the contamination can result or is likely to result or has already resulted in the diminished utility of the property, the property is said to be contaminated. It is immaterial whether the diminished utility is for a short-term or long-term duration.

The monetary value of the contaminated property is always diminished. This is because the term monetary value has its basis in economics. The monetary value of the property is determined in the market where there are buyers and sellers and when there is a supply and demand of these goods and services.

3.2 ENVIRONMENTAL CONTAMINATION

Broadly, environmental contamination has been divided into two types, viz. Physical contamination and Non–physical contamination.

3.2.1. PHYSICAL CONTAMINATION

Physical contamination is on account of presence of physical contaminants in the environment. Physical contaminants are substances present in, on or near a subject property in measurable quantities and identified as having harmful environmental impact. It also includes substances which are hazardous i.e. ignitable, corrosive, toxic or reactive.

A hazardous substance is any substance or preparation which by reason of its chemical or physico-chemical properties or handling is liable to cause harm to human beings, other living beings, plants, microorganisms, property or the environment which has an adverse effect on marketability of the assets.

In ordinary words, the physical contaminants are those contaminants which may bring change resulting from human perception. These may include asbestos, heavy metals such as lead, mercury or mining products like arsenic, cyanide, pesticides or organic compounds like formaldehyde, coal tar from coal used in power house operations etc.

3.2.2. NON-PHYSICAL CONTAMINATION

Non-physical contamination is the result of non-physical contaminants present in the environment. Contaminants that have no tangible physical substance are defined as non-physical contaminants. In other words, all contaminants other than physical contaminants are non-physical contaminants. These contaminants are in many forms and are considered as 'real' as the physical contaminants. Illustrations include – proximity to noise sources often diminishes utility and therefore property value, or electromagnetic radiation originating from nearby power lines or radio-wave transmission devices.

3.3 CONTAMINATED SITE

As defined by the Contaminated Sites Management Working Group of Treasury Board of Canada Secretariat, a contaminated site is that at which, substances occur at concentrations (1) above background levels and pose or are likely to pose an immediate or long term hazard to human health or the environment, or (2) exceed levels specified in policies and/or regulations.

The Canadian Council of Ministers of the Environment has developed a national classification system for contaminated sites (NCSCS, 2003) to provide a basis for classifying sites according to their current and potential adverse impact on human health and environment. According to their priority for action, contaminated sites are placed into classes one to five, namely:

Class-1: **High Priority for Action**– available information (assessment) indicates that action (*e.g.*, further site characterization, risk management, remediation, etc.) 'is required' to address the existing concerns for public health and safety.

Class-2: **Medium Priority for Action**– available information (assessment) indicates that there is a high potential for adverse impacts due to off-site migration, although threat to human health and the environment is generally not imminent. Action is 'likely required'.

Class-3: **Low Priority for Action**- available information (assessment) indicates that the site is currently not a high concern. However, additional investigation may be carried out to confirm the site classification and some degree of action 'may be required'.

Class-N : Not a Priority for Action - available information (assessment) indicates that there is probably no significant environmental impact or human health threats and there is action 'not likely required' unless new information becomes available indicating greater concerns when the site be re-examined.

Class-I or **INS : Insufficient Information** – some initial site assessment action has been taken but there is insufficient information to classify the site and additional information is required.
NCSCS is a tool specifically for the classification and prioritization of contaminates sites. The system screens sites with respect to the need for further action (e.g. characterisation, risk assessment, remediation, etc.) to protect human health and environment.

3.4 CONCEPT AND PRINCIPLES OF VALUATION OF ENVIRONMENTALLY AFFECTED PROPERTY

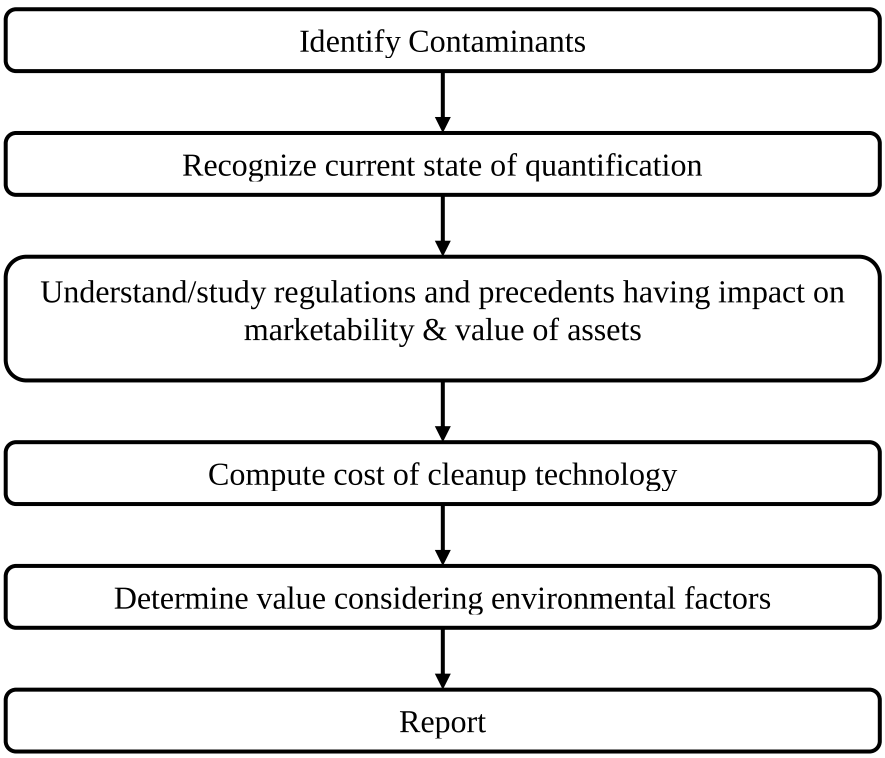
The ‘Environmental Impact Assessment' subject addresses the impact of environmental contamination on asset value. To understand such effect, valuers must have knowledge on the following aspects:

- CONTAMINANTS: The substances, contaminants or conditions currently thought to produce contamination.
- DETECTION, MONITORING and ABATEMENT: Recognizing the current state of detection, monitoring and abatement technology.
- LEGAL STATUS: Understanding the legal state of current regulations and court decisions (precedents) which have greater impact on the marketability and value of asset.
- HAZARDOUS SUBSTANCES: List of the substances that are hazardous and their level of concentration which are considered harmful, their clean up technology and such other treatments.
- REMEDIATION: The effect of technology that facilitates safe and efficient clean-up of contaminant and help in minimizing or reducing the stigma value (negative value).However, the cost factor must be identified. It may include :

  (1) Cost of Physical clean up, and

  (2) Continued costs of monitoring and legal costs.

Schematic block diagram showing important aspects that valuer must know for valuation of contaminated property.



3.5 LIABILITY OF VALUERS AS TO CONTAMINATION

Public or residents near nuclear power plants may not be aware of potential effect of radon gas emitted from such plants. Similarly, public may not be aware of potential impact of electromagnetic radiation from proximity to overhead power distribution lines of transmission towers or about hazards associated with the use of asbestos as construction material. But the valuers must be aware of the impact of such environmental factors as applicable to valuation of assets. The valuer is also liable for value determination and valuation calculations considering environmental factors while ultimate preparation of valuation of assets - may it be for financial statements, market value estimates, security against loan and all such other purposes.

Valuers should have primary knowledge as to quality of data of site which may include:

- ✓ Proposed use of data/ information
- ✓ Nature of adjacent land or similar type of assets.
- ✓ Source(s) of contamination and elimination if possible by substitute
- ✓ If elimination not possible, temporary measures as to how to cover it to make the property fit for use.
- ✓ Mitigation of contamination by optimum use of technology

Valuers are also required to encompass the substantial report on environmental factors considered while preparing valuation of assets in the valuation report. A detailed report in a clear narrative text must be prepared. It must delineate each factor identified, its concentration and its impact on property, level of mitigation and cost of removal of stigma on the property under consideration.

3.6 APPOINTMENT OF AN ENVIRONMENTAL EXPERT

A valuer is unlikely to have knowledge or skills to undertake an environmental audit in accordance with the Environment (Protection) Act-1986 or guidelines given by the Ministry of Environment and Forests, New Delhi. However, valuers may employ environmental expert or client may appoint a suitable consultant. But in any case, valuers must have primary knowledge as to the quality of data regarding the subject site and its proposed temporary or permanent use.

Amongst the other items which might be introduced in brief are:

a) Can the source of contamination of hazard be successfully eliminated economically?

b) If the contamination of hazard cannot be entirely eliminated, can it be converted or contained so as to make the property fit for a particular use? or

c) Is it possible to mitigate the effect of the contamination of hazard in any way?

The expert's report then covers the following:-

- ⇨ Identification of hazard, its degree and extent. (i.e. identification and qualification)
- ⇨ Treatment, measured to be taken to bring the property to acceptable condition.
- ⇨ Cost of such measures (and effects of any such works undertaken).

3.6.1 SAFEGUARDING THE VALUER- TEMPORARY MEASURE

If a consultant is not appointed, the standard clause for safeguarding valuers from legal implications can be written as under:

"We have neither made any attempt nor arranged for any investigation to be carried out to determine whether or not any deleterious or hazardous material has been used in the construction of this property and we are therefore unable to report that property is free from risk in this respect. For the purpose of this evaluation, we have assumed that such investigation would not disclose the presence of any such material to any significant extent."

3.7 REVIEWING YOUR UNDERSTANDING

1. In which type of contaminant Chromium is categorised?
   - Domestic wastewater
   - Industrial wastewater
   - Physical contamination
   - Non-physical contamination

2. The objective of environmental valuation is
    - preparing valuation brief for the client
    - determining the value of the assets in conditions of contamination
    - determining the factors of the contamination
    - none of the above

3. A valuer is likely to have
    - knowledge or skills to undertake an environmental audit
    - knowledge of hazardous material present in the property
    - primary knowledge as to the quality of data regarding site
    - none of the above

4. List the various physical and non-physical contaminants.

5. Define contaminated land and contaminated property and discuss their ingredients

6. State the principal causes of contamination of land.

7. Define contaminated site and contaminated land and bring out causes of the same.

8. Show by a block diagram the important aspects the valuers must know for the valuation of contaminated property.

MODULE-4

GENERAL EFFECTS OF CONTAMINATION OF PROPERTY

4.0 INTRODUCTION

Valuation is the act of determining the value of the asset which is based on its quality, nature and utility which includes all forms of rights and interest arising out of the asset. The impacts of the presence of the contaminants normally lead to value diminution compared with open market price. The impact therefore means change in the value of the assets on account of presence of contaminants.

Impacts can be short term or long term depending upon the persistence or duration of the impacts. It is necessary to identify the short term and long term impacts because its significance is based on duration it remains on the environment. The loss of grass or other low lying herbaceous vegetation on a particular property is a short term impact because the said property can be re-vegetated through seeding and manure in a relatively short period of time. The loss of value of the asset therefore in such cases is temporary or short term. But the loss of a mature forest can be considered as a long term impact because of the time required to re-forest the area and for the trees to reach maturity. The loss of the value of the asset in such cases is permanent or long term.

4.1 GENERAL EFFECTS OF CONTAMINATED PROPERTY ON VALUATION

The property market as such has now become sensitive to various detrimental effects on account of contamination caused to the assets. The general effects of contaminated property on its valuation can be enumerated as under:

FALL OF DEMAND

The demand of the contaminated property falls because normally no buyer will be interested to purchase such a property when non-contaminated property is available in the market. Fall of demand and fall of price of a property is due to the stigma. 'Stigma' is intangible factor. It may not be measurable in terms of remediation cost or cost to cure but certainly affects market value.

4.1.2. FALL OF PRICE

The buyer may demand discount on account of contamination. The discount demanded may or may not be in proportion to the level of contamination. It is otherwise also obvious that fall of demand leads to fall of price.

4.1.3 ASSETS OFF THE MARKET

Some companies in absence of the market data on contaminated assets believe that assets would not be sold at any price and such companies keep the assets off the market.

Normally, valuers keep themselves abreast of the market price of the various assets and they would however be deprived of such important information when the assets are contaminated. It has been observed that valuers find it very difficult to collect the data about contamination and analyse them for the valuation purposes.

4.1.4 RISK OF LAW SUITS

It is a substantial fact that the companies have fear that buying a contaminated asset may create contingent liabilities associated with law suits. If the subject property has used any hazardous material in construction and the valuer has not taken into consideration the impact of such materials while preparing valuation brief, there are chances that litigation may take place on account of carelessness on the part of the valuer. It may attract various criminal offences like cheating and thereby dishonestly inducing delivery of the property or offence on account of using as genuine a forged document which was known to the valuer to be forged.

Thus litigation is likely to take place against the seller or valuer and it may be difficult to prove innocence of the seller or the valuer as regards the knowledge of the presence of the contaminant(s). As a result, both the seller may refrain from buying and the valuer from valuing such contaminated property.

4.1.5 REDUCED MARKET VALUE

Whenever stigma is attached, the property remains in less demand even though complete clean-up has been established. This creates situation similar to the 'obsolescence'. This is because the market will pay less for a once-contaminated but now restored property; the value of the property is diminished. Thus, an effect of this nature may be for some temporary period and efforts should be made to re-establish the market for that restored property.

Even though the water from a previously contaminated well now meets all environmental standards, the property value remains reduced till the seller builds a new well in different location or establishes an independent alternate water supply.

If the property owner makes no attempt to overcome the stigma and thereby accepts a lower price for the property, the price may not accurately reflect market.

4.1.6 DIFFICULTY IN GETTING FINANCE

It is difficult to mortgage and get finance on contaminated properties especially when the property is known to be contaminated. This is so because the return on investment on such property is believed to be such that the finance companies foresee risk in funding project on such contaminated land.

4.1.7 DIFFICULTY IN GETTING FUNDS FOR REMEDIATION

For a contaminated property, remediation is most essential to enhance its utility. Remediation means that act or process of eliminating environmental contamination from, on, in or under the asset to restore the asset to an uncontaminated state. It is also difficult to obtain additional funds for remediation. Even the funds are made available by some finance companies after many efforts. It can be concluded that such properties may increase the borrowing liabilities.

4.2 COST TO CURE

Cost is defined as a resource sacrificed or forgone to achieve a specific objective. Cost is considered as monetary amount that must be paid to acquire goods and services. Thus for combating the problem of contamination, some 'costs' are attached to acquire that objective. The cost comprises of Direct Costs and Indirect Costs.

Direct costs are those related to the particular cost object that can be traced to it in an economically feasible way.

Indirect costs are those related to the particular cost object but cannot be traced to it in an economically feasible way.

Broadly, costs arising from contamination are those costs which are related to either controlling the contamination or repairing the contaminated part of the property. Other costs are associated while the part property is under remediation and part is in use like operating, disruption, utility, stigma and so on.

4.1 STIGMA DUE TO ENVIRONMENTAL FACTORS - INTANGIBLE COST

The loss in property value resulting from a property's bad reputation on account of contamination is defined as 'Environmental Stigma'. As an intangible negative input factor, stigma is a market-imposed penalty that can affect a property that is known to be contaminated.

Thus, it must be borne in mind that the value of contaminated property ultimately depends not only on the extent of the contamination but also the way in which the contamination is perceived.

The reluctance of potential buyers to take on a once contaminated property because of fears of future liability and fears of hidden clean-up costs are intangibles that are difficult to translate into quantifiable costs.

Stigma may not be measurable in terms of cost to cure but may affect the market value when it is determined through sales comparison approach. According to Advisory Opinion (AO-9) in Uniform Standards of Professional Appraisal Practice (USPAP 2016-17) of the Appraisal Foundation-USA, **Environmental Stigma** is 'as an adverse effect on property value produced by the market's perception of increased environmental risk due to contamination'.

Environmental stigma is market imposed activity which has direct bearing on property value on following type of properties:

- **Environmentally contaminated property or source site**– these properties are absolutely known to be contaminated and market is not in a position to hide or make them off the market.

  These properties have adverse effect on value produced by the market perception of increased environmental risk due to contamination.

  Non-source sites are sites onto which, contamination generated from a source site has migrated.

- **Environmentally suspected property**-these are as such suspected to be contaminated and confirmatory reports are not available. These properties contribute stigma on account of following reasons:
  1. Risk of the remediation costs which are hidden
  2. Trouble factor
  3. Fear of future law suits
  4. Lack of saleability and mortgage-ability.

- **Environmentally remediated property**-these are the properties once known to be contaminated and remediation work is completed and now free from contamination. These properties contribute stigma due to following risks:
  1. Risk about its absolute remediation
  2. Risk of additional clean up in future and
  3. Risk of unexpected perception

- **Environmentally adjacent or proximate property/site** - these are the properties which were never contaminated but they are located in proximity to a contaminated property. Adjacent property shares a common property line with the source site. These properties are never reported to be contaminated but the stigma is attached to them as they are likely to be contaminated because they are believed to be very near to hazardous waste.

  Such property however can only be determined by people's perception and cannot be generalized.

While non-source sites are themselves also contaminated, adjacent and proximate sites in the neighbourhood are not contaminated but are affected by stigma.

4.4 COST TO CONTROL

Controlling a hazard encompasses both controlling by Systematic Operation & Maintenance and renovation which may include taking suitable steps to mitigate the impact of contamination on the assets. In short, it is the gross cost for controlling a hazard in a property.

4.5 COST TO PUBLIC LIABILITY

A toxic substance can destroy the life or it may tend to harm the health of a living animal or plant. Every substance has the ability to act as either a poison or a remedy, including water. The dose and the duration of exposure generally determine whether the given substance has harmful or beneficial effects. Toxic contamination may give rise to public liability. This cost is required to be incurred as the public at large is affected. The unanticipated release of toxic gases or flumes or contaminants onto the surrounding property may lead to substantial public liability. Discharge of improperly treated effluent may pollute the water body and presence of any toxic substance may get entry in the user of the said water body.

Public liability leads to a loss in property value because of following two reasons:

(a) The owner has to pay the costs related to the release of the toxic contaminants onto the surrounding properties and

(b) The owner may have to defend law suits associated with contamination. e.g. When contaminants penetrate into the ground water which is used for public water supply scheme.

4.6 COST TO DISRUPTION

The cost of disruption is cost of disturbance experienced during the remediation stage. This is indirectly the cost of remediation due to disrupted use of property on account of contamination. This is a fact that during the remediation period, a part of the property which is absolutely free from contamination can be used whereas the remaining part remains under renovation. The cost of disruption is due to trouble in operation temporarily or permanently due to contamination.

Cost to disruption is remediation cost e.g. Asbestos removal from office may require renovation expenses. Broadly the cost of disruption includes:

- removal of contamination from the subject property
- disposal of contaminant to the safer location like landfill site or incinerator site
- renovating the part of the property
- displacement of occupant/tenant, if any, and bringing other tenants

It is difficult to determine the cost of disruption. We may however estimate the profit from a business before disruption and after disruption.

4.7 COST TO OPERATION

Contamination may result into increase in operation and maintenance costs. This is because contaminated property may need extra supervisory personnel, additional testing, careful monitoring as well as security.

Similarly, special insurance of the property during remediation process, higher utility expenses like special ventilation system and the general & administrative expenses also ultimately increase.

4.8 COST TO UTILITY

This is the cost when the property cannot be fully utilized by the owner on account of contamination. The plans have been made for remediation. But the sanction of the plans has not yet been received. In other words the property is used partially. Thus cost to utility is due to lack of utility. Some portion of the property is under 'non-use' stage and cannot be utilized for the purpose for which it was contemplated.

Cost to utility can also be defined as deferred utility. Deferred utility indicates that the value of the property will be raised in future. This has obviously, therefore, a direct impact on the property value. Any contaminated property will show some impairment in its utility and thus value is affected.

Though the cost of utility and the cost of disruption apparently seem to be the same, it is not so. The cost to disruption is due to the remediation taking place in the property. No portion of the property is under 'non-use'. Cost to utility is prior to remediation. No option is available except waiting for the sanction from the authority and keeping the part of the property under 'non-use'. This normally happens when the contamination is quite less and the property has still substantial utility.

4.9 REDUCED REVENUES

When a contaminated property is given on rent, the rental value gets reduced. In other words, the net income gets diminished. This is so because the contaminated property as seen earlier under the head 'Operation & Maintenance Cost' will increase the operating expenses. The rent receivable will be reduced when the operating expenses are deducted from gross rent.

Sometimes the revenue may be found reduced though there is no contamination. This happens during the transition period when the building permit is awaited from the competent authority and tenants have feelings that the property is lightly contaminated. During this period it may be difficult to attract the tenants.

4.10 FORMAT OF VALUATION REPORT OF CONTAMINATED PROPERTY

In the profession of valuation, the format for valuation reports depending upon the purpose, are available or have been prescribed e.g. by Rule 8-D, Form No.O-1 under the Wealth Tax Act, 1957. Nevertheless, a concise format for valuation report on contaminated assets is not prescribed by any of the authority. Environmental Site Assessment (ESA) is the tool for valuation of the contaminated assets.

The format given below is purely for the guidance of the valuers and may be altered as per requirements. However, following minimum essential ingredients may be incorporated.

- **Basic Information of Contaminated Property**
  Name of the contaminated property valued, postal address of the site and details of the environmental agency including qualifications of environmental professional should be stated in the beginning of the report.

- **Introduction of Valuer and the Environmental Agency**
  This should bring out the summary of the terms and conditions under which the valuer has assigned the job to the environmental agency. Based on the purpose of the valuation, methodology used can be determined for ESA. This should be reflected under the head of 'Introduction'.

- **Major Elements in a valuation report for contaminated assets**
  The major components in a valuation report for contaminated assets should be stated under the following heads:
  - detailed site description and record studies
  - interviews and environmental site reconnaissance
  - inventory quantification of the contaminants
  - legal requirements
  - abatement technology
  - valuation process findings and conclusion followed by declarations

4.11 REVIEW YOUR UNDERSTANDING

1. The demand of the contaminated property falls as
   - A. The seller is ready to sell at a lower rate
   - B. Buyer is not interested in purchasing contaminated property
   - C. Buyer has option of purchasing non-contaminated property
   - D. None of the above
2. Which one is not environmental risk?
   - A. Additional risk in financing
   - B. Additional risk in buying
   - C. Additional risk in investing
   - D. None of the above

3. Which one is incorrect with reference to environmental stigma?
   A. Stigma is difficult to be explained
   B. Stigma is difficult to measure
   C. Stigma is equal to cost to cure
   D. None of the above
4. Environmentally contaminated property is
   A. Property known to be contaminated and market is not in a position to hide
   B. Property known to be contaminated and market is in a position to hide
   C. Property is suspected to be contaminated and confirmatory reports are not available
   D. None of the above
5. Environmental suspected property is
   A. Property known to be contaminated and market is not in a position to hide
   B. Property known to be contaminated and market is in a position to hide
   C. Property is suspected to be contaminated and confirmatory reports are not available
   D. None of the above
6. Environmentally remediated property is
   A. Never contaminated property
   B. Known to be contaminated and remediation work is completed
   C. Property is suspected to be contaminated and confirmatory reports are not available
   D. None of the above
7. Environmentally adjacent property is
   A. Never contaminated property
   B. Property which was never contaminated but are located in proximity
   C. Property is suspected to be contaminated and confirmatory reports are not available
   D. None of the above
8. Define environmental stigma. Explain whether environmental stigma is equivalent to the cost to cure.
9. Explain the word 'Environmental stigma' and discuss its bearing on different types of properties.

10. Cost to control is
    A. The gross cost of controlling a hazard in a property
    B. The cost of breaking the routes of chemical absorption
    C. The cost of remediation
    D. None of the above
11. In some of the industries, notices are displayed as regards protection from hazards at the work. What type of cost is it?
    A. Cost to reduce revenues
    B. Cost to utility
    C. Cost to control
    D. None of the above
12. The hazardous chemical enters normally by three routes. Which one is false from the options given below?
    A. Inhalation
    B. Dermal
    C. Ingestion
    D. Contact
13. Surveillance is examination of hazardous processes.
    A. Daily
    B. Periodically
    C. Annually
    D. None of the above
14. Providing isolation of risk from transportation of hazardous material forms
    A. Control by renovation
    B. Control by remediation
    C. Control by O & M
    D. None of the above
15. Public liability leads to a loss in property value because
    A. The owner has to pay the costs related to release of the toxic contaminants onto surrounding properties
    B. The owner has to control hazards by O & M programme
    C. The owner has to incur the expenses on administrative control
    D. None of the above

16. The duration of the operating cost is
    A. For the specific period
    B. Frequently occurring
    C. Twice in a year
    D. None of the above
17. Write short notes on followings:-
    A. Cost to disruption
    B. Cost to utility
    C. Cost to reduced revenues

MODULE-5

ENVIRONMENTAL VALUATION TECHNIQUES

5.0 INTRODUCTION

The existence of contamination is a factor that affects the highest and best use (HABU) of a subject property and the valuer should analyse the contamination's impact on the use of subject property. Contamination or the risk of contamination can result in a diminished utility for a property and the type of impact (short or long term) will determine the particular valuation techniques to be applied. These impacts include (*source: Appraisal Guidelines – Environmental Impacts, Public Works and Government Services, Canada, 1998*):

- Cost of controls (remediation)
- Change in operating costs
- Limitations in maximum income that could be anticipated, and
- Loss of marketability due to public perceptions of increased risk (stigma).

The valuer should understand that the value of a contaminated property may not be measurable by simply deducting the remediation costs from the value as-if unaffected. Other factors may influence value and must be considered, including the impact of stigma and the possibility of change in highest-and-best use as well as potential income.

The following are some of the specialised terms and definitions given in AO-9 of USPAP (2016-17) that are relevant for contaminated property valuation.

- **Unimpaired Value:** The market value of a contaminated property developed under the hypothetical condition that the property is not contaminated.

- **Impaired Value :** The market value of the property being appraised with full consideration of the effects of its environmental condition and the presence of environmental contamination on, adjacent to, or proximate to the property. Conceptually, this could be considered the "as-is" value of a contaminated property.

- **Diminution in Value (Property Value Diminution) :** The difference between the unimpaired and impaired values of the property being appraised. This difference can be due to the increased risk and/or costs attributable to the property’s environmental condition.

- **Remediation Cost:** The cost to cleanup (or to remediate) a contaminated property to the appropriate regulatory standards. These costs can be for the cleanup of on-site contamination as well as mitigation of off-site impacts due to migrating contamination.

When the appraiser addresses the diminution in value of a contaminated property and/or its impaired value, the appraiser must recognize that the value of an interest in impacted or contaminated real estate may not be measurable simply by deducting the remediation or compliance cost estimate from the opinion of the value as if unaffected (unimpaired value). Rather, *cost, use* and *risk* effects can potentially impact the value of contaminated property.

Cost effects primarily represent deductions for costs to remediate a contaminated property. These costs are usually estimated by someone other than the appraiser, and should include consideration of any increased operating costs due to property remediation. The appraiser should also be aware that the market might not recognize all estimated costs as having an effect on value.

Use effects reflect impacts on the utility of the site as a result of the contamination. If the contamination and/or its cleanup rendered a portion of the site unusable, or limited the future highest and best use of the property, then there could be a use effect on value.

Risk effects are typically estimated by the appraiser and often represent the most challenging part of the appraisal assignment. These effects are derived from the market’s perception of increased environmental risk and uncertainty. The analysis of the effects of increased environmental risk and uncertainty on property value (environmental stigma) must be based on market data, rather than unsupported opinion or judgment.

It is an unacceptable practice to assume that environmental contamination will reduce the value of a property without adequate support derived from information in the relevant real estate market.

These three potential effects (cost, use, risk) influence the value of a potentially impacted site according to the following formula:

Impaired value = Unimpaired value
- Cost effects (remediation and related costs)
- Use effects (effects on site usability)
- Risk effects (environmental risk/stigma)

In general, the **unimpaired value of the property** being appraised can be estimated using (i) sales comparison approach, (ii) cost approach and (iii) income approach. Estimating the effects of environmental contamination on real property value usually involves the application of one or more specialized valuation methods.

The **impaired value** of a property that may be impacted by environmental contamination, can **rarely be estimated through one of the traditional approaches to value** due to data limitations and other factors; thus, alternative methods must be utilized but these should also be based on relevant market data.

Cost effects are derived from remediation costs, which typically are estimated by environmental specialists. Assuming the market recognizes these costs, the appraiser can usually deduct them as a lump sum from the unimpaired value in a similar manner to a capital expenditure for deferred maintenance. When a discounted cash flow analysis used, the anticipated costs can be deducted from the projected cash flows in the periods in which they are projected to occur. Uncertainty regarding cost estimates, projection, and timing would be reflected in the environmental risk premium added to the unimpaired property or equity yield rate (risk effect).

Use effects can be analyzed by estimating the highest and best use of the subject contaminated property in an impaired and unimpaired condition. If the conclusions of the two highest and best use analyses are the same, then there are no use effects on value. If they differ, then the unimpaired and impaired values would be estimated for different uses and compared.

Risk effects are derived from the perceived environmental risk and uncertainty related to a property's environmental condition. Measuring this element usually requires more sophisticated and less direct techniques as below:

- Analysis of environmental case studies
- Paired Sales Analysis of potentially impacted properties
- Multiple Regression analysis of potentially impacted neighbourhood areas or properties in proximity to a contamination source
- Market Interviews to collect data and information used in other approaches or to support and supplement the results of other analyses
- Income Capitalisation Analysis - adjustment of income and yield capitalization rates to reflect environmental risk premiums in an income capitalization analysis

Valuing contaminated properties is complex because circumstances are different for each affected property and because sufficient comparable sales may be unavailable, difficult to obtain, or subject to unreasonable or unsupportable adjustments for varying conditions and situations. Nevertheless, as in all other types of property valuation, **three approaches to value are recognized** and should be used (*source :Standard on the Valuation of Properties Affected by Environmental Contamination*, *International Association of Assessing Officers, USA, 2016*).

5.1 SALES COMPARISON APPROACH

The sales comparison approach also known as market approach is the systematic gathering, recording and analysing data of similarly affected properties recently sold and comparing sales to the contaminated property being valued. When adequate data exist for similarly affected properties, this approach is considered the most objective and supportable.

The sales comparison approach requires sufficient sales of similar properties. As in the general sales comparison approach **when data on comparable contaminated properties are limited**, the valuer should expand strata, the period from which sales are drawn, and geo-economically defined areas. However, appropriate adjustments must be made to ensure that proper comparability is achieved.

Rather than relying only on the limited data available for similarly contaminated property, **sales of similar uncontaminated (or unimpaired) property can also be used**. In this way a benchmark, unencumbered value can be established for the subject property, after which adjustments can be made for the contamination. Such adjustments should be based on the cost to cure (properly discounted or amortized), imposed limitations on use, increased insurance and financing costs, and potential liability.

This is the process wherein **joint efforts of valuers and environmental expert** are needed. The contribution of the valuer is to undertake valuation of *impaired* property or *as if unimpaired* but comparable in characteristics whereas the contribution of environmental engineer is to compare the contaminant present and the level of contamination of the comparable contaminated properties identified by the valuer with the subject property proposed to be valued.

The following steps are followed in this method:

<u>Step 1 - Identification of Contaminated Properties</u>

Identify as far as possible contaminated/impaired properties that are comparable. List the similar characteristics which can be considered comparable.

This involves both impaired / unimpaired properties and the contamination level that are comparable to the subject property. This is the investigation which cannot be exercised only by the valuer. Environmental expert reports about the presence of contaminant and the contamination level of comparable properties and the contamination level of subject property.

<u>Step 2 - Analyses and Comparison</u>

In this step, joint efforts are made in collecting necessary information about each such contaminated property and complete information of subject property is recorded.

The next step is to analyse the asset properties and contaminant characteristics. This will provide a scientific platform to analyse the market correctly and compare them with the subject property being valued.

The objective here is to establish the prices by comparable features of properties and contaminant. The comparable features of the properties are those which are considered in estimation of unimpaired value. It may include location, size, age, type of construction, etc. The comparable features of the presence of contaminant include the type of the contaminant(s) or hazardous substance(s) present in the properties being identified to be similar.

Step 3 - Adjustment of prices of comparable properties

In the third step, the differences between the sales of contaminated properties and the subject property are adjusted. The technique to be used is the same as generally used for unimpaired property.

Step 4 - Determination of the value estimate or stigma assessment

This is the final step of arriving at a value estimate**.** After the comparable sales of impaired properties have been carefully analysed and adjusted, the value estimate can be determined by 'adjusted sales'.

5.1.1 ILLUSTRATIONS ON SALES COMPARISON APPROACH

(1) A property has original unimpaired value of Rs.90,00,000/-. The comparable sales of the similar contaminated/impaired property transacted adjacent to such property very recently show that the value is Rs.55,45,000/-. The cost of remediation is found to be Rs.20,00,000/-. Determine the stigma value.

⇨ The sale evidenced from unimpaired property is given. Comparable price of contaminated site is also furnished.

Step 1 - Estimate the property value diminution due to contamination.

- Unimpaired Value : Rs.90,00,000/-
- Impaired Value : Rs.55,45,000/-
- Property Value Diminution : Unimpaired Value – Impaired Value

= Rs.(90,00,000-55,45,000) = Rs.34,55,000

Step 2 - Determine the stigma considering the remediation cost.

- Property Value Diminution : Rs.34,55,000/-
- Cost of Remediation : Rs.20,00,000/-
- Stigma Value : Value Diminution – Remediation Cost

= Rs.(34,55,000 - 20,00,000)

= Rs.14,55,000/-

(2) Determine the stigma value in percentage based on the following data gathered by scientific method.

Sr. no.	Transaction after due adjustments	Amount (Rs.)
1	Sale Price derived from comparable non-contaminated assets	5,00,000/-
2	Sale Price derived from comparable contaminated sites	2,50,000/-
3	Cost of remediation as worked out by environmental consultant	2,00,000/-

⇨ Step 1 - Estimate the Property Value Diminution.

Sr. no.	Transaction after due adjustments	Amount in Rs.
a	Sales from non-contaminated (unimpaired) assets	5,00,000/-
b	Sale price of contaminated (impaired) site	2,50,000/-
c	Property Value Diminution (a – b)	2,50,000/-

Step 2 - Determine the stigma considering the remediation cost.

Sr. no.	Transaction after due adjustments	Amount in Rs.
d	Property Value Diminution	2,50,000/-
e	Remediation Cost	2,00,000/-
f	The amount of stigma (d – e)	50,000/-
g	The value of stigma in percentage (f/a)	10

From the illustration, it will be seen that even after the remediation works are completed, the original value is not regained in the market. The difference of the Property Diminution Value and Remediation Cost is the market imposed penalty which is known as Stigma. Here, the stigma is 10% which is quite low.

(3) Determine the current value of the property having 40 acre land parcel. Value prior to contamination was Rs.22,50,000peracre. Comparable sales of similar size, similarly contaminated properties indicate a value of Rs.4,05,000 per acre. This includes the cost of clean-up which is already capitalized in the sales price of the comparable sales.

Step1 - Determine the as-if unimpaired value of the property.

Thus, the unimpaired value	=	Area x unit rate
	=	40 acres x Rs.22,50,000/acre
	=	Rs.9,00,00,000/-

Step 2 - Determine the value after contamination discovery

Thus, Impaired Value	=	Area x unit rate
	=	40 acre x Rs.4,05,000/acre
	=	Rs.1,62,00,000/-

Step 3- The value after discovery of contamination is itself the current value of the property.

5.1.2 REVIEW YOUR UNDERSTANDING

1. The Sales Comparison Approach involves:
   A. Analysing the sales of contaminated properties
   B. Comparing the sales of subject property
   C. Comparing level of contamination
   D. None of the above
2. In a 'Sales Comparison Approach':
   A. There is no need to hire the services of environmental expert
   B. There is a need to hire the services of environmental expert
   C. Joint efforts of valuers and environmental experts are needed
   D. None of the two are needed
3. Which step is not involved in the Sales Comparison Approach?
   A. Identification of contaminated properties
   B. Analysing and comparing the asset and contaminants characteristics
   C. Preparing a report of environmental contaminants present in the adjacent property.
   D. Adjusting price of comparable properties and determination of value estimate.

4. Which one is the most important connotation to use 'Sales Comparison Approach'?

   A. Sufficient statistics of comparable contaminated assets must exist along with environmental expert's report.
   B. Not only the amount of contamination but the risk associated must be known to be the same.
   C. Manufacturing and process of comparable properties must be identical
   D. The current and future utility of the comparable contaminated properties must be the same.

5. Explain the steps involved in sales comparison approach in detail.
6. Discuss the conditions which must be satisfied to use the sales comparison approach.
7. A property has an original (unimpaired) value of Rs.66 lakhs. The derived sale price from comparable sales of adjacent properties is Rs.45.66 lakhs. The cost of remediation as per environmental expert is Rs.18 lakhs. Determine stigma value.
8. Determine stigma value in percentage when the cost of remediation is found to be Rs.25 lakhs for subject property. Sale price from contaminated sitesisRs.30 lakhs and sale price from non-contaminated assets is Rs.42 lakhs.

9. Determine the current value of the property from following data.

Sr. no.	Description	Rs in Lakhs
1	Value of property with contamination	55.35
2	Comparable sales value inclusive of remediation	38.65

5.2 COST APPROACH

The principle of cost approach is determination of cost of producing a similar property as a replacement, so it is clear that in this approach the valuation must calculate the replacement cost by adjusting the estimates of the remediation cost and diminution in value of the property resulting from market impact due to stigma. The estimation part for stigma is difficult.

The estimate becomes higher if the provable loss is overstated because when the costs are not foreseeable, it is the general tendency of the valuer to be on higher side.

The cost approach is often applicable in cases of environmental contamination, provided the present worth of direct and indirect costs is calculated and used and provided adjustments are made for overestimation or underestimation of costs and impact. The cost approach, however, may ignore the value-in-use concept and thereby overstate the impact of costs to cure contamination problems.

This approach is normally used in all techniques for contaminated property valuation in different form, but to value the properties which are not leased or not within the orbit of sale in open market, the only approach viable in all such cases is the cost approach.

The following steps are followed in this method:

Step1 - Estimating the value of the subject property as if unimpaired

This is the step wherein the cost of substitution is estimated considering the **hypothetical condition** (*contrary to the fact*) that there is no contamination. This is the usual process for a valuer to determine the estimate based on comparative area method, unit in place method, index method or the actual quantity method by considering every physical component, certain specific features and based on their marketability or utility. Here, the current utility must be considered based on the judgment of valuer.

Step2 - Determining the direct and indirect costs due to contamination

Primarily, direct cost in the contamination is cost to cure. It is the clean-up cost required to bring the property to a status of unimpaired in the market. This would therefore also include the stigma factor. Thus in this step, the valuer with the help of environmental expert must determine the following costs:

(a) The cost of remediation

The cost of remediation depends upon many factors viz.

- Type of the property
- Nature of the pollution
- Concentration of each of the contaminants present
- Sequence of the treatment which is most economical and effective for a given situation
- Designing of the treatment system consisting of many components
- The estimated cost of such system or components.

(b) The stigma factor based on 'provable losses'

The provable loss can be calculated by associating the property with utility. It is the period for which the property or part of the property remained in non-use or non-functional stage. This is the duration when the contamination was first noticed to the appointment of environmental consultant who submitted the remediation plans to the owner. The further period of the 'provable loss' is the time it has taken to undertake the remediation- the period till the property value moves up to current market value. Thus the provable loss will take into consideration the following costs:

- Cost of disruption
- Cost of operation
- Cost to utility
- Cost to revenue
- Cost to liability

These 'costs' as a 'provable loss' can be well assessed by the assessors/valuers.

(c) The **specialized costs** which include the additional costs for management of remediation and clean-up.

The specialized costs may include:

- Contamination related legal expenses, that is professional legal fees for dealing with State Pollution Control Board, Government or courts;
- Contamination related insurance expenses- additional insurance during the remediation programme;
- Cost of discovery of contamination like professional fees to consultants;
- Future monitoring cost to avoid recurrence of such contamination, a part t`ime environment engineer for periodic monitoring of the property to take action at the appropriate time before the matter reaches to market;
- Cost to cure functional non-use i.e. obsolescence are then added to accrued depreciation.

Step3 - Estimating the value of contaminated properties considering both the steps 1 and 2

The cost approach is based on the premise that the market value of an improved parcel is equal to the market value of the land plus the current construction costs of the improvement less accrued depreciation.

The cost to cure a problem reduces the utility of property and should be considered a form of functional or economic obsolescence of improvements. This would then be added to the accrued depreciation because current replacement cost new would be based on the assumption of a typical, presumably clean environment.

The cost to cure includes all expenses associated with a cleanup, including the expenses that reduce stigma.

Specialised cost such as contamination-related legal and insurance expenses, above those that would be typical for ordinary operation, must be considered. In addition, provision must be made for the cost of discovery of contamination and future monitoring to watch for recurrence of contamination.

5.2.1 ILLUSTRATIONS ON COST APPROACH

(A) The subject land (25 m x 50 m) is located in the vicinity of secured landfill. The reproduction cost is found to be Rs.4,200/- per m^2.

The cost of contaminant containment (in terms of m^2 basis) is found to be Rs.505/-. Based on the provable loss during the containment, stigma was worked out to Rs.302/-m^2. The accrued depreciation may be ignored. Determine the replacement cost of improved property.

➩ **Market Value**

Reproduction cost of land	=	Area x unit rate
	=	25 m x 50 m x Rs.4200/m^2
	=	Rs.52,50,000/-
Cost of remediation	=	25 m x 50 m x Rs.505/m^2
	=	Rs.6,31,250/- partial
Stigma due to non-use factor	=	25 m x 50 m x Rs.302/m^2
	=	Rs.3,77,500/-
Total Costs due to contamination	=	Rs.(6,31,250 + 3,77,500)
	=	Rs.10,08,750/-
Replacement Cost of improved land	=	Rs.52,50,000 +Rs.10,08,750
	=	Rs.62,58,750/-

(B) Determine the market value if the cost of construction is found diminished on account of discovery of contamination by 35% of its current construction cost. The industrial property worth Rs.20,00,000/- located in Sachin Industrial Estate, Gujarat (India) was constructed in the year 1995. The construction index of 1995 is 1450 and that of current year is 2000.

➩

Step 1

Estimate the current construction cost as if the property is unimpaired

$$= \text{Rs.}20{,}00{,}000 \times \frac{2000}{1450}$$

= Rs.20,00,000 x 1.38

= Rs.27,60,000/-

Step 2

Accrued depreciation	=	Rs.27,60,000 x 0.35
	=	Rs.9,66,000/-

Step 3

Impaired Value = Rs.27,60,000 - Rs.9,66,000

= Rs.17,94,000/-

5.2.2 REVIEWING YOUR UNDERSTANDING

1. Cost Approach involves
   - A. Estimating the value of subject property unimpaired and determination of remediation cost
   - B. Comparing level of contamination
   - C. Comparing sales of contaminated properties
   - D. None of the above
2. What is the principle of Cost Approach for contaminated property valuation?
   - A. Determination of cost of producing similar property as a replacement
   - B. Systematic gathering, recording and analysing data of similarly affected properties and comparing sales of the contaminated property being appraised
   - C. Determination of income which the contaminated property still can derive
   - D. None of the above
3. In the cost approach
   - A. There is no need to hire environmental consultant
   - B. There is a need to hire environmental consultant
   - C. Only valuer is needed
   - D. None of the above
4. Determining direct cost in the contamination in the Cost Approach is
   - A. Cost to cure
   - B. Cost to operation
   - C. Cost to utility
   - D. None of the above
5. The 'specialised costs' in the Cost Approach is
   - A. Additional costs for management of remediation and clean up
   - B. Cost to construct new facilities
   - C. Cost to operation
   - D. None of the above

6. What is the 'Provable Loss' as applied in Cost Approach of valuation of contaminated property? Explain the term in detail.

7. Discuss the steps involved in cost approach for contaminated property valuation.

8. The subject property is located near the biomedical waste incinerator site. Determine the market value of land from the following data.

Cost of land	=	Rs.62.50 lakhs
Cost of remediation	=	Rs.12.80 lakhs
Stigma due to non-use factor	=	Rs.8.40 lakhs

9. The current construction cost of the property as if unimpaired is Rs.50 lakhs. The construction cost of contaminated property is Rs.16.50 lakhs. Determine the market value of the property.

5.3 INCOME APPROACH

The income approach estimates property value by determining the present value of the projected typical income stream for the type of property. Income-producing properties are the most common property type influenced by environmental regulations and subject to contamination. Often the greatest and most easily measured effect is on the ability of the property to continue to generate income. For this reason, the income approach is often the most suitable approach for contaminated properties.

The income approach is also effective in dealing with the situation that occurs when even the present worth of the cost to cure a problem far exceeds the replacement cost of property. There is a value-in-use to the owner even where no other market exists so long as the owner continues to operate the facility. Value-in-use may be impaired by temporary closure or loss of customers, and therefore some adjustments in income stream and income-determined value is likely.

The basic principle involved in this approach is to estimate the impact of the contaminant on the value. This is determined based on the reduced ability of a subject property to generate the income. Income approach estimates reasonable estimate of value because in this process, the present value of the property is derived by measuring actual income against income typical for properties of the same type.

The logic behind this principle is the relation of property usefulness / utility and the income generated from it. Contaminated property by definition itself has diminished utility and therefore the income generated is reduced.

Following steps are followed in this technique.

<u>Step1 - Estimating the annual gross income stream by obtaining market rental data</u>

Use of market rental data assumes that the property has utility (is still in use or will be shortly) and is capable of commanding rent. When these conditions are met, market rental data forms an important source for establishing the "base capitalization rate". The income stream however is required to be modified to account for the cost to cure the contamination problem and any loss of utility.

- Modification should be based on the amortised present worth of actual costs, recognising that permissible alternatives may limit costs to those necessary to satisfy the regulatory agency, not necessarily the full cost to cure the problem.
- Further, income modification may be necessary to account for more expensive substitute processes or materials that can no longer be manufactured on site. Adjustments to reflect temporary closure or loss of customers must also be considered.

The primary objective of income capitalization is translating incomes into value. The data of gross income of the contaminated property may help the valuer in selecting capitalization rate that reflect the real estate investment market in its true sense. The overall capitalization of rate of contaminated properties from market sales can be determined by using the ratio of net income to selling price.

The income stream however is diminishing provided immediate actions are taken to remediate it. In other words, the income stream requires to be altered by considering two aspects i.e. Cost to cure and the loss of utility of the property. The cost to cure should be based on the amortized present worth of the actual costs.

To determine the annual gross rental and arrive at the appropriate capitalization rate, the valuer must keep the database of contaminated and remediated properties containing data like the type of the real estate, contamination, costs, market history and capitalization rate in consideration while determining value.

Step2 - Obtaining income or allowable expenses related to contamination

The allowable expenses which must be subtracted from the gross income are the expenses incurred to remove the specific contaminant and includes amortized present worth of the cost to cure. Cost to cure as usual includes the disruption cost as there is a partial loss of income due to its partial non-use.

Cost to discovery of contamination including professional fees paid to the environmental expert is an allowable expense.

Legal expenses for handling litigation on account of contamination and monitoring expenses are allowable expenses. Ongoing monitoring is often expensive and inflation will often increase costs which are often incurred over lengthy periods. Any money spent for improving operation may also be a part of allowable expense. Other unforeseen expenses may be disclosed during the clean-up operation and can also be considered a part of the allowable expenses. Ongoing monitoring and inflation will increase the cost with respect to time. These aspects must be considered in developing modified income streams.

In summary, all the expenses associated with removal of contaminant which are actual, current or reliably anticipated must be recorded. It must be remembered that the expenses documented must be provable. Expenses to be used should be based on current cleanup mandates and not the ones that are invoked only upon sale of property or change in use Subtracting allowable expenses from gross income gives effective gross income or net income.

Step3 - Determination of the Value of contaminated property using Capitalization Rate

Capitalization is the process of converting net income of a property into its equivalent capital value. Capitalization process reflects the time value of money by reducing or discounting future income to present worth by the Year's Purchase concept.

$$Y = V*R$$

where,

Y = Yield

V = Value of the property

R = Rate of return

As such, capitalization rate in the income approach is such a rate of return that directly or indirectly provides for return on investment (interest) and return of investment (capital recovery).

The capitalized rate is based on the equity yield rate, mortgage terms and anticipated appreciation or depreciation. In many cases of contaminated properties, mortgages may be unobtainable and future appreciation is applicable. Contaminated properties also suffer from lack of appeal due to possible future clean up requirement and public liability exposure. This leaves the equity yield rate as the major component of capitalization rate.

In developing this rate, the presumption must be that the property is still capable of producing income. Adjusted rates may be developed for property not currently producing income but expected to do so at a predictable level at a predictable time in future. The capitalization rate must reflect the difference between comparable contaminated and uncontaminated properties. Capitalisation rate may be increased to reflect added risk.

- **Financing (unusual term)**

  Financing is known to affect property value. The impact is particularly significant when favourable or unfavourable financing is obtained because the market has already accepted the influence of typical financing costs.

  In the case of environmentally contaminated properties, two types of financing effects need to be considered:

  (i) the ability of a prospective buyer to finance the purchase of the property; and

  (ii) the terms for financing the actual costs to cure contamination problems.

  If prospective buyers cannot obtain typical financing due to the problem, the cash equivalency value of the property will be diminished. If terms for financing the costs to cure problems are poor, additional liability or unfavourable debt will reduce buyer income anticipation and thereby reduce market value.

  Demand for alternative uses particularly those compatible with contaminated site will result in sale. Financing may facilitate a sale but will require adjustment in any sales analysis. Income generation is predicted based on the report of environmental expert as to the date of completion of the remediation project. When the market comes to know that remediation is in process, perception starts improving and the stigma effect begins to diminish.

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5.3.1 ILLUSTRATIONS ON INCOME APPROACH

(A) Kamal had rented his property at Rs.30,000/- per annum net of outgoings. The yield upto last year was found to be 10%. Subsequent to the complaint made by the tenant, the discovery of the contaminant was made and the yield was found to be 12%. Determine the value of contaminated property.

⇨

Step 1

Determine the value of the unimpaired property

Net Income (NI) = Rs.30,000 per annum

Unimpaired Value = NI x YP

= Rs.30,000 x $\frac{100}{10}$

= Rs.3,00,000/- (1)

Step 2

Determine the value of the impaired property as found in the current year

Net income = Rs.30,000/- per annum

Impaired Value of property = NI x $YP_{impaired}$

= Rs.30,000 x $\frac{100}{12}$

= Rs.2,50,000/- (2)

Step 3

Determine the loss in value of contaminated property or Property Value Diminution

= (1) - (2)

= Rs.3,00,000 – Rs.2,50,000

= Rs.50,000/-

(B) The effective gross income of the industrial property contaminated due to chromium fumes is Rs.88,25,540/-. The annual expenses towards the cost to cure and other legal and disruption expenses are Rs.38,78,200. From similar contaminated property, it indicates that 9% rate of return is appropriate. Find the value estimate of the property.

⇨

Effective gross income	=	Rs.88,25,540/-
Annual expenses	=	Rs.38,78,200/-
Net income	=	Rs.88,25,540 – Rs.38,78,200
	=	Rs.49,47,340/-

Capitalization rate is 9% or 0.09

Thus, Impaired Value $= \frac{Net\ income}{Capitalization\ rate}$

$= Rs. \frac{49,47,340}{0.09}$

= Rs.5,49,70,444/-

(C) An industrial property is leased at rent of Rs.220/- per sq. ft and has an annual net operating income of Rs.55,00,000/-. The said property is found to be partially contaminated. The loss of the useful space will reduce the net operating income to Rs.42,50,000/- during the clean-up operations which may be completed within one year.

The remediation contract is given on turnkey basis to M/s. Enviro Group who will be paid for in 5 equal instalments of Rs.12,50,000/- every year over five years.

The yearly payment of instalment is proposed to be made from the net operating income. The rents are expected to be absolutely market based and market-derived discount rate is 12%.

⇨

	Year 1	Year 2	Year 3	Year 4	Year 5
Net Income (Rs.)	30,00,000	30,00,000	30,00,000	30,00,000	30,00,000
Present Value Factor	0.892857	0.797194	0.71178	0.635518	0.567427
Present Value of Income (Rs.)	26,78,571	23,91,582	21,35,340	19,06,554	17,02,281

Term Value = Rs.(26,78,571 + 23,91,582 + 21,35,340 + 19,06,554 + 17,02,281)

= Rs.1,08,14,328/-

Residual (or Reversionary) Value = Terminal Income x $YP_{perpetuity}$ x PV factor

$$= Rs.55,00,000 \times \frac{100}{12} \times \frac{1}{(1 + 0.12)^5}$$

= Rs.2,60,05,833/-

Value of Lessor's Interest = Term Value + Residual value

= Rs.(1,08,14,328 + 2,60,05,833)

= Rs.3,68,20,161/-

(D) The net income of the contaminated property is Rs.32,28,540/-. The market derived overall capitalization rate for this property is 11%. The income of a similar uncontaminated property is Rs.55,14,775/-. Determine the loss in value.

⇨

- Contaminated property net income = Rs.32,28,540/-

  Hence, Impaired Value $= \frac{Income}{Capitalization\ rate}$

  $= \frac{32{,}28{,}540}{0.11}$

  = Rs.2,93,50,364/-

- Uncontaminated property net income = Rs.55,14,775/-

  Hence, Unimpaired Value $= \frac{55{,}14{,}775}{0.11}$

  = Rs.5,01,34,318/-

- Property Value Diminution = Unimpaired Value – Impaired Value
  = Rs.(5,01,34,318 - 2,93,50,364)
  = Rs.2,07,83,954/-

Thus, Rs.2,07,83,954/- represents the indicated loss in value due to contamination and required clean up.

(E) Find percent reduction in value from following data.

1) The value of the non-contaminated property by comparison approach – Rs.15,00,000
2) Effective contamination control and management measures – Rs.75,000
3) Regular monitoring of the site – Rs.10,000
4) Clean up of onsite contamination – Rs.3,50,000
5) Indemnity insurance for the future – Rs.10,000
6) Control of migration from other sites – Rs.15,000
7) Present value of Re.1 after 20 years @ 7.5% - 0.235
8) Anticipated economic life of building, years - 20
9) Avoidance of origination of contamination of adjacent sites – Rs.1,00,000

⇨

Total Cost of Remediation = (75,000 + 10,000 + 3,50,000 + 10,000 + 15,000 + 1,00,000)
= Rs.5,60,000 incurred at the end of 20^{th} year

Present value of treatment = Total Cost x PV factor for 20 years
= Rs.5,60,000 x 0.235
= Rs.1,31,600/-

Adjusted Value (excluding Stigma Allowance) = Rs.15,00,000 – Rs.1,31,600
= Rs.13,68,400/-

i.e. 13,68,400 / 15,00,000 or 91.27%

% Reduction in Value = (100 - 91.27)%
= 8.73%

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5.3.2 REVIEW YOUR UNDERSTANDING

1. Contaminated property receive reduced income because
   - A. It has diminished utility
   - B. property is off the market
   - C. It has lost the reputation
   - D. None of the above
2. Base capitalization rate can be established based on
   - A. Market rental data
   - B. Real estate market current rate
   - C. Remediation cost
   - D. None of the above
3. The allowable expenses which must be subtracted from the gross income
   - A. Is expense involved to remove the specific contaminant
   - B. Are expenses involved to remove the specific contaminant and amortized present worth of the cost to cure
   - C. Is the amortized present worth of the cost to cure
   - D. None of the above
4. Which one is not allowable expense in income approach of valuation?
   - A. Cost to cure
   - B. Disruption cost
   - C. Cost of discovery of contaminant and legal expenses
   - D. Cost of maintenance
5. Explain the process of income approach with each step in detail.
6. Shweta rented the property at Rs.6000/- per month. The yield upto last year was found to be 12%. Subsequent to the complaint made by the tenant and the contaminant cadmium in excess concentration was discovered, the yield was found to be 14%. Determine the value of contaminated property.
7. The net income of the contaminated asset is Rs.55 lakhs and the market derived overall capitalization rate is 11%. The income of a similar unimpaired property is Rs.75 lakhs. Determine the loss in value.
8. Find reduction in value from following data of contaminated property.
   - (a) Value of non-contaminated property by comparison approach – Rs.22 lakhs

(b) Effective contamination control –
Rs.1.0
0 lakh
(c) Regular monitoring of site –
Rs.0.5
0 lakh
(d) Cleanup cost –
Rs.4.0
0 lakh
(e) Insurance –
Rs.0.2
0 lakh
(f) Control of migration from other sites –
Rs.0.3
0 lakh
(g) Present value of Re.1 for 20 years @ 7.5% –
Rs.0.2
35 lakh
(h) Anticipated economic life of building –
25
years
(i) Avoidance of origination of contamination of adjacent sites –
Rs.1
lakh

9. Determine the value estimate of property from the following data

- Effective gross income Rs.80 lakhs
- Annual cost to cure, legal & disruption expenses Rs.32 lakhs
- Rate of return from similar contaminated property 9%

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PROFESSIONAL ETHICS AND STANDARDS

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Chairman, CVSRTA

Model Code of Conduct as notified by MCA under the Companies (Registered valuers and valuation) Rules 2017 and Other Engagement Considerations

1. Integrity and Fairness:

- A valuer should, in the conduct of his/its business, follow high standards of integrity and fairness in all his/its dealings with his/its clients and other valuers.
- A valuer should maintain integrity by being honest, straightforward, and forthright in all professional relationships.
- A valuer should endeavour to ensure that he/it provides true and adequate information and shall not misrepresent any facts or situations.
- A valuer should refrain from being involved in any action that would bring disruption to the profession.
- A Valuer shall keep public interest foremost while delivering his services.

2. Professional Competence and Due Care:

- A valuer should always render high standards of service, exercise due diligence, ensure proper care and exercise independent professional judgment.
- A valuer should carry out professional services in accordance with the relevant technical and professional standards that may be specified from time to time.
- A valuer should continuously maintain professional knowledge and skill to provide competent professional service based on up-to-date developments in practice, prevailing regulations/guidelines and techniques.
- In the preparation of a valuation report, the valuer should not disclaim liability for his/its expertise or deny his/its duty of care, except to the extent that the assumptions are statements of fact provided by the company and not generated by the valuer.

A valuer should have a duty to carry out with care and skill, the instructions of the client insofar as they are compatible with the requirements of integrity, objectivity and independence.

- A Valuer should clearly state to his client the services that he would be competent to provide and the services for which he would be relying on other valuers or professionals or for which the client can have a separate arrangement with other valuer/ professional.

- A professional valuer should take reasonable steps to ensure that those working under the professional valuer's authority in a professional capacity have appropriate training and supervision.
- If a professional valuer does not have the professional knowledge and necessary experience to competently undertake a valuation assignment that is offered, the professional valuer should decline that assignment.

3. Independence and Disclosure of Interest:

- A valuer should act with objectivity in his/its professional dealings by ensuring that his/its decisions are made without the presence of any bias, conflict of interest, coercion, or undue influence of any party, whether directly connected to the valuation assignment or not.
- A valuer should not take up an assignment under the Act/Rules if he/it or any of his/its relatives or associates is not independent in relation to the company and assets being valued.
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- A valuer should not indulge in "mandate snatching" or "convenience valuations" in order to cater to the company's needs or client needs. A valuer should communicate in writing with a prior valuer if there is knowledge of any prior valuer having been appointed before accepting the assignment.
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- A valuer should appear, co-operate and be available for inspections and investigations carried out by the Registration Authority, any person authorised by the Registration Authority, the Valuation Professional Organisation with which he/it is registered or any other statutory regulatory body.
- A valuer should provide all information and records as may be required by the Registration Authority, the Tribunal, Appellate Tribunal, the Valuation Professional Organisation with which he/it is registered, or any other statutory regulatory body.
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- A valuer, or his/its relative should not accept gifts or hospitality which undermines or affects his independence as a valuer.
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- A valuer should not conduct business which in the opinion of the Registration Authority or the registered valuer organisation is inconsistent with the reputation of the profession.

VALUATION OF PLANT AND MACHINERY

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Please refer to the following literature:

(a) Valuation of plant and machinery (Theory & Practice) 2017 3rd Edition
(b) Valuing machinery & equipment, the fundamentals of appraising machinery & technical assets -3rd Edition by American Society of Appraisers

for

the following topics of the syllabus of this subject

- Role, functions and responsibilities of a plant and machinery valuer
- Cost, price, value and valuation;
- Types of Market, Demand and Supply curve, Bell curve for overall sales performance (Probability Distribution)
- Annuities – capitalization – rate of capitalization – years purchase -- sinking fund – Redemption of capital – Reversionary Value

Definitions of the various terms:

(a) Plant and machinery, furniture, fixtures and fittings – the judicial interpretation of these terms (b) Market value, Highest and best use value

Meaning of the terms:

Basis of Valuation. Value in use, value in exchange, value to the buyer, value to the seller, value to the occupier, value in existing use in situ, value in existing use in ex-situ, value in alternative use in situ, value in alternative use in ex-situ, liquidation value in situ/ex situ, orderly liquidation value, forced sale value.

- Investment property, marketable non-investment property, non-marketable -non-investment property with their characteristics and approaches to value.
- Factors having direct bearing on value (valuation maxims) like: physical, legal, social,economic,utility,marketability,transferability,scarcity,present worth of future benefits and intangible rights
- **Identification of plant and machinery/Physical verification of plant and machinery**

- Inventory (listing of machinery) and data to be collected while taking inventory
- Importance of Technical specifications of plant and machinery in valuation exercise
- Assessment of Condition of PME based on visual inspection
- Comparing inventory with plant and machinery records maintained by the company
- Ascertaining discrepancy
- Identification of productive, non-productive, surplus and off-balance sheet assets

- Age, effective age, total economic life, economic balance life, physical life and their importance in valuation.
- Factors affecting life both in terms of years or hours used based on type of assets, sources of economic useful life, study of maintenance schedules of plant.
- Difference between historical cost, acquisition cost, book cost, written down value and net book value.
- The items of building to be treated as plant and machinery-like chimneys to the boiler, brick, concrete or RCC foundation for plant and machinery, water and sewerage installations, effluent treatment plant etc.
- Installed capacity of the plant, actual production, raw material availability, level of technology used such as current or obsolete, issues if any regards to these.
- Part, fraction and whole valuation
- Relationship of Earnings and Assets
- Difference between business specific economic viability and economic obsolescence.
- Efficiency of plant layout, imbalances in different production sections and their relevance in valuation

Three approaches to value – cost, market and income

Cost approach

- Reproduction cost new, replacement cost new, depreciated reproduction cost/ depreciated replacement cost (DRC), Difference and similarity in DRC and market value
- Difference between Reproduction cost new and replacement cost new
- Methods of computation of reproduction cost new
  - Market inquiry of current cost of brand new machine with identical specifications from same manufacturer i.e replica
  - Indexation and its limitations
  - Cost to capacity method and its limitation
- Methods of computation of replacement cost new when identical machine/plant is not available i.e. machine/plant of like kind and type-factors to be taken into consideration
- Direct and indirect costs for estimation of Reproduction new /Replacement cost new
- Meaning of the term depreciation for wear and tear. Factors influencing depreciation-its measurements and application by valuers of plant and machinery. Concept of salvage value and scrap value along with the basis of the same.
- Methods of depreciation – observed deterioration, straight line, diminishing balance (WDV),
- Difference between accounting and technical depreciation
- Factors to be taken into consideration for selection of depreciation method

- Obsolescence-technological, functional and economic
- DRC subject to potential profitability
- Limitations of cost approach.

Market Approach-Sales comparison method

- Data collection
- Elements of comparability and application of appropriate weightages to identified comparable to estimate value of subject plant and machinery asset being valued. Instances when sales comparison method is not feasible and limitations of sales comparison method.

Income Approach

- The concept of income approach
- Gross income-outgoings, net income and year's purchase
- Actual income Vs Potential income
- Terminal income
- Remunerative and accumulative rates of interest and various methods of determining the same
- Capitalization of earnings method
- Discounted future earnings method (DCF Technique)
- Pitfalls of DCF technique

Process of Valuation

Check List for Valuation of Plant and Machinery, documents to be studied prior to Plant Visit/Inspection, ABC analysis
The items to be treated as plant and machinery
The items to be treated as land and buildings
Physical verification (survey and inspection)
Data collection and valuation analysis under replacement cost new method (cost approach)

Broad categories of machines to be encountered by plant and machinery valuers in actual practice -

Valuation of a machine for which current cost of identical brand new machine is available

Valuation of a machine for which current cost of identical brand new machine is not available

Valuation of a machine which is no longer manufactured

- The reasons for the differences in the prices of the machines with same technical specifications and features by different manufacturers
- The factors to be considered while adopting cost approach.
- Data collection and valuation analysis under -Cost, market and income approaches

Leasing of plant and machinery

- Definition of Lease
- Leasing, hiring and renting
- Obligations of supplier of asset, user of asset, hire purchase company/lessor in cases of loan, supplier's credit, hire purchase and leasing
- Leasing as an instance of bailment, nature of the bailment agreement, features of bailment, contracts law on bailment
- Leasing rules
- Types of leases and their characteristics
- Steps in the structuring of a lease contract
- Leasing from point of view of lessor/Lessee
- Limitations of leasing
- The structure of a lease agreement
- Treatment of leased assets in company accounts – accounting practice for leased plant and machinery as per Indian Accounting Standard
- Assessment of lease related risk
- Risk and Return trade-off

- Valuation of leased plant and machinery
- Valuation of plant and machinery for following purposes:
  - Mergers and acquisitions (including purchase price allocation)
  - Financial statements
  - Impairment
  - Auction
  - Insurance
  - Leasing
  - Disposal
  - Capital raising
  - Corporatization and privatization
  - Stamp duty
  - Any other purpose not referred above

Case laws

- Fixture - Holland Vs. Hodgson (1872) L.R.7C.P.328 AT 335
- Plant and Machinery in nature of land and buildings - Duncan's case - AIR 2000 SC 355
- Obsolescence – Westingshouse Electric Corporation US 1993 NCApp.710.379S.E.2D 37(1989)
- Just because a Plant and Machinery are fixed in the earth for better functioning it does not automatically become an immovable property - Sirpur Paper Mills Pvt. Ltd Vs. The Collector of Central Excise 1998(1) SCC 400
- Plant and Machinery in nature of land and buildings - Official Liquidator Vs. Sri Krishna Deo and Ors. (AIR 1959 All 247)

Valuation of specialized plant and machinery by Cost approach is subject to potential profitability - Symex Holdings Ltd. Vs. Commissioner of State Revenue, Victoria, Australia (2007 VSC 159)

The study material for the balance topics is given as under hereinafter from page no. 2:

(i) Construction and use of valuation tables by Rashmi K. Gandhi

(ii) The Depreciation under Income Tax Act, 1961 as well as Companies Act 2013, Useful lives to compute depreciation as per Schedule II of Companies Act,2013, Factors to be considered for componentization of Assets

(iii) Machine tools by Hemant Vasavada

(iv) Factory Equipment by Sanjay Shah given in this section later.

(v) Utility Equipment used as engineering services in an Industry by Hemant Vasavada.

(vi) Impact of Indian accounting standards, International Valuation Standards and Standards to be published by Ministry of Corporate Affairs, GOI on valuation of plant and machinery.

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Kirit P. Budhbhatti

Chairman, CVSRTA

I. Construction and use of valuation tables

Valuation of an asset is principally an economic decision and hence all parameters which affect this decision have to be thoroughly understood and evaluated by a valuer. Interest rates prevalent in the market at the time of relevant date of valuation is one such parameter. Similarly yield or return expected by an investor on his capital investment in an asset is also equally important aspect for consideration by a valuer because value of any asset yielding monthly or yearly income depends on the rate of interest on investment expected by an investor.

A Valuer is also concerned in his working about the present worth of a rupee receivable at some future date. If an investor buys from a Lessor a leased-out asset which will revert back to the lessor at some future date, say after 20 years, a valuer must know how to evaluate present worth of said asset revertible after 20 years. It is therefore clear that a valuer must thoroughly learn and understand mathematical working process of compound interest tables and formulae to estimate value under different circumstances.

In this section we shall discuss and study various formulae and their applications to arrive at the value of a rupee/ rupee per annum receivable in future / during specified period. In other words, we can say that the study of these tables will enable a valuer to ascertain monetary evaluation of the asset.

Working process and formulae given herein after would enable a valuer to work out required rupee value under different circumstances. However ready made valuation tables are also available giving such values for different periods at different rates of interests. Valuation Tables prepared by Shri. A.E. Mirams, a prominent valuer of the past, are well known and these tables are very useful as it saves lot of time of a valuer in working out actual figures from fundamentals. Some books on valuation also gives these ready valuation tables. However, if such tables are not readily available, required figures can be worked out from basics viz. by use of respective formulae discussed below. Construction of new Valuation Tables for higher or lower interest rates is possible with the help of these formulae.

1.0 Simple Interest Amount Working : If we want to work out gross amount that would accrue at the end of given period of time, on the principal sum, at the given rate of simple interest, the said amount can be worked out by application of following formula worked out from fundamental concepts of interest yields.

(i) $I = P \times R \times N$

(ii) $A = P + I$

Where,

'I' is the total interest amount accrued in given period.

'P' is the principle amount deposited.

'R' is the rate of interest adopted.

'N' is the period in number of years.

'A' is the Gross Amount including principal sum and total interest.

By use of above formula, we can work out Gross Amount that would accrue after specified period of time at specified rate of simple interest.

1.1 Example – 1 :

A person deposits sum of Rs.5,000/- at 4% simple interest rate, for 5 years period. Calculate Gross Amount receivable after 5 years period including total interest amount at simple interest basis.

Solution :

$I = P \times R \times N$

$= 5000 \times 4/100 \times 5$

$=$ Rs.1000

$A = P + I$

$= 5000 + 1000$

Gross Amount 'A' = Rs.6,000/- (Receivable after 5 years)

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2.0 Compound Interest Amount Working : Gross amount that would accrue at compound interest rate, after a given period of time, can be worked out from following formula. (Also refer to the Table No.7 of Miram's Valuation Tables.)

(i) Total Interest Amount (I) = $(1 + R)^n$

(ii) Gross Amount (A) = $P \times (1 + R)^n$

Where,

'R' = Rate of compound interest.

'n' = number of years.

'P' = Principal Amount,

'A' = Gross Amount receivable at end of given period.

2.1 Example – 2 :

A person deposits Rs.5,000/- in Bank at 4% compound interest rate for 5 years period. Calculate gross amount receivable after 5 years period including total interest amount on compound interest basis.

Solution :

$$
\begin{aligned}
A &= P \times (1 + R)^n \\
&= 5{,}000 \times (1 + 4/100)^5 \\
&= 5{,}000 \times (1.04)^5 \\
&= 5{,}000 \times 1.216 \\
&= \text{Rs. } 6{,}080/-
\end{aligned}
$$

It will be seen that investor gets Rs.80/- extra after 5 years if interest is worked out not on simple interest basis but on compound interest basis.

If you see Mirams Table No.7 compound interest computation 'I' is readily worked out and given. In 5 years period line in 4% rate column, said table 7 shows 'I' value at 1.217 almost same as 1.216 value worked out in this example.

2.2 Example – 3 :

An investor purchased, a machine for Rs.200,000/- and spent Rs.25,000/- on erection, installation and bringing the machine to operation. However, he could only start commercial production after 3 years. Calculate value of the Amount that is blocked up in investment, after 3 years period, on the basis of purchase price and other expenses, by considering 7% compound rate of interest.

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Solution : Principal Sum (P) = 200,000 + 25,000 = Rs.2,25,000

R = 7% and N = 3 years

Invested amount (A) after 3 years = 225,000 x $(1 + 7/100)^3$

= 225,000 x $(1.07)^3$

= 225,000 x 1.225

= Rs. 275,625/-

3.0 Present Value of a Rupee : (Refer Table 2 in Mirams Val. Tables) :

Working out present worth of a Rupee receivable after certain period at given rate of compound interest is the reverse mathematical process of the working given in above para 2.0.

Following formula will give present worth of a Rupee and present worth of capital sum receivable at future date.

(i) Present value of a Rupee (PV) $= \frac{1}{(1+R)^n}$

(ii) Present worth of amount receivable (PVA) $= C \times \frac{1}{(1+R)^n}$

Where,

'C' = Capital sum Receivable at future date.

'R' = Rate of interest

'n' = number of years.

This process of working out present reduced amount receivable at some future date, is also known as deferring or discounting of receivable sum at given rate of interest for a given period.

3.1 Example – 4 :

A Lessor will receive back machinery worth Rs.20,00,000/- after 10 years. Calculate its present worth by adopting 6% rate of interest.

Solution : Capital Amount Receivable (C) = Rs.20,00,000/-

R = 6% N = 10 years

Present worth of Receivable Amount (PVA)

$$= C \times \frac{1}{(1+R)^n}$$

$$= 20{,}00{,}000 \times \frac{1}{(1 + 6/100)^{10}}$$

$$= 20{,}00{,}000 \times \frac{1}{(1.06)^{10}}$$

= 20,00,000 x 1/1.79

= 20,00,000 x 0.558

= Rs.11,16,000/-

Note :- If you refer to Mirams Table-2, you will find present Rupee value at 0.5584 in 6% rate column at 10 years period row (line).

3.2 Example – 5 :

What is the present value of the reversion of machinery let for 15 years period. Assume that the value of the machinery at the end of 15 years will be Rs.800,000/- and rate of interest expected is 6%.

Solution : In this example C = 800,000, R = 6% and n = 15 years

$$\therefore PVA = 800,000 \times \frac{1}{(1+0.06)^{15}}$$

$$= 800,000 \times \frac{1}{2.397}$$

$$= 800,000 \times 0.417$$

= Rs.333,600/-

3.3 Example – 6 :

Find out present amount payable for an instrument which guarantees payment of capital sum of Rs.80,000/- after 5 years. Adopt 7% rate of interest.

Solution : Present Value Amount $= C \times \frac{1}{(1+R)^n}$

$$= 80,000 \times \frac{1}{(1+0.07)^5}$$

$$= 80,000 \times \frac{1}{1.402}$$

$$= 80,000 \times 0.713$$

= Rs.57,040/-

3.4 Example – 7 :

What is the present value of the right to receive following sums of money, at 6% interest rate, at 5 years intervals as given below.

(i) After 5 years Rs.10,000

(ii) After 10 years Rs.30,000

(iii) After 15 years Rs.50,000

Solution : It will be necessary to compute present value in 3 parts as under :-

(i) Present value of Rs.10,000 $= C \times \frac{1}{(1+R)^n}$

$= 10,000 \times \frac{1}{(1+.06)^5}$

$= 10,000 \times 0.7472$

= Rs.7,472/- ...(a)

(ii) Present value of Rs.30,000 $= 30,000 \times \frac{1}{(1+.06)^{10}}$

$= 30,000 \times 0.5584$

= Rs.16,752/- ...(b)

(iii) Present value of Rs.50,000 $= 50,000 \times \frac{1}{(1+.06)^{15}}$

$= 50,000 \times 0.4173$

= Rs.20,865/- ...(c)

(iv) Present value of right to receive sums in 3 stages at 5 years interval .

= (a) + (b) + (c)

= Rs.7,472/- + Rs.16,752/- + Rs.20,865/- = Rs.45,089/-

4.0 Amount of Re.1/Annum working:

(refer Table 6 in Mirams Valuation Table.)

Many a times valuer is required to work out Gross Amount that would accumulate after the given period of time, at the given rate of interest, on the fixed sum receivable every year. Such accumulated sum is worked out by use of following formula.

(i) Accumulated sum for Re.1/year (APA) $= \dfrac{(1+R)^n - 1}{R}$

(ii) Gross Accumulated Sum $= C \times \dfrac{(1+R)^n - 1}{R}$

'R' = Rate of Interest.

'n' = number of years.

'C' = Capital Amount received/Year.

4.1 Example – 8 :

A person saved Rs.1000/- each year and invested this yearly saving each year at 8% interest for 25 years period. What will be gross capital yield at the end of 25 years?

Solution : APA $= \dfrac{(1+R)^n - 1}{R}$

$$= \frac{(1+0.08)^{25} - 1}{0.08}$$

$$= \frac{6.85 - 1}{0.08} = 73.106$$

Gross Capital Sum = C x APA = 1000 x 73.106

= Rs.73,106/-

4.2 Example – 9 :

From the salary of an employee, Rs.500/month is deducted and said sum is invested in provident fund scheme annually at 7% interest. Calculate gross provident fund amount accumulated under the scheme after 20 years service. There are no withdrawals from the fund during this period.

Solution :

$$APA = \frac{(1+0.07)^{20} - 1}{0.07}$$

$$= \frac{3.869 - 1}{0.07} = 40.995$$

Gross P.F. Amount (after 20 yrs) = C x APA = 500 x 12 x 40.995

= Rs.245,970/-

5.0 Annual Sinking Fund Working :

(Refer Table-5 of Mirams Valuation Table)

In order to find out depreciated worth of an old existing building, a valuer has to consider Sinking Fund amount that has to be set aside annually by a building owner, at given rate of interest, for the period which is equal to past age of the building. The working of this amount is the reverse process to that adopted (Vide para 4.0 above) for finding out worth of known annual payment after given period of time at given rate of interest. In present working, we have to find out annual payment that is required to be set aside each year in order to receive Re.1 at the end of given period, at given rate of interest. Gross Sinking Fund (G.S.F.) can be worked out from following formula.

(i) ASF $= \frac{R}{(1+R)^n - 1}$

(ii) Gross S.F. $= C \times \frac{R}{(1+R)^n - 1}$

Where,

ASF = Annual Sinking Fund amount to be set aside each year for recouping Re.1 at end of given period, at given interest rate.

'R' = Rate of interest

'N' = Number of years.

'C' = Total capital recoupment expected.

'GSF' = Gross Sinking Fund.

5.1 Example – 10 :

Find out Gross Sinking Fund required to be set aside every year to recoup total capital sum of Rs.400,000/- at the end of 60 years life of building at 4% rate of compound interest.

Solution :

$$ASF = \frac{R}{(1+R)^n - 1}$$

$$= \frac{0.04}{(1+0.04)^{60} - 1}$$

$$= \frac{0.04}{10.519 - 1}$$

$$= \frac{0.04}{9.519} = 0.0042$$

Gross Sinking Fund (GSF) = C x ASF

= 400,000 x 0.0042 = Rs.1680/Year

If you apply the formula given in previous para 4.0, using 1680/year as annual saving ,you will notice that this sum of Rs.1680/- per year accumulates to the gross capital sum of Rs.400,000/- at 4% rate of interest after 60 years period.

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5.2 Example – 11 :

An individual has to repay loan amount of Rs.40,000/- after 20 years. What amount should be set aside every year to enable it to repay loan amount with 4% interest ?

Solution :

$$ASF = \frac{R}{(1+R)^n - 1} = \frac{0.04}{(1+0.04)^{20} - 1}$$

$$= \frac{0.04}{2.19 - 1} = \frac{0.04}{1.19}$$

$$= 0.0336$$

$$GSF = C \times ASF$$

$$= 40{,}000 \times 0.0336 = \text{Rs. } 1344/\text{Year.}$$

6.0 Present value of an amount of Re.1/year (Single rate basis) :

(Refer Years Purchase Table-1 in Mirams Valuation Table)

Present worth of future annual income flow, for given period of time, at given single rate of interest compounded could give us present market worth of the asset generating such income. Hence this Y.P. working is very useful to valuers. The income flow is normally a perpetual income for immovable property..

Such single rate of interest being remuneration for capital invested is known as "Remunerative Interest"

As only remunerative rate of interest is considered for the perpetual income in this working, it is known as single rate working. The technique of arriving at years purchase for Re.1 is very simple. We have to separately work out present value of Re.1 receivable after 1st year, P.V. of Re.1 receivable after 2nd year and so on up to Re.1 receivable after given number of years and total up all these sums. This will give us Y.P. value for Re.1/year after given number of years. The formula for working out Years Purchase and value of asset are as under :-

(i) Present value of Re.1/year (Y.P.) = $\dfrac{1 - \dfrac{1}{(1+R)^n}}{R}$

(ii) Value of asset = C x Y.P.

Where,

‘R’ = Rate of interest.

Y.P. = Years Purchase

‘n’ = numbers of years.

‘C’ = Capital income (Annuity) received each year.

6.1 Example – 13 :

A residential house yields net rental income (Annuity) of Rs.3000/- per year. If this income ceases after 80 years (Future life of building), what is present value of this property at 7% rate of interest. (Income receivable for 80 years is as good as perpetual income & hence Single Rate)

Solution : Y P. $= \dfrac{1 - \dfrac{1}{(1+R)^n}}{R}$

$= \dfrac{1 - \dfrac{1}{(1+0.07)^{80}}}{0.07}$

$= \dfrac{1-0.004459}{0.07} = 14.222$

Present value of property = C x YP = 3000 x 14.222

= Rs.42,666/- Say Rs.43,000/-

6.2 Example – 14 :

What is the present value of an Annuity which would continue yielding income of Rs.2000/month for 60 years period at 4% rate of interest. (Income receivable for 60 years or more is considered as perpetual income. Hence Single Rate)

Solution : Y.P. $= \dfrac{1 - \dfrac{1}{(1+R)^n}}{R} = \dfrac{1 - \dfrac{1}{(1+0.04)^{60}}}{0.04}$

$= \dfrac{1 - 0.905}{0.04} = 22.623$

Present value of annuity = C x YP = 2000 x 12 x 22.623

= Rs.542,952/-

7.0 Present value of an amount of Re.1/year (Dual Rate basis) :

(Refer years purchase table – 1 in Mirams Valuation Table) :

It is very essential in number of cases to provide for recoupment of capital sum invested also, in addition to annual yield income from the asset. Whenever income is terminable at future date, dual interest rates have to be considered. As two interest rates are considered for terminable income, this working is known as Dual Rate working. Table used is called dual rate table.

One rate is called remunerative interest rate and it is for the REMUNERATION (yield) for the capital sum invested. Second rate of interest is called Accumulative rate of interest since it is for **ACCUMULATION** of annual sinking fund set aside (Getting back of original capital) of capital invested, for period after which annual income is likely to cease. In this case the income is terminable and hence provision for accumulation of capital (Getting back of capital) has to be made. The accumulative rate of interest is considered at lower rate as because highest security for accumulation of capital is needed.

Remunerative interest rate is higher and accumulative (recoupment) interest rate is minimum. This is nothing but to provide for setting aside Sinking Fund amount each year for full period so as to get back capital sum invested. This is also known as Redemption of Capital. As two interest rates are considered in this working, this is known as Dual Rate. The formula for working out years purchase with redemption of capital and formula to arrive at value of asset are as under.

(i) Present value of Re.1/year (YP) = $\frac{1}{(R+S)}$

(ii) Sinking Fund (S) = $\frac{r}{(1+r)^n - 1}$

(iii) Value of asset = C x YP

Where,

'R' = Remunerative Interest Rate.

'S' = Sinking Fund

Y.P. = Years Purchase

'r' = Interest rate for recoupment of capital i.e, Accumulative rate of interest.

'n' = Numbers of year.

'C' = Capital income received each year.

7.1 Example –15:

A Lessee took a plot on 60 years lease and on the plot he built a house yielding net income of Rs.15,000/year. After 30 years, he decided to sale the property. Calculate present sale value of the property if expected yield on investment is 8% and rate of redemption of capital is 3%.

Solution : $Y.P. = \frac{1}{R+S}$ unexpired lease period = 60 – 30 = 30 Yr.

$$S = \frac{r}{(1+r)^n - 1} = \frac{0.03}{(1+0.03)^{30} - 1} = 0.021$$

$$YP = \frac{1}{0.08 + 0.021} = 9.90$$

Present value of property = C x YP = 15,000 x 9.9 = Rs.148,500/-

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II. The Depreciation under Income Tax Act, 1961 as well as Companies Act 2013, Useful lives to compute depreciation as per Schedule II of Companies Act,2013, Factors to be considered for componentization of assets.

1. Introduction

There are two types of assets: Tangible & Intangible

Most types of tangible property (except, land), such as buildings, machinery, vehicles, furniture, and equipment are **depreciable.**

Likewise, certain intangible property, such as patents, copyrights, and computer software are **depreciable.**

Valuer estimates the cost of reproduction of or replacement for existing structure and the improvements and then deducts all accrued depreciation in the property being valued from the reproduction cost or replacement cost of the structure as of the valuation date.

When the value of the land is separately added to above figure, one would get the total value of the property.

- Depreciation is an income tax deduction that allows a taxpayer to recover the cost or other basis of certain property. It is an annual allowance for the wear and tear, deterioration, or obsolescence of the property.
- Depreciation is a measure of the wearing out, consumption or other loss of value of a depreciable asset arising from use, passage of time or obsolescence through technology and market changes.
- Depreciation is one of the expenditure debited to profit and loss account. It is non-cash expenses.

Purpose of Depreciation: Accounting & Tax purpose

2. Various Terminology

Depreciation:

It is the systematic allocation of the ***depreciable amount*** of an asset over its ***useful life.***

Depreciable Amount:

It is the cost of an asset, or other amount substituted for cost, less its ***residual value.***

Useful Life:

- The period over which an asset is expected to be available for use by an entity; or
- The number of production or similar units expected to be obtained from the asset by an entity.

Carrying Amount:
It is the amount at which an asset is recognized after deducting any ***accumulated depreciation*** and ***accumulated impairment losses.***

Impairment Loss:
It is the amount by which the carrying amount of an asset exceeds its ***recoverable amount.***

Recoverable Amount:
It is the higher of an asset 's ***fair value*** less costs to sell and its ***value in use.***

Fair Value:
It is the estimated amount that an entity would currently obtain from disposal of the asset, after deducting the estimated costs of disposal, if the asset were already of the age and in the condition expected at the end of its ***useful life***.

Value in Use:
The present value of the future cash flows expected to be derived from an asset or cash-generating unit.

Amortization:
It is the systematic allocation of the depreciable amount of an ***intangible asset*** over its useful life.

Gross Book Value
It is ***historical cost*** or other amount substituted for cost of asset in the books of account or financial statements.

Net Book Value:
Gross book value is shown net of accumulated depreciation and impairment loss or accumulated amortization.

Block of Assets:
Block of Assets means group of assets falling within a class of assets for which same rate of depreciation is prescribed.
Please refer to the Article on "Depreciation on block of assets under Income Tax Act,1961" by Prof. Prakash E. Humbad, Prof. Ramkrushan More College, Akurdi, Pune published in Vol. 2, Issue 3, March, 2016 of International Research Journal of Multidisciplinary Studies available on http://irjms.in/sites/irjms/index.php/files/article/viewFile/412/380.

Depreciable Asset:
An asset which are expected to be used during more than one accounting period and have a limited useful life and are held by the enterprise for use in the production or supply of goods and services.

3. Depreciation under Income Tax Act, 1961 & Companies Act 2013

Sr. No.	Income Tax Act, 1961	Companies Act, 2013
1	Based on block of assets	Based on individual asset
2	Using Written Down Value Method (WDV) method	Using Straight Line Method (SLM), Written Down Value Method (WDV) & Unit of Production (UoP)
3	Rate of depreciation	Based on useful life
4	Adoption of lower rate of depreciation is not permitted	Deviation from useful life specified in Schedule II, Part C is permitted provided that the financial statements shall disclose such difference and provide justification in this behalf duly supported by technical advice
5	Residual value is not prescribed	Deviation from limit of residual value specified in Schedule II, Part C, is permitted provided that the financial statements shall disclose such difference and provide justification in this behalf duly supported by technical advice
6	100% depreciation for cost less than Rs. 5000	Does not specify
7	Different rate for extra shift	Increase in % for extra shift
8	Component accounting is not specified or optional	Useful life specified in part C of the schedule is for whole of the asset. Where cost of a part of the asset is significant to total cost of the asset and useful life of that part is different from the useful life of the remaining asset, useful life of that significant part shall be determined separately.

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4. Useful Lives as per Schedule II of Companies Act, 2013

Sr. No.	Name of Plant	Year
1	P&M related to production and exhibition of Motion Picture Films	13
2	P&M except direct fire glass melting furnaces — Recuperative and regenerative glass melting furnaces	13
3	P&M except direct fire glass melting furnaces — Moulds	08
4	Float Glass Melting Furnaces	10
5	P&M used in Telecommunications – Towers	18
6	Telecom transceivers, switching centers, transmission and other network equipment	13
7	Telecom—Ducts, Cables and optical fiber Satellites	18
8	Crude Oil Refineries & its related asset	25
9	Field operations (above ground) Portable boilers, drilling tools, well-head tanks, etc.	08
10	Thermal/ Gas/ Combined Cycle or Hydro or Nuclear Power Generation Plant	40
11	Sinter Plant, Sinter Plant, Coke Oven, Rolling Mill of Steel Plant	20
12	Metal pot line, Bauxite crushing and grinding section, Digester Section, Turbine, Equipments for Calcinations, Copper Smelter, Roll Grinder for non-ferrous metal plant	40
13	Soaking Pit, Annealing Furnace, Rolling Mills, Equipments for Scalping, Slitting , etc. for non-ferrous metal plant	30
14	Reactors, Distillation Columns, Drying equipments/Centrifuges and Decanters, Vessel/storage tanks for pharmaceuticals and chemicals plant	20

5. Factors to be taken into consideration for estimation of Useful Life

- Utility
- Physical & working condition
- Status of repair & maintenance
- Availability of raw material
- Availability of spares & parts
- Demand & supply

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6. What is a Componentization of Asset?

If fixed asset has two or more major components with substantially different useful lives, these assets should be treated as separate components and depreciated over the different useful lives. This is called componentization of Asset.

A part of the machinery is said to be a component which is having a significant value in relation to the total cost of the asset and total useful life of the part is also significantly different from the total useful life of the main asset. The component is treated as a separate asset for treatment of depreciation as well as for capitalization of subsequent expenditure on restoring or replacing.

7. Factors to be considered for Componentization of Assets

- Identifiability or Separability
  The component must be identifiable and separable. Any component which is not separable from its parent asset for replacement or maintenance, it cannot be treated as a separate component.
- Identifiable in terms of cost / Measurement of cost from market
  The replacement cost of identified component should be available
- Significant difference in terms of total useful life
  The percentage rate for depreciation is dependent on the total useful life; hence the significant difference in total Useful life for parent asset and component is required to be ascertained.

Example – Componentization of Aircraft
Aircraft has an engine, a body and Electronic System that have very different useful lives. The engine may need to be replaced multiple times over life of the aircraft. The useful life of the body may be 20 years, whereas the useful life of the engine and Electronic System may be 8 years and 5 years respectively. The body would be treated as a separate component and it is depreciated over 20 years, while the engines would be depreciated over 8 years (or perhaps based on the number of flight hours) and Electronic System would be depreciated over 5 years.

Sr. No.	Components	Component Amount	Useful Life	Depreciation/ Year
		In INR	In Yr.	In INR
1	Air frame (with balance unidentifiable assets)	4,800,000,000	20	240,000,000
2	Engine	2,560,000,000	8	320,000,000
3	Electronic System	640,000,000	5	128,000,000
	Total	8,000,000,000		688,000,000

Valuation of machine tools, factory and utility equipment

Three approaches to value applicable to valuation of plant and machinery are also applicable to valuation of machine tools, factory and utility equipment and same have been covered in KPB's book.

It is equally important for valuers of plant and machinery to get familiarise with machine tools, factory and utility equipment and then only he can do proper valuation and therefore same have been covered in this study material.

The technical specifications are vital for machines falling under this category. The technical specifications of machine tools and factory equipment are covered under section IV and technical specification of utility equipment are covered under subject of Industrial Processes.

III. Machine Tools.

by
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INDEX

Prologue:

A quality production is the fundamental moto of any manufacturing unit. There are certain basic need for a sustained quality production like wel maintained machinary, means an equiped work shop, quick emergency handling (well designed fire fighting & Alarm system) and efficient materials handling and peripharials.

This machine tools & factory equipment is a vast subject with horizon as a limit. There are numerous types of machinary available in the market. The types of machinary and equipment used can vary from one product to another and also from one unit to another. An effort is made to cover and briefly introduce all major types of machine tools used in a factory. Also all important peripharial equipments and systems are discussed.

So much is available on the subject that it has to be compiled in a systematic manner with a target group in mind. This text offers a comprehensive & flexible introduction to the basic machine tools. It is designed specifically for heterogeneous classes. As a matter of fact this subject is being natured for non-engineering background students & hence a special care is taken to avoid design aspects as far as possible. We shall study the basic engineering machines, tools, material handling equipments and some of the popular variance of the standard equipment.

The entire subject is divided in six chapters or units.

- The first unit deals with “Introduction to metal Working”.- i.e. various types of metal working processes are discussed here.
- The second unit – deals with various types of machines and machining operations.
- Third units discusses the tools used in the operation and special equipments thereof.
- Fourth unit “Measuring Equipments” – adapts various measuring equipments deployed for accurate measurements. The Fifth unit being extension of the fourth one deals with various “Non Destructive Testing” procedures & methods.
- The last unit is dedicated to various aspects of “Material Handling” starting with lifting & transport equipments like cranes, conveyors, winch to vehicle like forklifts, tractors, bulldozer, excavators etc. It also overviews the basic Fire & Control equipments and Communication systems.

An effort is made so that after studying all the units, the student will understand the basic working of a factory machine tool work shop and other periphereals services. Having understood the basic working and the type of usage, a valuer can judge the value of the equipment in question by putting his valuation practices in use.

I also wish to put on record the valuable guidance received from Mr. Kirit Budhbhatti to make this work more beneficial to the students.

CHAPTER-1

INTRODUCTION TO METALWORKING

Metalworking is the craft and practice of working with metals to create structures or machine parts. The term covers a wide range of work-from large ships, bridges and oil refineries to delicate jewellery and instruments. Consequently, this craft covers a wide range of skills and entails the use of many types of tools.

History

Metalworking is a trade, art, hobby and industry that relates to metallurgy - a science, jewelery making - an art and craft, as a trade and an industry with ancient roots spanning all cultures and civilizations. Metalworking had its beginnings millennia in the past. Early humans, we speculate, realized different stones had different properties. These were freed metal ores on the earth's surfaces. We can further speculate that some indigenous groups attributed magical and spiritual significance to them. At some imprecise point humankind discovered that these lustrous rocks were meltable, and ductile and able to be formed into various articles for tools, adornment and practical uses. Humans over the millennia learned to work raw metals into objects of art, adornment, trade and practicality.

Through trial and error, and crude harnessing of the malleability of metals, inquisitions as to the sources of these elements probably began. By the historical periods of the Pharohs in Egypt, the Vedic Kings in India, and the Tribes of Israel, and Mayan Civilization in North America among other ancient populations, precious metals began to have value attached to them, and in some cases rules for ownership, distribution, and trade were created, enforced and agreed upon by respective peoples. By the above periods skills at creating objects of adornment, religious artifacts, and trade instruments of precious metals (non-ferrous), as well as implements of inhumanity, and other weaponry usually of ferrous metals and/or alloys were finely honed and flawlessly executed skills and techniques practised by artisans, blacksmiths, atharvavedic practitioners, alchemists, and other categories of metalworkers around the globe. For example, the ancient technique of granulation is found spontaneously around the world in numerous ancient cultures before the historic record shows people travelled seas or overland to far regions of the earth to share this process still being used, and attempted by metalsmiths today.

As time progressed metal objects became more common, and ever more complex. The need to further acquire and work metals grew in importance. Skills related to extracting metal ores from the earth began to evolve, and metalsmiths became more knowledgable. Metalsmiths became important members of society. Fates and economies of entire civilizations were greatly affected by the availability of metals and metalsmiths.

Today modern mining practices are more efficient, and conversely more damaging to the earth, and the workers that are engaged in the industry. Those that finance the operations are driven by profits per ounce of extracted precious metals and today's gold market which as of the date of this editing, are at a 25 year high.

The metalworker though depends on the extraction of precious metals to make jewelery, build more efficient electronics, and for industrial and technological applications from construction to shipping containers to rail, and air transport. Without metals, goods and services would cease to move around the globe on the scale we know today. More individuals then ever before are learning metalworking as a creative outlet in the forms of jewelery making, hobby restoration of aircraft and cars, blacksmithing, tinsmithing, tinkering, and in other art and craft pursuits. Trade schools continue to teach welding in all of its forms, and there is a proliferation of schools of Lapidary and Jewelers srts and sciences at this- the beginning of the 21st. Century a.c.e./a.d.

Processes

- 1.0 Shape modifying by material removal processes
    - 1.1 Milling
    - 1.2 Turning
    - 1.3 Cutting
    - 1.4 Drilling and threading
    - 1.5 Grinding
- 2.0 Shape modifying with material retention processes
    - 2.1 Casting
    - 2.2 Plastic deforming
    - 2.3 Powder forming
    - 2.4 Sheet metal
- 3.0 Joining processes
    - 3.1 Welding
    - 3.2 Hand fabrication
- 4.0 Preparation and validation
    - 4.1 Marking out

1.0 Shape modifying by material removal processes

1.1 Milling

Milling is the complex shaping of metal (or possibly other materials) parts, by removing unneeded material to form the final shape. It is generally done on a milling machine, a power-driven machine that in its basic form is comprised of a milling cutter that rotates about the spindle axis (like a drill), and a worktable that can move in multiple directions (usually three dimensions [x,y,z axis] relative to the workpiece, whereas a drill can only move in one dimension [z axis] while cutting). The motion across the surface of the workpiece is usually accomplished by moving the table on which the workpiece is mounted, in the x and y directions. Milling machines may be operated manually or under computer numerical control (CNC), and can perform a vast number of complex operations, such as slot cutting, planing, drilling and threading, rabbeting, routing, etc. Two common types of millers are the horizontal miller and vertical miller.

1.2 Turning

A lathe is a machine tool which spins a block of material so that when abrasive, cutting, or deformation tools are applied to the workpiece, it can be shaped to produce an object which has rotational symmetry about an axis of rotation, called Solids of Revolution. Examples of objects that can be produced on a lathe include candlestick holders, table legs, bowls, baseball bats, crankshafts or camshafts.

The material may be held in place by a chuck or worked between one or two centers of which at least one can be moved horizontally to accommodate varying material lengths. In a metalworking lathe, metal is removed from the workpiece using a hardened cutting tool which is usually fixed to a solid moveable mounting called the "toolpost", this arrangement is then moved around the workpiece using handwheels and/or computer controlled motors. The main difference between the Milling Machine and the Lathe is that in the Milling Machine the tool is moving but in the Lathe, the work is moving.

1.3 Cutting

There are many technologies available to cut metal. Sawing, chisel, shearing, burning by Laser, gas jet and plasma, erosion by water jet or electric discharge, and good old fashioned hand cutting.

1.4 Drilling and threading

Drilling is the process of using a drill bit in a drill to produce holes. Under normal usage, swarf is carried up and away from the tip of the drill bit by the fluting. The continued production of chips from the cutting edges pushes the older chips outwards from the hole. This continues until the chips pack too tightly, either because of deeper than normal holes or insufficient backing off (removing the drill slightly [breaking the chip] or totally from the hole [clearing the bit] while drilling). Lubricants (or coolants) (i.e. cutting fluid) are sometimes used to ease this problem and to prolong the tool's life by cooling, lubricating the tip and improving chip flow.

Taps and dies are tools commonly used for the cutting of screw threads in metal parts. A tap is used to cut a female thread on the inside surface of a predrilled hole, while a die cuts a male thread on a preformed cylindrical rod.

1.5 Grinding

Grinding uses an abrasive process to remove material from the workpiece. A grinding machine is a machine tool used for producing very fine finishes or making very light cuts, using an abrasive wheel as the cutting device. This wheel can be made up of various sizes and types of stones, diamonds or of inorganic materials.

2.0 Shape modifying with material retention processes

These processes modify the shape of the object being formed, without removing any material.

2.1 Casting

- Sand casting
- Shell casting
- Investment casting (called Lost wax casting in art)
- Die casting

2.2 Plastic deforming

- Forging
- Rolling
- Extrusion
- Spinning

2.3 Powder forming

- Sintering

2.4 Sheet metal

- Bending :A calculated deformation of the metal from it original shape.
- Drawing
- Pressing
- Spinning
- Flow turning

3.0 Joining processes

3.1 Welding

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material that cools to become a strong joint, but sometimes pressure is used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them.

Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding can be done in many different environments, including open air, underwater and in space. Regardless of location, however, welding remains dangerous, and precautions must be taken to avoid burns, electric shock, poisonous fumes, and overexposure to ultraviolet light.

4.0 Marking out

Marking out (also known as layout) is the process of transferring a design or pattern to a workpiece and is the first step in the handcraft of metalworking. It is performed in many industries or hobbies, although in the repetition industries the need to mark out every individual piece is eliminated.

In the metal trades area, marking out consists of transferring the engineers plan to the workpiece in preparation for the next step, machining or manufacture.

Exercise:

1. What is metal working?
2. Describe Processes of metal working.
3. What is Welding?
4. What is the significance of Marking out ?

CHAPTER - 2

MACHINES & MACHINING OPERATIONS

Lathe Machine

A lathe is a common tool used in machining.

A lathe is a tool which spins a block of material to perform various operations such as cutting, sanding, knurling, drilling or deformation with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation.

Lathes are used in woodturning, metalworking, metal spinning, and glassworking. A lathe used for working with clay is more commonly known as a potter's wheel. Most suitably equipped metalworking lathes can also be used to produce most solids of revolution, plane surfaces and screw threads or helices. Ornamental lathes can produce three-dimensional solids of incredible complexity. The material is held in place by either one or two centers, at least one of which can be moved horizontally to accommodate varying material lengths. Examples of objects that can be produced on a lathe include candlestick holders, cue sticks, table legs, bowls, baseball bats, crankshafts and camshafts.

A metal lathe

In a metalworking lathe, metal is removed from the workpiece using a hardened cutting tool, which is usually fixed to a solid moveable mounting called the "toolpost", which is then moved against the workpiece using handwheels and/or computer controlled motors.

The toolpost is operated by leadscrews that can accurately position the tool in a variety of planes. The toolpost may be driven manually or automatically to produce the roughing and finishing cuts required to turn the workpiece to the desired shape and dimensions, or for cutting threads, worm gears, etc. Cutting fluid may also be pumped to the cutting site to provide cooling, lubrication and clearing of swarf from the workpiece. Some lathes may be operated under control of a computer for mass production of parts.

Metalworking lathes are commonly provided with a variable ratio gear train to drive the main leadscrew. This enables different pitches of threads to be cut. Some older gear trains are changed manually by using interchangeable gears with various numbers of teeth, while more modern or elaborate lathes have a quick change box to provide commonly used ratios by the operation of a lever.

The threads that can be cut are, in some ways, determined by the pitch of the leadscrew: A lathe with a metric leadscrew will readily cut metric threads (including BA), while one with an imperial leadscrew will readily cut imperial unit based threads such as BSW or UTS (UNF,UNC).

The workpiece may be supported between a pair of points called centres, or it may be bolted to a faceplate or held in a chuck. A chuck has movable jaws that can grip the workpiece securely.

Varieties
The smallest lathes are "jewelers lathes" or "watchmaker lathes", which are small enough that they may be held in one hand. Although the workpieces machined on a jeweler's lathes are metal, jeweler's lathes differ from all other metal working lathes in that the cutting tools (called "gravers") are hand held, supported by a T-rest, not fixed to a cross slide. The work is usually held in a collet and two spindle bores to receive such collets are common, namely 6 mm and 8 mm. Two patterns of bed are common, the WW (Webster Whitcomb) bed, which is found only on 8 mm Watchmakers lathes which is a truncated triangular prism and the continental D-style bar bed used on both 6 mm and 8 mm lathes by firms such as Lorch and Star. Other designs have been used, e.g. Boley used a triangular prism as bed on some 6.5 mm lathes, and IME used a V edged bed on their 8 mm lathes.

- Lathes that sit on a bench or table are called **"bench lathes".**
- Lathes that do not have additional intergal features for the purposes increased production rates, but rather have individual part production or modification as the primary role, are called **"engine lathes".**
- Lathes with a very large spindle bore and a chuck on both ends of the spindle are called **"oil field lathes."**

- Fully automatic mechanical lathes, employing cams and gear trains for controlled movement, are called **automatic screw machines.**
- Lathes that are controlled by a computer are **CNC lathes.**
- Lathes with the spindle mounted in a vertical configuration, instead of horizontal configuration, are **called vertical lathes or vertical boring machines**. They are used where very large diameters must be turned, and the workpiece is not very long.
- A lathe with a cylindrical tailstock that can rotate around a vertical axis, so as to present different facets towards the headstock (and the workpiece) are **turret lathes.**
- A lathe equipped with indexing plates, profile cutters, spiral or helical guides, etc., so as to enable ornamental turning is an **ornamental lathe**.
- Various combinations are possible: e.g. one could have a "vertical CNC lathe", etc.
- Lathes can be combined with other mechanisms into more complex machines, such as those with an overhead drill or vertical milling unit. These are usually referred to as **combination lathes.**

SCREW M/C

A **Screw Machine** is a metalworking machine used in the high volume manufacture of turned components.

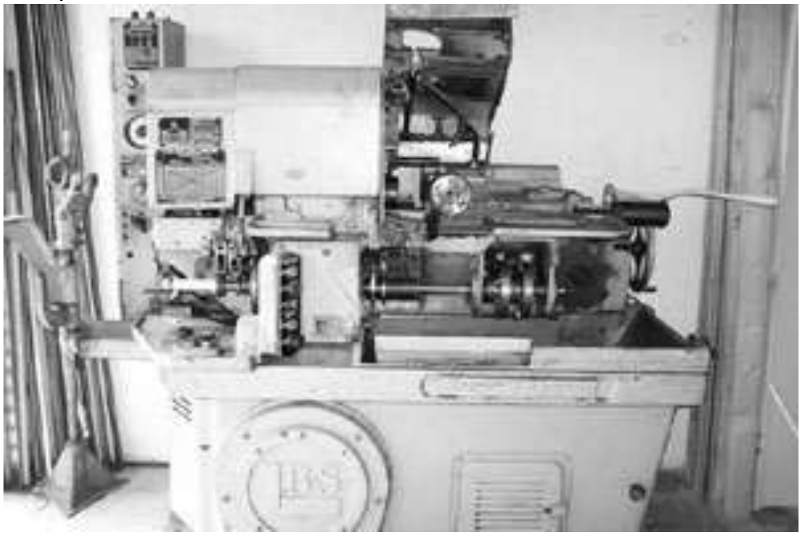
In operation, a Screw Machine is similar to a Lathe. Essentially a Screw Machine is an Automated Turret Lathe.

Screw Machines have been replaced by CNC Lathes to some extent. However, for high volume production of turned components nothing is as cost efficient as a Screw Machine.

In the hierarchy of manufacturing machines, the Screw Machine sits at the top when large volume of product is needed. An Engine Lathe sits at the bottom, taking the least amount of time to set-up but the most amount of skilled labor and time to actually produce a part. A turret lathe has traditionally been one step above a Lathe, needing greater set-up time but being able to produce a higher volume of product and usually requiring a lower skilled operator once the set-up process is complete. Screw Machines may require an extensive set-up but once running, a single operator can monitor the operation of several machines.

A Screw Machine may have a single spindle but, in contrast to a lathe, a Screw Machines may have multiple spindles. Each spindle contains a bar of material that is being machined simultaneously. A common configuration is six spindles. The cage that holds these six bars of material indexes after each machining operation is complete. Each station may have multiple tools that cut the material in sequence. The operation of these tools being very similar to that of a turret lathe.

By way of example then: a bar of material is fed forward through the spindle. The face of the bar is machined (facing operation). The Outside of the bar is machined to shape (turning operation). The bar is drilled (boring operation) and finally, the part is cut off (parting operation).



In a single spindle machine, these four operations would most likely be performed sequentially with four cross-slides each coming into position in turn to perform their operation. In a multiple spindle machine, each operation would be performed on each spindle simultaneously, with the material being positioned at each station in sequence.
Screw Machines are mechanically driven, the position of the cutting tool is determined by the shape of a cam that rotates in step with the machine, but at a slower speed.
For the machining of complex shapes, it is common to use a Form Tools.

This contrasts with the cutting that is performed on an Engine Lathe where the cutting tool is usually a Single-Point Tool. A Form Tool has the form or contour of the final part but in reverse, so it cuts the material leaving the desired component shape. A Single-Point Tool is designed to cut on one point at a time and the shape of the component is dictated by the motion of the tool rather than its shape.

The name "Screw Machine" is somewhat of a misnomer since Screw Machines spend most of their time making things that are not screws and are not even threaded. However, threading is frequently performed on a screw machine. Unlike a lathe, single point threading is rarely if ever performed, single point threading is too time consuming for the short cycle times that are typical of Screw machines. A threading die can cut rapidly but it requires the machine to reverse in order to be removed from the work. It is impractical to reverse the rotation of the spindle[s] of the machine so it is necessary to have a cutting tool that can cut in one direction and cut fast and be removed without interrupting the rotation of the machine. Threading is performed with a Die Head - a device that cuts the thread then opens and withdraws rapidly.

Cutting

Cutting is the separation of a physical object, or a portion of a physical object, into two portions, through the application of an acutely directed force. An implement commonly used for cutting is the knife or in medical cases the scalpel. However, any sufficiently sharp object is capable of cutting if it has a hardness sufficiently larger than the object being cut, and if it is applied with sufficient force. Cutting also describes the action of a saw which removes material in the process of cutting.

Cutting is a compressive and shearing phenomenon, and occurs only when the total stress generated by the cutting implement exceeds the ultimate strength of the material of the object being cut. The simplest applicable equation is stress = force/area: The stress generated by a cutting implement is directly proportional to the force with which it is applied, and inversely proportional to the area of contact. Hence, the smaller the area (i.e., the sharper the cutting implement), the less force is needed to cut something.

Saw

A saw is a tool for cutting wood or other material, consisting of a serrated blade (a blade with the cutting edge dentated or toothed) and worked either by hand or by steam, water, electric or other power. The teeth of the saw are each bent to specific angle and this angle is called "set". The set of a tooth is dependent on the kind of cut the saw will be making. For example a "rip saw" has a tooth set that is similar to the angle used on a chisel. The idea is to have the teeth rip or tear the fibers of the wood apart.

Mechanically powered saws

Mechanically powered saws mechanically move the teeth past the wood while the saw itself is held stationary. This is accomplished in one of three ways: the teeth are along the perimeter of a flat, circular blade; the blade reciprocates up and down rapidly; or the teeth are along one edge of a continuous band. They are more specifically differentiated as follows:

Circular blade saws

- Circular saw, machine-driven for industrial sawing of log and beams, typically found in sawmills - also name given to smaller hand-held saws
- Table saw, circular blade rises through a slot in a table. It is the most common piece of stationary woodworking equipment. The smaller direct-drive versions that can be set on a workbench are called workbench saws. Smaller belt-driven ones generally set on steel legs are often called Contractor's Saws. The heavier, more precise and more powerful, often driven by multiple belts, with an enclosed base stand as an integral part of the saw are called Cabinet saws. A relatively new version, called a hybrid saw, has the lighter weight mechanism of a Contractor saw but with an enclosed base like the Cabinet saw.
- Radial arm saw, versatile machine used mainly for cross-cutting where the blade is pulled on a guide arm through a piece of wood held stationary on the saw's table
- Rotary saw, for making accurate cuts without the need for a pilot hole in wallboard, plywood, and other thin materials, also called a spiral cut saw or a "RotoZip". The latter is a trademark owned by Bosch Tool Corp. who pioneered this type of saw - design is similar to a small wood router, bits are similar to a twist drill, some cut on the upward twist, some cut downwards
- Electric miter saw, (also called chop saw, cut-off saw or power miter box) – for making accurate cross cuts and miter cuts. The basic model has its circular blade fixed at a 90° angle to the vertical, a compound miter saw's blade can be adjusted to other angles. A sliding compound miter saw has a blade which can be pulled through the work similar to the action of a radial arm saw, which gives a greater capacity for cutting wider workpieces.
- Concrete saw, usually powered by an internal combustion engine and used with a Diamond Blade to cut concrete or asphalt pavement.

Reciprocating blade saws

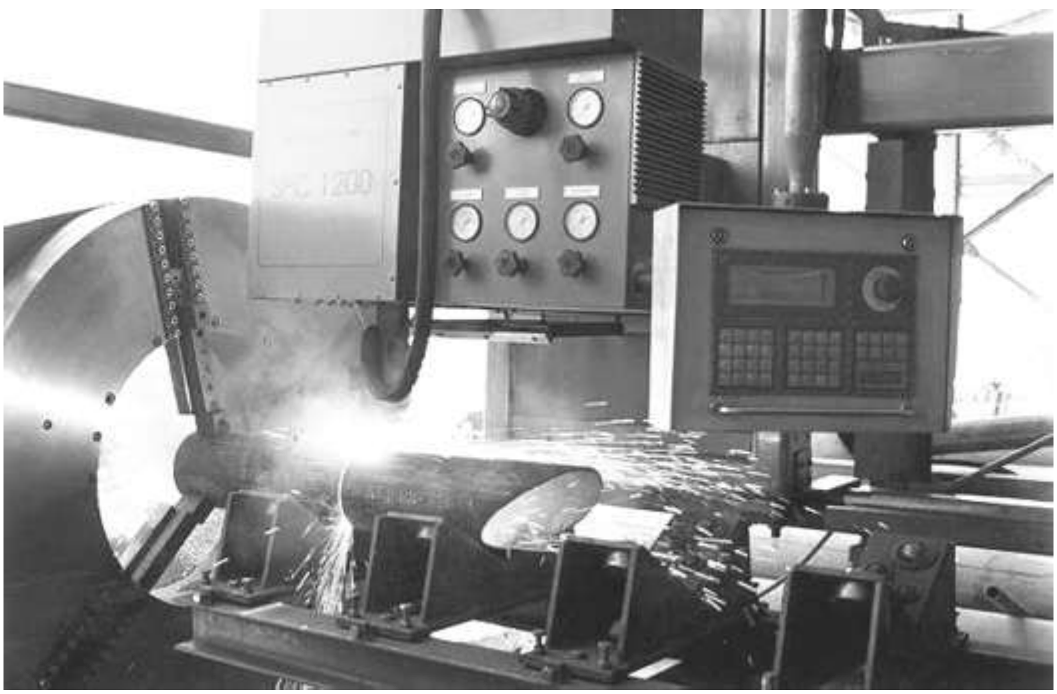
- Jigsaw or saber saw (mainly US), narrow blade for cutting irregular shapes, typically held in one hand with the barrel perpendicular to the saw blade. Historically, the term jigsaw was also commonly used for what is now usually called a scroll saw.
- Reciprocating saw or sabre saw (mainly UK and Australia), action similar to a jigsaw, but much larger, more powerful and with a longer stroke with the blade parallel to the barrel. Normally held in both hands, useful for demolition work or for cutting pipe. Sometimes powered by compressed air.

- Scroll saw, saw for making intricate curved cuts (scrolls), the first of which were pedal powered. Traditionally called a jigsaw.
- Dragsaw, internal combustion powered saw used for bucking logs before the advent of the chainsaw.
- Sternal saw, used in surgery to open a patient's sternum.

  Continuous band
- Band saw, with motor-driven continuous band

Metal Cutting Band Saws

When cutting metals, special band saws are required that include coolant pumps which provide a constant flow of liquid coolant over the blade. The coolant keeps blades cool, adding blade life. They also include a powered wire brushwheel to remove chips and buildup from the blade as it exits the material. Metal cutting band saws are available in vertical and horizontal designs. These units range from manual to semi-automatic and even automatic controls.



CNC Cutting Machine

Machine shop bandsaws are horizontal, vertically cutting saws. Small, manual shop saws are usually employ a gravity-fed blade that falls in an arc around a pivot point. The rate of descent is controlled by a shock absorber that has an adjustable rate. When a manual saw is set up for another cut, the operator raises the saw by hand and leaves it in a 45 degree position. The material is unclamped, moved up to hit the part stop (which is then moved out of the way), material reclamped, and the operator hits the rapid advance switch to lower the saw just before the cut begins. The saw's piston is then set to cut advance, and another cut is made.

Guillotine Shear m/c

A guillotine is a machine used to accurately cut sheet metal. It may be foot-operated (or less commonly hand-operated), or powered. An angled blade is driven down which slices the metal along the length of the cut, shearing it off very cleanly.

Depending on the capacity of the machine, the angle of the blade may be varied along with the clearance between the upper and lower blades. The thicker the material, the greater the angle and clearance given to the blades.

The angle of the blade is referred to as shear, and this provides a slicing rather than a chopping action; by slicing the material a cleaner cut is produced and less energy is used. This is because the blade contacts only a small area at a time rather than the full length of the cut (which is also how scissors work).

Clearance is defined as the separation between the blades, measured at the point where the cutting action takes place, and perpendicular to the direction of blade movement. It affects the finish of the cut (burr) and the machine's power consumption, and is directly related to the material's composition. The cut of a guillotine is in part a fracturing process; the blade partially penetrates the material but the final separation is due to the material fracturing. Harder materials (such as stainless steel) fracture more readily than softer ones (such as brass).

The design of press tools and guillotine blades is an engineering compromise. A sharp edge is required, along with strength and durability, so to achieve these two objectives the blades for metal work tend to be square-edged rather than knife-edged. The difference between the two angles is called the rake

Drilling

Under normal usage, swarf is carried up and away from the tip of the drill bit by the fluting. The continued production of chips from the cutting edges produces more chips which continue the movement of the chips outwards from the hole. This continues until the chips pack too tightly, either because of deeper than normal holes or insufficient backing off (removing the drill slightly or totally from the hole while drilling). Lubricants and coolants (i.e. cutting fluid) are sometimes used to ease this problem and to prolong the tools life by cooling and lubricating the tip and chip flow. Coolant is introduced via holes through the drill shank.

Straight fluting is used for copper or brass, as this exhibits less tendency to "dig in" or grab the material. If a helical drill (twist drill) is used then the same effect can be achieved by stoning a small flat parallel with the axis of the drill bit.
For heavy feeds and comparatively deep holes oil-hole drills can be used, with a lubricant pumped to the drill head through a small hole in the bit and flowing out along the fluting.

Jig borer

The jig borer is a type of machine tool invented at the end of World War I to make possible the quick-yet-very-precise location of hole centers.

Before the jig borer was developed, hole center location had been accomplished either with layout (either quickly-but-imprecisely or painstakingly-and-precisely) or with drill jigs (themselves made with painstaking-and-precise layout). The jig borer was invented to expedite the making of drill jigs, but it helped to eliminate the need for drill jigs entirely by making quick precision directly available for the parts that the jigs would have been created for. The revolutionary underlying principle was that advances in machine tool control that expedited the making of jigs were fundamentally a way to expedite the cutting process itself, for which the jig was just a means to an end. Thus the jig borer's development helped advance machine tool technology toward later NC and CNC development. The jig borer was a logical extension of manual machine tool technology that began to incorporate some then-novel concepts that would become routine with NC and CNC control, such as:

- coordinate dimensioning (dimensioning of all locations on the part from a single reference point);
- working routinely in "tenths" (ten-thousandths of an inch, 0.0001") as a fast, everyday machine capability (whereas it formerly was the exclusive domain of special, time-consuming, craftsman-dependent manual skills); and
- circumventing jigs altogether.

Milling machine
A milling machine is a power-driven machine used for the complex shaping of metal (or possibly other materials) parts. Its basic form is that of a rotating cutter or endmill which rotates about the spindle axis (similar to a drill), and a movable table to which the workpiece is affixed. That is to say the cutting tool generally remains stationary (except for its rotation) while the workpiece moves to accomplish the cutting action. Milling machines may be operated manually or under computer numerical control.

Milling machines can perform a vast number of complex operations, such as slot cutting, planing, drilling, rebating, routing, etc.Cutting fluid is often pumped to the cutting site to cool and lubricate the cut, and to sluice away the resulting swarf.

Types of milling machines
There are two main types of mill: the vertical mill and the horizontal mill. In the vertical mill the spindle axis is vertically oriented. Milling cutters are held in the spindle and rotate on its axis. The spindle can generally be extended (or the table can be raised/lowered, giving the same effect), allowing plunge cuts and drilling. There are several subcategories of vertical mills: the bedmill and the turret mill. Turret mills, like the ubiquitous Bridgeport, are generally smaller than bedmills, and are considered by some to be more versatile. In a turret mill the spindle remains stationary during cutting operations and the table is moved both perpendicular to and parallel to the spindle axis to accomplish cutting. In the bedmill, however, the table moves only perpendicular to the spindle's axis, while the spindle itself moves parallel to its own axis. Also of note is a lighter machine, called a mill-drill. It is quite popular with hobbyists, due to its cheap price. These are frequently of lower quality than other types of machines, however.

A horizontal mill has the same sort of x–y table, but the cutters are mounted on a horizontal arbor across the table. A majority of horizontal mills also feature a +15/-15 degree rotary table that allows milling at shallow angles. While endmills and the other types of tools available to a vertical mill may be used in a horizontal mill, their real advantage lies in arbor-mounted cutters, called side and face mills, which have a cross section rather like a circular saw, but are generally wider and smaller in diameter.

Because the cutters have good support from the arbor, quite heavy cuts can be taken, enabling rapid material removal rates. These are used to mill grooves and slots. Plain mills are used to shape flat surfaces. Several cutters may be ganged together on the arbor to mill a complex shape of slots and planes. Special cutters can also cut grooves, bevels, radii, or indeed any section desired. These specialty cutters tend to be expensive. Simplex mills have one spindle, and duplex mills have two. It is also easier to cut gears on a horizontal mill.

A more complex form of the milling machine is the Universal milling machine, in which the rotating cutter can be oriented vertically or horizontally, increasing the flexibility of the machine tool. The table of the universal machine can be swiveled through a small angle (up to about 15 degrees), enabling tapered cuts to be made over the length of the table.

Milling machine variants

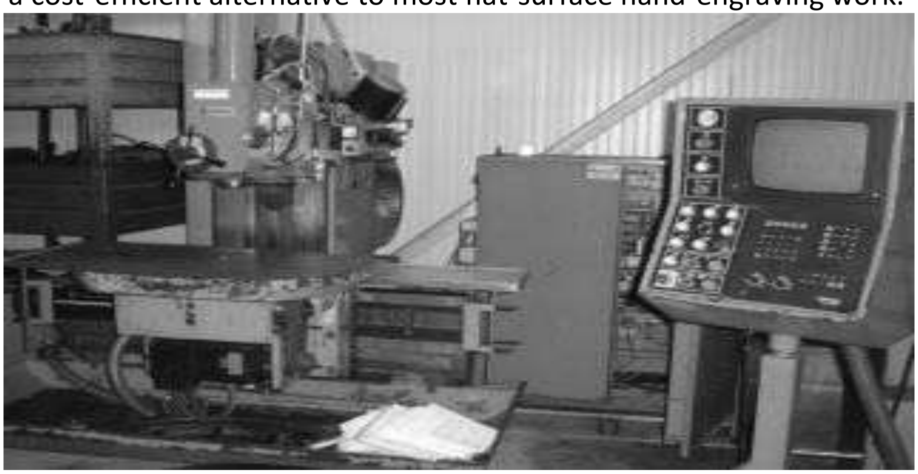
- Box or column mills are very basic hobbyist bench-mounted milling machines that feature a head riding up and down on a column or box way.
- Turret or Vertical ram mills are more commonly referred to as bridgeport-type milling machines. The spindle can be aligned in many different positions for a very versatile, if somewhat less rigid machine.
- C-Frame mills are larger, industrial production mills. They feature a knee and fixed spindle head that is only moble vertically. They are typically much more powerful than a turret mill, featuring a separate hydaulic motor for intergal hydraulic power feeds in all directions, and a twenty to fifty horsepower motor. Backlash eliminators are almost standard equipment. They use large NMTB 40 or 50 tooling. The tables on C-frame mills are usually 18" by 68" or larger, to allow multiple parts to be machined at the same time.
- Knee mill refers to any milling machine that has a vertically adjustable table.
- Bed mill refers to any milling machine where the spindle is on a pendant that moves up and down to move the cutter into the work. These are generally more rigid than a knee mill.
- Jig borers are vertical mills that are built to bore holes, and very light slot or face milling. They are typically bed mills with a long spindle throw. The beds are more accurate, and the handwheels are graduated down to .0001" for precise hole placement.
- Horizontal boring mills are large, accurate bed horizontal mills that incorporate many features from various machine tools. They are predominantly used to create large manufacturing jigs, or to modify large, high precision parts. They have a spindle stroke of several (usually between four and six) feet, and many are equipped with a tailstock to perform very long boring operations without losing accuracy as the bore increases in depth. A typical bed would have X and Y travel, and be between three and four feet square with a rotary table or a larger rectangle without said table. The pendant usually

has between four and eight feet in vertical movement. Some mills have a large (30" or more) intergal facing head. Right angle rotary tables and vertical milling attachments are available to further increase productivity.

- Floor mills have a row of rotary tables, and a horizontal pendant spindle mounted on a set of tracks that runs parallel to the table row. These mills have predominantly been converted to CNC, but some can still be found (if one can even find a used machine available) under manual control. The spindle carriage moves to each individual table, performs the machining operations, and moves to the next table while the previous table is being set up for the next operation. Unlike any other kind of mill, floor mills have floor units that are entirely movable. A crane will drop massive rotary tables , X-Y tables, and the like into position for machining, allowing the largest and most complex custom milling operations to take place.

CNC milling machines

Most CNC milling machines or machining centers are computer controlled vertical mills with the ability to move the spindle vertically along the Z-axis. This extra degree of freedom permits their use in engraving applications, and also allows to create 2.5D surfaces such as relief sculptures. When combined with the use of conical tools or a ball nose cutter, it also significantly improves milling precision without impacting speed, providing a cost-efficient alternative to most flat-surface hand-engraving work.



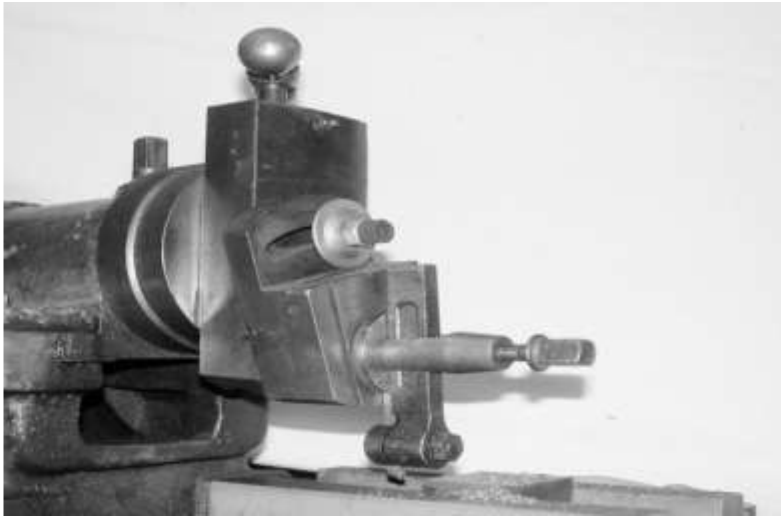
CNC machines can exist in virtually any of the forms of manual machinery, like horizontal mills. The most advanced CNC milling-machines, the 5-axis machines, add two more axes in addition to the three normal axes (XYZ). Horizontal milling machines also have a C or Q axis, allowing the horizontally mounted workpiece to be rotated, essentially allowing asymmetric and eccentric turning. The fifth axis(B-Axis) controls the tilt of the tool itself. When all of these axes are used in conjunction with each other, extremely complicated geometries, even organic geometries such as a human head can be made with relative ease with these machines. But the skill to program such geometries is beyond that of most humans. Therefore, 5-axis milling machines are practically always programmed with CAM.

Shaper

A shaper is a machine tool used for shaping or surfacing metal and other materials.

History

Shapers have been largely superseded by milling machines or grinding machines in modern industrial practice. They rapidly fell out of favour with modern industry as they were time consuming in operation, the amount of material removal by a single point cutting tool being no match for recent methods, however they are still popular with some amateurs, or where production time is not a factor. The basic function of the machine is still sound and tooling for them is minimal and very cheap to reproduce. They can be invaluable for jobbing or repair shops where only one or a few pieces are required to be produced and the alternative methods are cost or tooling intensive. The mechanically operated machines are simple and robust in construction, making their repair and upkeep easily achievable.



Types

They may be vertical or horizontal, with the horizontal arrangement being the most common. Vertical shapers are generally fitted with a rotary table to enable curved surfaces to be machined. The vertical shaper differs to a slotter (slotting machine) as the slide can be moved from the vertical, a slotter is fixed in the one plane.

Very small machines have been successfully made to operate by hand power. Once size increases, up to a potential 36 inch stroke, the power needs increase and it becomes necessary to use an electric motor. This motor drives a mechanical arrangement (using a pinion gear, bull gear and crank) or a hydraulic motor which supplies the necessary movement via hydraulic cylinders.

Uses

The most common use is to machine straight, flat surfaces but with ingenuity and some accessories a wide range of work can be done. Other examples of its use are:

- Keyways in the boss of a pulley or gear can be machined without resorting to a dedicated broaching setup.
- Dovetail slides
- Internal splines
- Keyway cutting in blind holes

Planer

A metalworking planer is a type of metalworking machine tool, analogous to a shaper but larger and with the entire workpiece moving beneath the cutter (instead of the cutter moving above a stationary workpiece). The work table is moved back and forth on the bed beneath the cutting head by either mechanical means (a rack and pinion gear) or by a hydraulic cylinder.

Planers and shapers were used generally for two types of work: generating accurate flat surfaces and cutting slots (such as keyways). Planers and shapers are now obsolescent, because milling machines have eclipsed them as the machine tools of choice for doing such work. However, they have not yet entirely disappeared from the metalworking world.

Modern planers are used by smaller tool and die shops within larger production facilities to maintain and repair large stamping dies and plastic injection molds. Additional uses include any other task where an abnormally large (usually in the range of 4'×8' or more) block of metal must be squared when a (quite massive) horizontal planing or floor mill is not available, too expensive, or unpractical for the situation. While not as precise as grinding, a planer can remove a tremendous amount of material in one pass and still maintain a high degree of accuracy. Metal planers come in two kinds: double-housing and open-side. The double-housing variety has vertical supports on both sides of its long bed; the open-side variety has a vertical support on only one side, allowing the workpiece to extend beyond the bed. Metal planers can vary in size from a table size of 30"×72" to 20'×62', and in weight from around 20,000 lbs to over 1,000,000 lbs.

Grinding machine

A grinding machine is a machine tool used for producing very fine finishes or making very light cuts, using an abrasive wheel as the cutting device. This wheel can be made up of various sizes and types of stones, diamonds or of inorganic materials. For machines used to reduce particle size in materials processing see grinding.

Construction

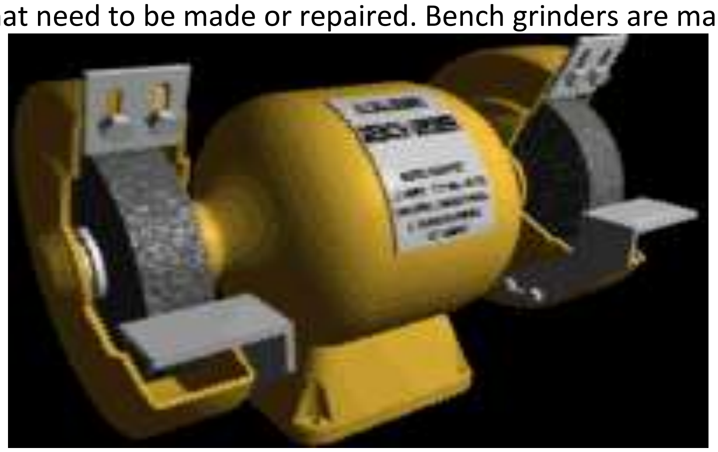
The grinding machine consists of a power driven grinding wheel spinning at the required speed (which is determined by the wheels diameter and manufacturers rating, usually by a formula) and a bed with a fixture to guide and hold the work-piece. The grinding head can be controlled to travel across a fixed work piece or the workpiece can be moved whilst the grind head stays in a fixed position. Very fine control of the grinding head or tables position is possible using a vernier calibrated hand wheel, or using the features of NC or CNC controls.

Grinding machines remove material from the workpiece by abrasion which can generate substantial amounts of heat, they therefore incorporate a coolant to cool the workpiece so that it does not overheat and go outside its tolerance, the coolant also benefits the machinist as the heat generated may cause burns in some cases. In very high-precision grinding machines (most cylindrical and surface grinders) the final grinding stages are usually set up so that they remove about 2/10000mm (less than 1/100000 in) per pass - this generates so little heat that even with no coolant, the temperature rise is negligible.

Types of grinders

Belt grinder, which is usually used as a machining method to process metals and other materials, with the aid of coated abrasives. Sanding is the machining of wood, grinding is the common name for machining metals. Belt grinding is a versatile process suitable for all kind of applications like finishing, deburring and stock removal

- Bench grinder, which usually has two wheels of different grain sizes for roughing and finishing operations and is secured to a workbench. It is used for shaping tool bits or various tools that need to be made or repaired. Bench grinders are manually operated.



- Cylindrical grinder which includes the centerless grinder. A cylindrical grinder may have multiple grinding wheels. The workpiece is rotated and fed past the wheel/s to form a cylinder. It is used to make precision rods.

Cylindrical Grinding Machine

- Surface grinder which includes the wash grinder. A surface grinder has a "head" which is lowered, and the workpiece is moved back and forth past the grinding wheel on a table that has a permanent magnet for use with magnetic stock. Surface grinders can be manually operated or have CNC controls.
- Tool and Cutter grinder and the D-bit grinder. These usually can perform the minor function of the drill bit grinder, or other specialist toolroom grinding operations.
- Jig grinder, which as the name implies, has a variety of uses when finishing jigs, dies, and fixtures. It's primary function is in the realm of grinding holes and pins. It can also be used for complex surface grinding to finish work started on a mill.

Forge

The forge or smithy is the workplace of a smith or a blacksmith. Forging is the term for shaping metal by plastic deformation. Cold forging is done at low temperatures, while conventional forging is done at high temperatures, which makes metal easier to shape and less likely to fracture.

A basic smithy contains a forge, sometimes called a hearth for heating the metals, commonly iron or steel to a temperature where the metal becomes malleable (typically red hot), or to a temperature where work hardening ceases to accumulate, an anvil to lay the metal pieces on while hammering, and a slack tub to rapidly cool, and thus harden, forged metal pieces in. Tools include tongs to hold the hot metal, and hammers to strike the hot metal.

Once the final shape has been forged, iron and steel in particular often get some type of heat treatment. This can result in various degrees of hardening or softening depending on the details of the treatment.

Forging

Forging is the working of metal by plastic deformation. It is distinguished from machining, the shaping of metal by removing material, such as by drilling, sawing, milling, turning or grinding, and from casting, wherein metal in its molten state is poured into a mold, whose form it retains on solidifying. The processes of raising, sinking, rolling, swaging,drawing and upsetting are essentially forging operations although they are not commonly so called because of the special techniques and tooling they require.

Forging results in metal that is stronger than cast or machined metal parts. This is because during forging the metal's grain flow changes in to the shape of the part, making it stronger. Some modern parts require a specific grain flow to ensure the strength and reliability of the part.

A Black Smith

Many metals are typically forged cold but iron and its alloys are almost always forged hot. This is for two reasons: first, if work hardening were allowed to progress, hard materials such as iron and steel would become extremely difficult to work with; secondly, most steel alloys can be hardened by heat treatments, such as by the formation of martensite, rather than cold forging. Alloys that are amenable to precipitation hardening, such as most structural alloys of aluminium and titanium, can also be forged hot, then made strong once they achieve their final shape. Other materials must be strengthened by the forging process itself.

Forging was done historically by a smith using hammer and anvil, and though the use of water power in the production and working of iron dates to the twelfth century CE the hammer and anvil are by no means obsolete. The smithy has evolved over centuries to the forge shop with engineered processes, production equipment, tooling, raw materials and products to meet the exacting demands of modern day society and industry.

In modern times, industrial forging is commonly done either with presses or with hammers powered by compressed air, electricity, hydraulics or steam. These hammers are very large, having reciprocating weights in the thousands of pounds. Smaller power hammers, 500 pounds or less reciprocating weight, and hydraulic presses are common in art smithies as well. Steam hammers are becoming increasingly obsolete.

In industry a distinction is made between open- and closed-die forging. In open-die work the metal is free to move except where contacted by the hammer, anvil, or other (often hand-held) tooling. In closed-die work the material is placed in a die resembling a mold, which it is forced to fill by the application of pressure. A great many common objects, like wrenches and crankshafts, are produced by closed-die forging, which is well suited to mass production. Open-die forging lends itself to very short runs and is appropriate for art smithing and custom work.

Closed-die forging is more expensive for mass production than is casting, but produces a much stronger part, and is therefore used for tools, high-strength machine parts and the like. In particular, forgings are commonly used in automotives, where a high strength requirement is demanded of the part, with a contraint on the mass of the part - in short, a high strength-to-mass ratio. Forged parts are more suitable for mass production. The process of forging a part is becomes cheaper with higher volumes. For these reasons forgings are used in the automotive industry, usually after some machining. One particular variant, drop forging, is often used to mass produce flat wrenches and other household tools.

Machine press

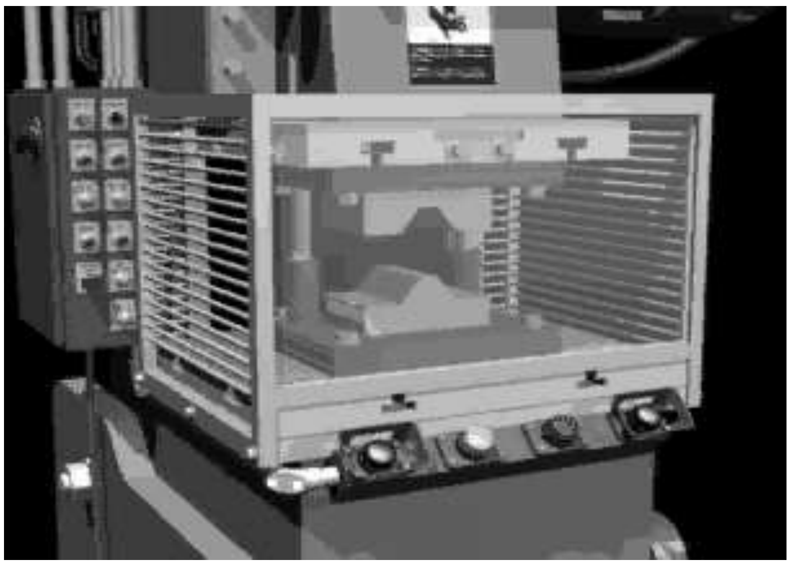
A press, or a machine press is a tool used to work metal (typically steel) by changing its shape and internal structure.

A forge press reforms the workpiece into a three dimensional object—not only changing its visible shape but also the internal structure of the material. A stronger part results from this process than if the object was machined.

Bending is a typical operation performed and occurs by a machine pressing, or applying direct pressure, to the material and forcing it to change shape. A press brake is a typical machine for this operation.

An easy to understand type of machine press is a set of rollers. Metal is fed into the rollers, which are turning to pull the material through. The space between the rollers is smaller than the unfinished metal, and thus the metal is made thinner and/or wider.
Another kind of press is a set of plates with a relief, or depth-based design, in them. The metal is placed between the plates, and the plates are pressed up against each other, deforming the metal in the desired fashion. This may be coining or embossing or forming. A punch press is used for forming holes.

Progressive stamping is a manufacturing method that can encompass punching, coining, bending and several ways of modifying the metal, combined with an automatic feeding system. The feeding system pushes a coil of metal through all of the stations of a progressive stamping die. Each station performs one or more operations until a finished part is made per the requirements on the print. The final operation is a cutoff operation, which separates the finished part from the carrying web. The carrying web, along with metal that is punched away in previous operations, is considered scrap metal.



A Press Brake is a special type of machine press that bends sheetmetal into shape. A good example of the type of work a press break can do is the backplate of a computer case. Other examples include brackets, frame pieces and electronic enclosures just to name a few. Some press breaks have CNC controls and can form parts with accuracy to a fraction of a millimeter. These machines can be dangerous considering the knife-edge bending dies and powerful 100+ ton bending force. However in the hands of a skilled operator the machine presents minimum hazard.

Machine presses are used extensively around the world for shaping all kinds of metals to a desired shape. A typical toaster (for bread) has a metal case that has been bent and pressed into shape by a machine press.

Also remember that machine presses have a high hazardous level , so safety measures must always be taken. Injuries in a press may aways be permanent , since there are over 100s tons on top of a limb. Bimanual controls (both hands need to be on the buttons to make the press work) are a very good way to prevent accidents. Also light sensors that keep the machine from working if the operator is in range of the die (tool that goes inside the press to shape metal), or any limbs is in range.

CVSRTA

Hydraulic press

A hydraulic press is a hydraulic mechanism for applying a large lifting or compressive force. It is the hydraulic equivalent of a mechanical lever, and is also known as a Bramah press after the inventor, Joseph Bramah. Hydraulic presses are the most commonly-used and efficient form of modern press.

Guillotine Shear m/c

A guillotine is a machine used to accurately cut sheet metal. It may be foot-operated (or less commonly hand-operated), or powered. An angled blade is driven down which slices the metal along the length of the cut, shearing it off very cleanly.

Depending on the capacity of the machine, the angle of the blade may be varied along with the clearance between the upper and lower blades. The thicker the material, the greater the angle and clearance given to the blades.

The angle of the blade is referred to as shear, and this provides a slicing rather than a chopping action; by slicing the material a cleaner cut is produced and less energy is used. This is because the blade contacts only a small area at a time rather than the full length of the cut (which is also how scissors work).

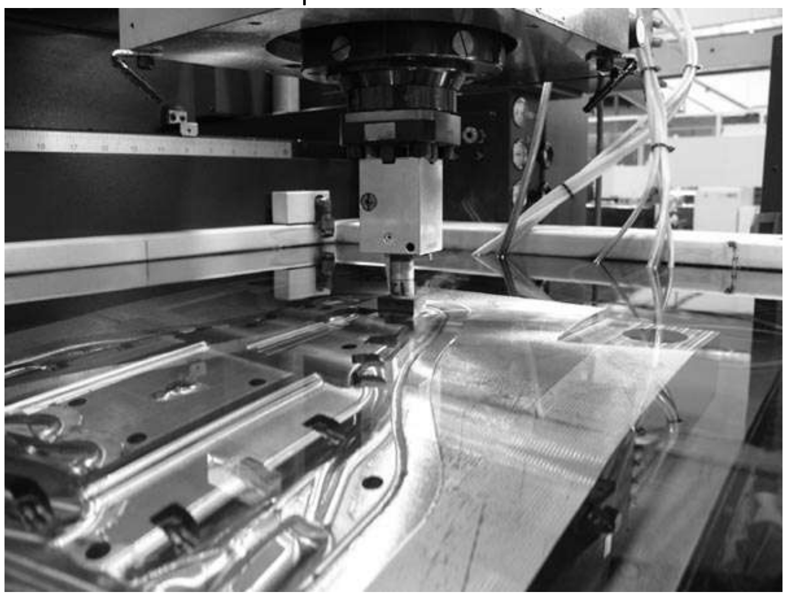
Clearance is defined as the separation between the blades, measured at the point where the cutting action takes place, and perpendicular to the direction of blade movement. It affects the finish of the cut (burr) and the machine's power consumption, and is directly related to the material's composition. The cut of a guillotine is in part a fracturing process; the blade partially penetrates the material but the final separation is due to the material fracturing. Harder materials (such as stainless steel) fracture more readily than softer ones (such as brass).

The design of press tools and guillotine blades is an engineering compromise. A sharp edge is required, along with strength and durability, so to achieve these two objectives the blades for metal work tend to be square-edged rather than knife-edged. The difference between the two angles is called the rake

Electrical discharge machining

Electrical discharge machining (or EDM) is a machining method primarily used for hard metals or those that would be impossible to machine with traditional techniques. One critical limitation, however, is that EDM only works with materials that are electrically conductive. EDM can cut small or odd-shaped angles, intricate contours or cavities in extremely hard steel and exotic metals such as titanium, hastelloy, kovar, inconel and carbide.

Sometimes referred to as spark machining or spark eroding, EDM is a nontraditional method of removing material by a series of rapidly recurring electric arcing discharges between an electrode (the cutting tool) and the work piece, in the presence of an energetic electric field. The EDM cutting tool is guided along the desired path very close to the work but it does not touch the piece.



Consecutive sparks produce a series of micro-craters on the work piece and remove material along the cutting path by melting and vaporization. The particles are washed away by the continuously flushing dielectric fluid.

Engraving

Engraving is the practice of incising a design onto a hard, flat surface, by cutting grooves into it. The result may be a decorative object in itself, as when silver or gold are engraved, or may provide an intaglio printing plate, of copper or another metal.

The engraving process

Engravers use a hardened steel tool called a burin to cut the design into the surface, most traditionally a copper plate. Gravers come in a variety of shapes and sizes that yield different line types. The burin produces a unique and recognizable quality of line that is characterized by its steady, deliberate appearance and clean edges. The angle tint tool has a slightly curved tip that is commonly used in printmaking. Florentine liners are flat-bottomed tools with multiple lines incised into them, used to do fill work on larger areas. Flat gravers are used for doing fill work on letters, as well as most musical instrument engraving work. Round gravers are commonly used on silver to create bright cuts (also called bright-cut engraving), as well as other hard-to-cut metals such as nickel and steel.

Burins are either square or elongated diamond-shaped and used for cutting straight lines. Other tools such as mezzotint rockers, roulets and burnishers are used for texturing effects.

Laser engraving

Laser engraving is the practice of using lasers to engrave, etch, or mark an object. The technique can be very technical and complex, and often a computer system is used to drive the movements of the laser head. Despite this complexity, very precise and clean engravings can be achieved at a high rate. The technique does not involve tool bits which contact the engraving surface and wear out. This is considered an advantage over alternative engraving technologies where bit heads have to be replaced regularly.
The impact of laser engraving has been more pronounced for specially-designed "laserable" materials. These include polymer and novel metal alloys.

In situations where physical alteration of a surface by engraving is undesirable, an alternative such as "marking" is available. This is a generic term that covers a broad spectrum of surfacing techniques, including printing and hot-branding. In many instances, laser engraving machines are able to do marking that would have been done by other processes.

Laser engraving machines

A laser engraving machine can be thought of as three main parts: a laser, a controller, and a surface. The laser is like a pencil - the beam emitted from it allows the controller to trace patterns onto the surface. The controller (usually a computer) controls the direction, intensity, speed of movement, and spread of the laser beam aimed at the surface. The surface is picked to match what the laser can act on.

There are two main genres of engraving machines: The most common is the X-Y table where, usually, the workpiece (surface) is stationary and the laser moves around in X and Y directions drawing vectors. Sometimes the laser is stationary and the workpiece moves. Sometimes the workpiece moves in the Y axis and the laser in the X axis. The other genre is for cylindrical workpieces (or flat workpieces mounted around a cylinder) where the laser effectively traverses a fine helix and on/off laser pulsing produces the desired image on a raster basis.

The point where the laser (the terms "laser" and "laser beam" may be used interchangeably) touches the surface should be on the focal plane of the laser's optical system, and is usually synonymous with its focal point. This point is typically small, perhaps less than a fraction of a millimeter (depending on the optical wavelength). Only the area inside this focal point is significantly affected when the laser beam passes over the surface.

The energy delivered by the laser changes the surface of the material under the focal point. It may heat up the surface and subsequently vaporize the material, or perhaps the material may fracture (known as "glass" or "glass up") and flake off the surface. This is how material is removed from the surface to create an engraving.

If the surface material is vaporized during laser engraving, ventilation through the use of blowers or a vacuum pump are almost always required to remove the noxious fumes and smoke arising from this process, and for removal of debris on the surface to allow the laser to continue etching.

A laser can remove material very efficiently because the laser beam can be designed to deliver energy to the surface in a manner which converts a high percentage of the light energy into heat. The beam is highly focused and collimated - in most non-reflective materials like wood, plastics and enamel surfaces, the conversion of light energy to heat is more than {x%} efficient {example reference needed}. However, because of this efficiency, the equipment used in laser engraving may heat up rather quickly. Elaborate cooling systems are required for the laser. Alternatively, the laser beam may be pulsed to decrease the amount of excessive heating.

Exercise:

1. What is a lathe?
2. Discuss various types of lathe.
3. Name the varients of “cutting m/c”
4. Describe the process of drilling.
5. Describe the types of:-
    a. Milling m/c
    b. Grinding m/c
    c. Engraving

CHAPTER - 3
MACHINE TOOLS & EQUIPMENTS

A cutting tool, in the context of metalworking is any tool that is used to remove metal from the workpiece by means of shear deformation. In order to last, cutting tools must be made of a material harder than the material which is to be cut, and they must be able to withstand the heat generated in the metal cutting process. They also must have a specific geometry, designed so that the cutting edge can contact the workpiece without the rest of the tool dragging on its surface. The angle of the cutting face is also important.

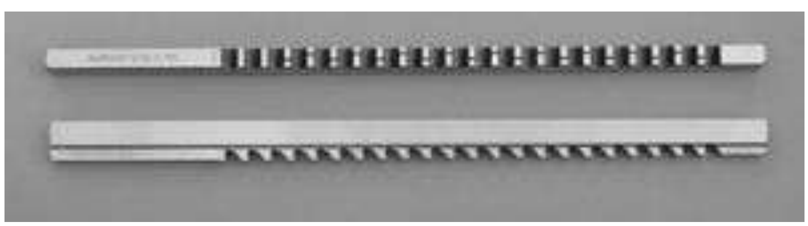
Types of cutting tools

- Broach
- Endmill
- Reamer
- Drill bit
- Tool bit (used in a lathe, flycutter, shaper or planer)
- Countersink

There are many other types of cutting tools, but these are a few of the important ones

Broach

A broach is a series of progressively taller chisel points mounted on a single piece of steel, typically used to enlarge a circular hole into a larger noncircular shape such as a square or other desired shape.



Another typical use of a broach is to cut splines or a square keyway (see image) on objects such as gears, driveshafts, pulleys etc. The amount of material removed by each broach tooth (or chisel) varies with the material being cut. A broach tooth designed to cut steel might remove only 0.05 mm (0.0025 inch), while a broach tooth designed to cut brass might remove as much as 0.10 mm (0.004 inch). The succession of teeth (chisels) removes the total amount of material required. A broach may also be designed to be pushed or pulled through an existing hole; broaching machines are therefore designed accordingly.

Wobble or Rotary Broach

A somewhat different design of tool that can achieve the irregular hole shape of a broach is called a wobble broach. This type of tool is often used on rotating machines such as lathes. The wobble broaching process is also called rotary broaching.

The tool has a contour similar to the desired final shape but the leading edge of the tool is wider than the body. The tool is free to rotate but the axis of rotation is inclined slightly to the axis of rotation of the work. A typical value for this misalignment is 1 degree. As the work rotates, the broach is pressed against it and rotates synchronously with it. However, since the axis of rotation is different, the leading (cutting) edge of the broach "wobbles" with respect to the work.

If the tool is inclined at an angle of 1 degree to the work, the sides of the tool must have a 1 degree or greater draft.

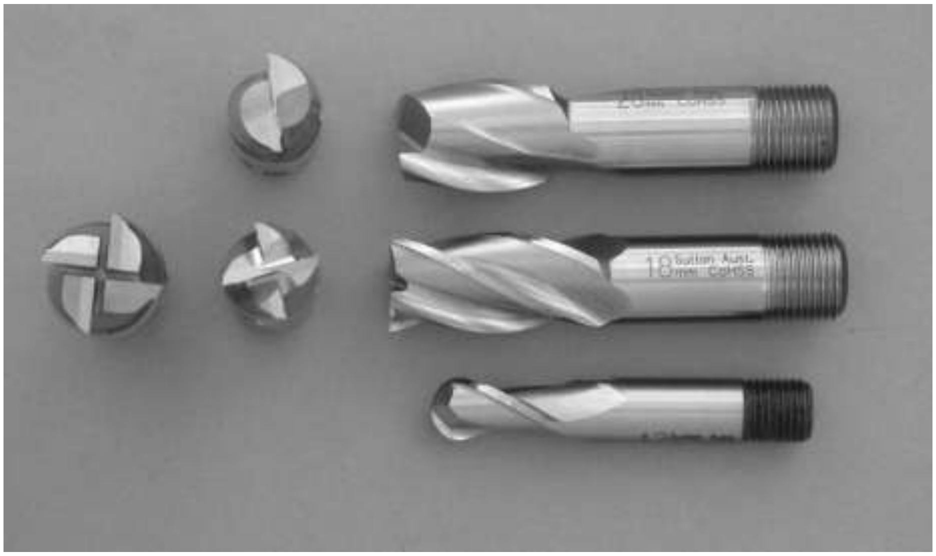
Ideally the tool advances at the same rate that it cuts. So a 1/2" diameter tool should advance at 0.009" per revolution. 1/2*sin(1). If it advances any faster than that then the tool becomes choked, if it advances any more slowly then you get an interrupted or zig-zag cut. Since all work material is elastic, you would actually cut a little less than the ideal rate just to release the load on the non-cutting edge of the tool.

There is some spiraling of the tool as it cuts so the bottom of the hole may be rotated with respect to the top of the hole. Spiraling may be undesirable because it binds the body of the tool and prevents it from wobbling freely. One solution to this is to reverse the rotation in mid cut causing the tool to spiral in the opposite direction. If reversing the machine is not practical, then interrupting the cut is another possible solution.

In general, a wobble broach will not cut as accurately as a push or pull broach. However, the ability to use a wobble broach on high production machinery such as a screw machine makes this a desirable manufacturing method.

Endmill

An endmill is a type of Milling cutter, a cutting tool used in industrial milling applications. It is distinguished from its cousin, the drill bit, in its application, geometry, and manufacture. The term "endmill" is sometimes considered to be machinist's slang, but has come into standard usage in industry publications, trade magazines, and manufacturers catalogues.



Types

A broad category of end and face milling tools exists, such as flat bottom, ball nose, radius, inverted radius, and chamfer tools. Each category may be further divided by specific application and special geometry.

It is becoming increasingly more common for traditional solid endmills to be replaced by more cost-effective inserted cutting tools (which, though more expensive initially, reduce tool-change times and allow for the easy replacement of worn or broken cutting edges rather than the entire tool).

Endmills are sold in both imperial and metric shank and cutting diameters. In the USA, metric is readily available, but not commonly used by machine shops; in Canada, due to the country's proximity to the US, much the same is true. In Asia and Europe, while imperial is readily available, metric diameters are standard.

Applications

Endmills are used in milling applications such as profile milling, tracer milling, face milling, and the like. Depending on the material being milled, and what task should be performed, different tool types and geometry may be used. For instance, when milling a material like aluminum, it may be adventageous to use a tool with a very shallow flute depth, and a pre-dulled (but polished) cutting edge.

Reamer

A reamer or ream is a tool for enlarging holes and is used in metalworking. It may be used as a hand tool or may have a specialized drive end. For production machine tools the drive will usually be a standard taper. For hand tools the drive will usually be a square drive, intended for use with the same type of wrench used to turn a tap for the cutting of screw threads.

A typical reamer consists of a set of parallel straight or helical cutting edges along the length of a cylindrical body. Each cutting edge is ground at a slight angle and with a slight undercut below the cutting edge. Reamers must combine both hardness in the cutting edges, for long life, and toughness, so that the tool does not fail under the normal forces of use. They should only be used to remove small amounts of material. This ensures a long life for the reamer and a superior finish to the hole.

The spiral may be clockwise or counter-clockwise depending on usage. For example, a tapered hand reamer with a clockwise spiral will tend to self feed as it is used, possibly leading to a wedging action and consequent breakage. A counter-clockwise spiral is therefore preferred even though the reamer is still turned in the clockwise direction.
reamer is still turned in the clockwise direction.

Drill bit

Drill bits are cutting tools used to create cylindrical holes. Bits are held in a tool called a drill, which rotates them and provides axial force to create the hole. Specialized bits are also available for non-cylindrical-shaped holes.

Drill Bits

This article describes the types of drill bits in terms of the design of the cutter. The other end of the drill bit, the shank, is described in the drill bit shank article. Drill bits come in standard sizes, described in the drill bit sizes article. A comprehensive drill and tap size chart lists metric and imperial sized drills alongside the required screw tap sizes.

The term drill can refer to a drilling machine, or can refer to a drill bit for use in a drilling machine. In this article, for clarity, drill bit or bit is used throughout to refer to a bit for use in a drilling machine, and drill refers always to a drilling machine.

Metal Drills

Twist drill

The twist drill bit is the type produced in largest quantity today. It can be used to create holes in metal, plastic, wood and stone.

The twist drill bit was invented by Steven A. Morse[1] of East Bridgewater, Massachusetts in 1861. He received U.S. Patent 38119 for his invention on 7 April 1863. The original method of manufacture was to cut two grooves in opposite sides of a round bar, then to twist the bar to produce the helical flutes. This gave the tool its name. Nowadays, the drill bit is usually made by rotating the bar while moving it past a grinding wheel to cut the flutes in the same manner as cutting helical gears.

Tools recognisable as twist drill bits are currently produced in diameters covering the range at least from 0.05 mm to 100 mm. Lengths up to about 1000 mm are available for use in powered hand tools.

The geometry and sharpening of the cutting edges is crucial to the performance of the bit. Users often throw away small bits that become blunt, and replace them with new bits, because they are inexpensive and sharpening them well is difficult.
For larger bits, special grinding jigs are available. A special tool grinder is available for sharpening or reshaping cutting surfaces on twist drills to optimize the drill for a particular material.

Manufacturers can produce special versions of the twist drill bit, varying the geometry and the materials used, to suit particular machinery and particular materials to be cut. Twist drill bits are available in the widest choice of tooling materials. However, even for industrial users, most holes are still drilled with a conventional bit of high speed steel.
The most common twist drill (the one sold in general hardware stores) has a point of 118 degrees. This is a suitable angle for a wide array of tasks, and will not cause the uninitiated operator undue stress by walking or digging in. A more aggressive (pointy) angle, such as 90 degrees, is suited for very soft plastics and other materials. The bit will generally be self-starting and cut very quickly. A shallower angle, such as 150 degrees, is suited for drilling steels and other tougher materials. This style bit requires a starter hole, but will not bind or suffer premature wear when a proper feed rate is set.

Drills with no point angle are used in situations where a blind, flat-bottomed hole is required. These style drills are very sensitive to changes in lip angle, and even a slight change can result in an inappropriately fast cutting drill bit that will suffer premature wear.

The tool geometry is broken down into several areas:

- The **helix**, or rate of twist in the drill, controls the rate of chip removal in a drill. A low helix drill is used in high feed rate applications under low spindle speeds, where removal of a large volume of swarf is required. High helix drills are used in cutting applications where traditionally high cutting speeds are used and the material has a tendency to gall on the drill or otherwise clog the hole, such as aluminum or copper.
- **Point angle** is determined by the material the drill will be operating in. Harder materials require a larger point angle, and softer materials require a more pointed angle. The correct point angle for the hardness of the material controls wandering, chatter, hole shape, wear rate, and a wide array of other characteristics.

- **Lip angle** determines the amount of support provided to the cutting edge. A greater lip angle will cause the drill to cut more aggressively under the same amount of point pressure as a drill with a smaller lip angle. Both conditions can cause binding, wear, and eventual catastrophic failure of the tool. The proper amount of lip clearance is determined by the point angle. A very acute point angle has more web surface area presented to the work at any one time, requiring an aggressive lip angle, where a flat drill is extremely sensitive to small changes in lip angle due to the small surface area supporting the cutting edges.

Tool bit

The term tool bit generally refers to a non-rotary cutting tool used in metal lathes, shapers, and planers. Such cutters are also often referred to by the set-phrase name of single-point cutting tool. The cutting edge is ground to suit a particular machining operation and may be resharpened or reshaped as needed. The ground tool bit is held rigidly by a tool holder while it is cutting.

Materials

Originally, all tool bits were made of high carbon tool steels with the appropriate hardening and tempering. Since the introductions of high-speed steel (HSS) (early years of the 20th century), sintered carbide (1930s), and ceramic cutters, those materials have gradually replaced the earlier kinds of tool steel in almost all cutting applications. Most tool bits today are either HSS or carbide

Carbides and ceramics

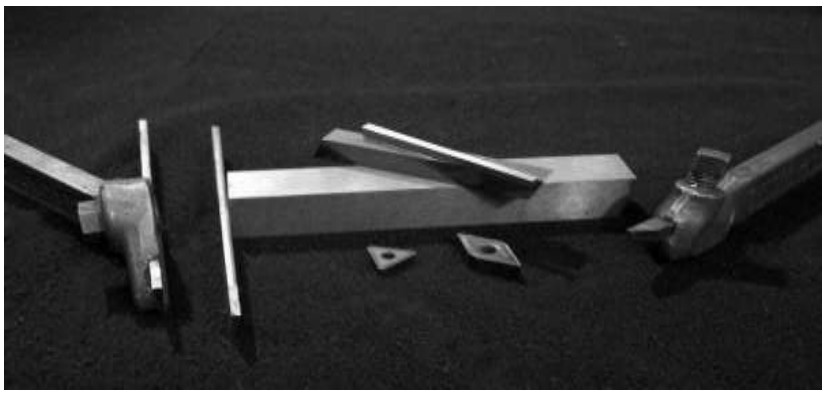
Carbide, ceramics (such as cubic boron nitride), and diamond, having higher hardness than HSS, all allow faster material removal than HSS in most cases. Because these materials are expensive and hard to work with, typically the body of the cutting tool is made of steel, and a small cutting edge made of the harder material is attached. The cutting edge is usually either screwed on (in this case it is called an insert), or brazed on to a steel shank (this is usually only done for carbide).

Tool holders

By confining the expensive hard cutting tip to the part doing the actual cutting, the cost of tooling is reduced. The supporting tool holder can then be made from a tougher steel, which besides being cheaper is also usually better suited to the task, being less brittle than the cutting-edge materials.

The tool holders may also be designed to introduce additional properties to the cutting action, such as

- Angular approach - direction of tool travel.
- Spring loading - deflection of the tool bit away from the material when excessive load is applied.
- Variable overhang - the tool bit may be extended or retracted as the job requires.
- Rigidity - the tool holder can be sized according to the work to be performed.
- Direct cutting fluid or coolant to the work area.



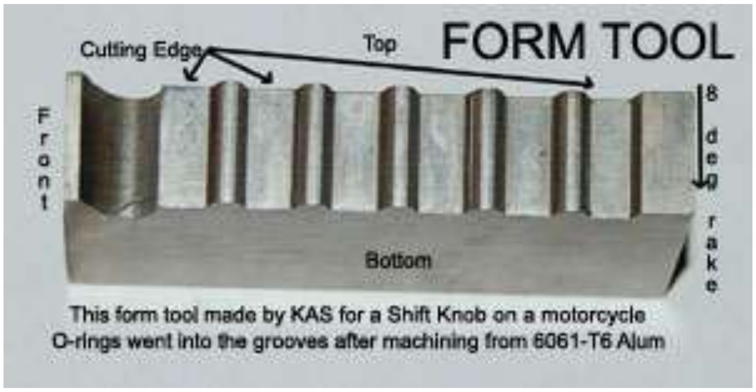
Inserts

Almost all high-performance cutting tools use the insert method. There are several reasons for this. First of all, at the very high cutting speeds and feeds supported by these materials, the cutting tip can reach temperatures high enough to melt the brazing material holding it to the shank. Economics are also important; inserts are made symmetrically so that when the first cutting edge is dull they can be rotated, presenting a fresh cutting edge. Some inserts are even made so that they can be flipped over, giving as many as 8 cutting edges per insert.

There are many types of inserts: some for roughing, some for finishing. Others are made for specialized jobs like cutting threads or grooves. The industry employs standardized nomenclature to describe inserts by shape, material, coating material, and size.

Form tools

This form tool is for a shift knob on a motorcycle. O-rings went into the grooves after machining from 6061-T6 Aluminum. This tool has an 8-degree rake from top to bottom for clearance. This tool was designed for a 2G Brown & Sharpe screw machine.



A form tool is precision-ground into a pattern that resembles the part to be formed. The form tool can be used as a single operation and therefore eliminate many other operations from the slides (front, rear and/or vertical) and the turret, such as boxtools. A form tool turns one or more diameters while feeding into the work. Before the use of forum tools, diameters were turned by multiple slide and turret operations, and thus more work to make the part. For example, a form tool can turn many diameters and in addition can also cutoff the part in a single operation and eliminate indexing the turret.

For single-spindle machines, bypassing indexing the machine can dramatically increase hourly part production. On long-running jobs it is common to use a 'roughing tool' tool on a different slide, or from the turret to remove the bulk of material to reduce wear on the form tool. There are also different types of form tools. Insert tools are the most common for short- to medium-range jobs (50 to 20,000 pcs). Circular form tools are usually for longer jobs, since the tool wear can be ground off the tool tip many times as the tool is rotated in its holder. There is also a skiving tool that can be used for light finishing cuts. Form tools can be made of cobalt, carbide, or high-speed steel. Carbide requires additional care because it is very brittle and will chip if chatter occurs.

A drawback when using form tools is that the feed into the work is usually slow, .0005" to .0012" per revolution depending on the width of the tool. Wide form tools create more heat and usually are problematic for chatter. Heat and chatter reduces tool life. Also, form tools wider than 2.5 times the smaller diameter of the part being turned have a greater risk of the part breaking off. When turning longer lengths, a support from the turret can be used to increase turning length from 2.5 times to 5 times the smallest diameter of the part being turned, and this also can help reduce chatter. Despite the drawbacks, the elimination of extra operations often makes using form tools the most efficient option.

Mandrel

A mandrel (pronounced "mandrul", and also transliterated as manderil) is either an object used to shape machined work; a tool component that grips or clamps materials to be machined; or a tool component that can be used to grip other moving tool components.

An example of one type of mandrel is a shaped bar of metal inserted in, or next to, an item to be machined or bent in a certain pattern. Exhaust pipes in automobiles are frequently bent using a mandrel during manufacture. The mandrel allows the exhaust pipes to be bent into smooth curves without undesirable creasing, kinking, or collapsing. Molten glass may be shaped in this way as well. Another example of this type of mandrel is found in jewelry manufacturing, where ring and bracelet mandrels are used to shape metal into a desired size and shape, using a tiny hammer to beat the metal against the mandrel.

Another type of mandrel is the clamp that a lathe uses to hold pieces of wood, metal or plastic to be machined as they are turned. In this way, rods can be threaded, furniture legs are turned to have beautiful patterns, and irregularly-shaped objects can be given a cylindrical or round shape.

The third type of mandrel discussed here is that which is used to hold circular saw blades, buffing wheels (used for polishing), and sanding discs onto drills, circular saws, and similar power tools. A mandrel of this type generally consists of a cylinder, threaded on one end, with a washer brazed onto the threaded end and an accompanying screw and second washer which are used to clamp the circular saw blade, sanding media, or other rotary tool onto the mandrel.

While most mandrels are driven by direct connection to an electric motor or engine, other mandrels are driven by attachment to a bearing-supported, pulley-driven shaft.
In fiber optics, an optical fiber is often wrapped around a mandrel to alter the light travelling in the fiber.

Chuck
A Chuck is a specialised type of clamp used to hold rotating tools or materials.

Collet
A collet is a sleeve with a (normally) cylindrical inside and a conical outside. The collet has kerf cuts along its length to allow it to expand and contract. A threaded section at the rear of the collet is used to pull it into a matching conical socket. As the collet is pulled into the socket, the collet will contract - gripping the contents of the inner cylinder. Collets are most commonly found on milling machines, lathes, wood routers, and precision grinders. There are many different systems, common examples being the ER and R8 systems. Collets can also be obtained to fit Morse or Brown and Sharpe taper sockets.

Typically collets offer far higher levels of precision and accuracy than self-centering chucks, and have a far shorter setting up time than independent-jaw chucks. The penalty is that most collets can only accommodate a single size of workpiece. An exception are ER collets which typically have a working range of 1 mm (about 0.04 inches).

Collets usually are made to hold cylindrical work, but are available to hold square, hexagonal or octagonal workpieces.

Drill Chuck

A drill chuck is a specialised three-jaw chuck used to hold drill bits or related tools.

The image at right shows an assembled keyless chuck at the top. The tightening action of this chuck style is performed by twisting the body using firm hand pressure only.

The lower images show the traditional keyed style of drill chuck with its key. The arbor is shown separately to the right. These chucks require a key to provide the necessary torque to tighten and loosen the jaws. The rotary action of the key turns the outer body which acts on an internal screw; this in turn moves the threaded jaws in or out along a tapered surface. The taper allows the jaws to encompass various sizes of drill shanks. The end view shows the three small jaws that slide within the body.

Some high precision chucks use ball thrust bearings to reduce friction in the closing mechanism and maximizing drilling torque. These chucks are sometimes referred to as "superchucks".

Special Direct System (SDS)

Developed by Bosch in 1975 for hammer drills, the SDS uses a cylindrical shank on the tool, with indents to be held by the chuck. A tool is inserted into the chuck by pressing in, and is locked in place until a separate lock release is used – no tightening required. The rotary force is supplied through wedges that fit into two or three open grooves. The hammer action actually moves the bit up and down within the chuck since the bit is free to move a short distance. Two sprung balls fit into closed grooves, allowing movement whilst retaining the bit. SDS relies on a tool having the same shank diameter as the chuck - there are three standard sizes:

- **SDS-Plus** – a 10 mm shank with two open grooves held by the driving wedges and two closed grooves held by locking balls. This is the most common size and takes a hammer up to 4 kg. The wedges grip an area of 75 mm² and the shank is inserted 40 mm into the chuck

- **SDS-top** a 14 mm shank similar to SDS-plus, designed for hammers from 2 to 5 kg. The grip area is increased to 212 mm² and the shank is inserted 70 mm. This size is not common
- **SDS-max** – an 18 mm shank with three open grooves and locking segments rather than balls. It is designed for hammers over 5 kg. The wedges grip an area of 389 mm2 and the shank is inserted 90 mm.

Many SDS drills have a "rotation off" setting, which allows the drill to be used for chiselling. The name SDS comes from the German "Steck – Dreh – Sitz" (Insert – Twist – Stay). German-speaking countries may use "Spannen durch System" (Clamping System), though Bosch uses "Special Direct System" for international purposes.

Three-jaw Chuck

A three-jaw chuck is a rotating clamp which uses three interconnected dogs or 'jaws' to hold onto a tool or work piece. Three-jaw chucks are usually self-centering and are best suited to grip circular cross sections, though independent versions can be obtained.

The image shows a three-jaw chuck and key with one jaw removed and inverted showing the teeth that engage in the scroll plate. The scroll plate is rotated within the chuck body by the key, the scroll engages the teeth on the underside of the jaws which moves the three jaws in unison, to tighten or release the workpiece.

The *Griptru™* style of self-centering chuck from Pratt Burnerd Intl., Ltd. has further adjustment screws which can be used to further improve the accuracy of the chuck at any chosen diameter of workpiece.

Three-jaw chucks can be found on lathes and indexing heads.

Four-jaw Chuck

A four-jaw chuck is similar to a three-jaw chuck, but with four jaws, each of which can be moved independently. This makes them ideal for gripping non-circular cross sections, but difficult to centre precisely. Four-jaw chucks are almost never used for tool holding. Four-jaw chucks can be found on lathes and indexing heads.

The image shows a four-jaw chuck with the jaws independently set. The key is used to adjust each jaw separately.

Multi jaw Chuck

For special purposes, and also the holding of fragile materials, chucks are available with six or eight jaws. These are invariably of the self-centering design, and are built to very high standards of accuracy.

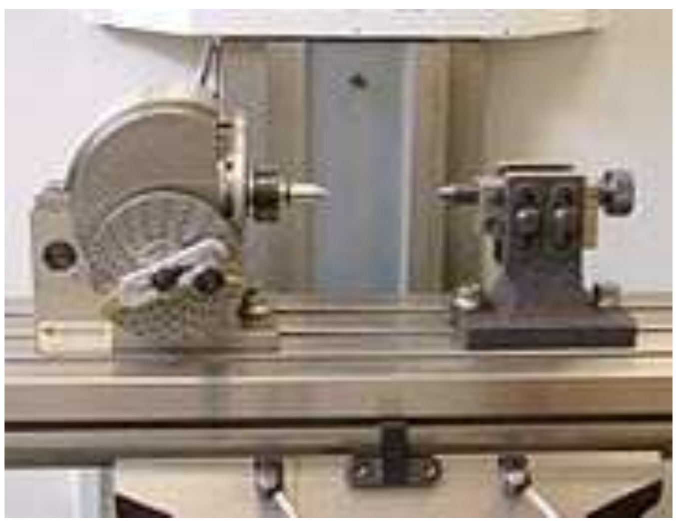
Self-centering four jaw Chuck

A four jaw chuck with a mechanism for centering the work piece. Sometimes used to refer to chucks where the jaws are moved in interconnected pairs.

Magnetic Chuck

Used only for holding ferro-metallic work pieces, a magnetic chuck consists of an accurately centred permanent magnet face. Electro Magnets or permanent magnets are brought into contact with fixed ferrous plates, or 'pole pieces', contained within a housing. These pole pieces are usuall flush with the housing surface. The part or 'work piece' to be held forms the closing of the magnetic loop or path, onto those fixed plates, providing a secure anchor for the work piece

Indexing head



Indexing head and tailstock set up on a milling machines table

An indexing head is a specialized tool that allows a work piece to be rotated to any angle or circular division.

The tool is similar to a rotary table except that it is designed to be adjustable through at least 90 &deg: (in fact it will over travel to approx 95°).

Indexing plates

Simple indexing consists of a series of preset holes in a backing plate, these divisions are provided for the most common angles (such as 90 °, 45 °, 30 °, etc). The remaining divisions of a circle are provided by manually rotating the dividing arm using index plates. Tables or calculations are required to use this method.

Lathe center

A lathe center (or center) is a tool that has been ground to an included angle of 60 ° and is used to accurately position a workpiece about its axis.

The primary use of a center in metalworking is to ensure concentric work is produced, this allows the workpiece to be transferred between operations without any loss of accuracy. A part may be turned in a lathe, sent off for hardening and tempering and then ground between centers in a cylindrical grinder. The preservation of concentricity between the turning and grinding operations is crucial for quality work. A center is also used to support longer work pieces where the cutting forces would deflect the work. excessively, reducing the finish and accuracy of the workpiece, or creating a hazardous situation.

A center has applications anywhere that a centered workpiece may be used, this is not limited to lathe usage but may include setups in dividing heads, cylindrical grinders, tool and cutter grinders or other related equipment. The term between centers refers to any machining operation where the job needs to be performed using centers.
A center is inserted into a matching hole drilled by a center drill.

Dead center

A dead center (one that does not turn freely, ie:- dead) may be used to support the workpiece at either the fixed or rotating end of the machine. When used in the fixed position, a dead center produces friction between the workpiece and center, due to the rotation of the workpiece. Lubrication is therefore required between the center and workpiece to prevent friction welding from occurring. Additionally the tip of the center may have an insert of carbide which will reduce the friction slightly and allow for faster speeds. Dead centers may also be fully hardened to prevent damage to the important mating surfaces taper of the taper and to preserve the 60 ° nose taper.

Machine taper

Machine tool operators must be able to install or remove cutting bits or other accessories quickly and easily from the machine tool's powered rotating spindle. A lathe, for example, has a rotating spindle in its headstock, to which one may want to mount a spur drive or work in a collet. Another example is a drill press, to which an operator may want to mount a bit directly, or using a drill chuck.

Several options exist: (1) a threaded spindle, into/onto which accessories are screwed, (2) a permanently mounted chuck (as with some drill presses), or (3) a taper mount.
This simple, low-cost, and versatile tool mounting system involves (A) tool bits or holders with gradually tapered shanks, and (B) a matching hollowed-out spindle. Tools are simply slipped onto or into the spindle; the pressure of the spindle against the workpiece drives the tapered shank tightly into the tapered hole. The friction across the entire surface area of the interface provides a surprisingly large amount of torque transmission, so that splines or keys are not required.
This system is known as a machine taper.

Magnetic base

A magnetic base is often used to hold a dial indicator, however its versatility is only limited by the operator's ingenuity.

The vertical post, side arm (as shown in the image at right) and the dial indicator (not shown) are connected by two swivelling connectors. These connectors allow free movement of the arms so that the indicator can be presented to the work in a suitable orientation. The magnetic base may have a "V" cut into the bottom of the base or the back, this "V" allows the base to be attached to a round bar such as the column of a drill press.

The base is made from two blocks of iron, with a round cavity bored through the centre. The halves are joined together with a non magnetic material such as brass or aluminium. A round permanent magnet is inserted into the bored hole and a handle is attached to allow easy rotation of the magnet. This act of rotation changes the direction of the magnetic field so that it is either directed into the two halves, where the iron blocks act as keepers (off position), or directed so that the field traverses the non-magnetic material between the two halves (on position).
In this on position the field is effectively passing across an air gap where it can be made to do work, if this gap is bridged with another piece of iron (or steel in our case) it becomes part of the magnetic field's "circuit" and will be attracted with the full strength of the magnet, this is the work we want it to do — clamping.

Rotary table

A rotary table is a precision work positioning device used in metalworking. It enables the operator to drill or cut work at exact intervals around a fixed (usually horizontal or vertical) axis. Some rotary tables allow the use of index plates for indexing operations, and some can also be fitted with dividing plates that enable regular work positioning at divisions for which indexing plates are not available. A rotary fixture used in this fashion is more appropriately called a dividing head.
(indexing head).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The table shown is a manually operated type. Powered tables under the control of CNC machines are now available, and provide a fourth axis to CNC milling machines.

Rotary tables are made with a solid base, which has provision for clamping onto another table or fixture. The actual table is a precision-machined disc to which the work piece is clamped (T slots are generally provided for this purpose). This disc can rotate freely, for indexing, or under the control of a worm (handwheel), with the worm wheel portion being made part of the actual table.

The ratio between worm and table is generally 40:1, but may be any ratio that can be easily divided into 360°. This is for ease of use when indexing plates are available. A graduated dial and, often, a vernier scale enable the operator to position the table, and thus the work affixed to it with great accuracy.
A center hole is usually machined into the table. Most commonly, this hole is machined to admit a Morse taper center or fixture.

Use

Rotary tables are most commonly mounted "flat" with the table rotating around a vertical axis, in the same plane as the cutter of a vertical milling machine. If the rotary table can be mounted on its end, so that it rotates about a horizontal axis, a tailstock can be used to hold the workpiece "between centers."

With the table mounted on a secondary table, the workpiece is accurately centered around the rotary table's axis, which in turn is centered around the cutting tool's axis. All three axes are thus coaxial. From this point, the secondary table can be offset in either the X or Y direction to set the cutter the desired distance from the workpiece's center. This allows concentric machining operations on the workpiece. Placing the workpiece eccentrically a set distance from the center permits more complex curves to be cut. As with other setups on a vertical mill, the milling operation can be either drilling a series of concentric, and possibly equidistant holes, or face or end milling either circular or semicircular shapes and conours.

A rotary table can be used:

- To machine spanner flats on a bolt
- To drill equidistant holes on a circular flange
- To cut a round piece with a protruding tang
- To cut complex curves (with proper setup)

Vise

A vise (American and Canadian English) or vice (British English) is a mechanical screw apparatus used for holding or clamping a work piece to allow work to be performed on it using other tools, such as saws, planes, drills, mills, screwdrivers, sandpaper, etc. In general, vises have a fixed jaw with another moved in relation to it by the use of the screw.

Varieties of vise or vice

Without qualification, "vise" usually refers to a bench vise with flat, parallel jaws, attached to a workbench.

- A woodworker's bench vice is a more or less integral part of the bench.
- An engineer's bench vise is bolted onto the top of the bench.

Other kinds of vise include:

- hand vises (hand-held),
- machine vises - drill vises (lie flat on a drill press bed). Vises of the same general form are used also on milling machines and grinding machines.
- compound slide vises are more complex machine vises. They allow speed and precision in the placement of the work.
- off-center vises,
- angle vises,
- sine vises, which use solving triangles and gauge blocks to set up a highly accurate angle,
- rotary vises,
- diemakers' vises,
- table vises,
- pin vises (for holding thin, long cylindrical objects by one end),
- jewellers' vises and by contrast,
- leg vises, which are attached to a bench but also supported from the ground so as to be stable under the very heavy use imposed by a blacksmith's work.

Woodworking vises

For woodworking, the jaws are made of wood,plastic or from metal, in the latter case they are usually faced with wood to avoid marring the work piece. The top edges of the jaws are typically brought flush with the bench top by the extension of the wooden face above the top of the iron moveable jaw. This jaw may include a dog hole to hold a bench dog. In modern metal woodworkers' vises, a split nut is almost universally used. The nut in which the screw turns is in two parts so that, by means of a lever, it can be removed from the screw and the screw and moveable jaw quickly slid into a suitable position at which point the nut is again closed onto the screw so that the vise may be closed firmly onto the work.

Metalworkers' vises

For metalworking, the jaws are made of metal which may be hardened steel with a coarse gripping finish. Removable soft jaws are usually kept for use where appropriate, to protect the work from damage.

Metalworking bench vises, known as engineers' or fitters' vises, are bolted onto the top surface of the bench with the face of the fixed jaws just forward of the front edge of the bench. The bench height should be such that the top of the vise jaws is at or just below the elbow height of the user when standing upright. Were several people use the one vise, this is a counsel of perfection but is still a good guide.

The nut in which the screw turns may be split so that, by means of a lever, it can be removed from the screw and the screw and moveable jaw quickly slid into a suitable position at which point the nut is again closed onto the screw. Many fitters prefer to use the greater precision available from a plain screw vise. The vise may include other features such as a small anvil on the back of its body but it is in general, better to separate the functions of the various tools.

Die head

A die head is a threading die that is used in the high volume production of threaded components.

 Die Heads 

Die heads are commonly used on lathes, turret lathes, screw machines and CNC lathes. They may be used for either cutting a thread or rolling a thread. They may also be used for internal or external thread cutting.

In operation, there are several moveable chasers that cut the thread then back away from the work to permit rapid removal of the tool. The lower picture at the right shows four sets of chasers. Each set of chasers is designed to cut a different thread. One set of chasers would be used at a time, each chaser is inserted into the die head and the die head is closed bringing the chasers down to their cutting position. When sufficient length of thread has been cut the die head will open allowing for rapid retraction of the head without interference with the newly formed thread.

With most die heads, all that is needed to open the chasers is a reverse load. Simply withdrawing the die head is all that is needed to open it.
The die head shown cuts an outside thread. There are also collapsible die heads that are used to cut an internal thread.

CHAPTER 4

WORKSHOP MEASURING EQUIPMENTS

Caliper

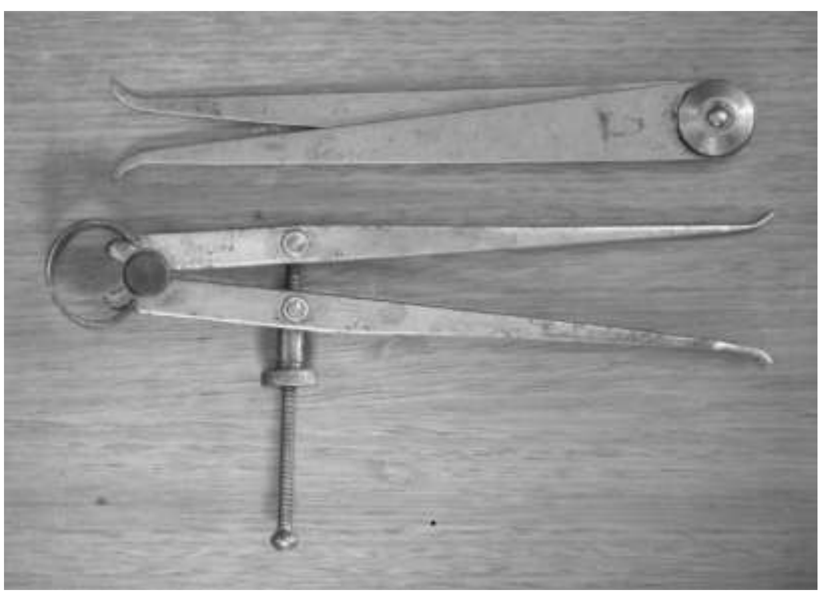
A caliper is a device used to measure the distance between two symmetrically opposing sides. A caliper can be as simple as a compass with inward or outward-facing points. The tips of the caliper are adjusted to fit across the points to be measured, the caliper is then removed and the distance read by measuring between the tips with a measuring tool, such as a ruler.

They are used in the metalworking field of mechanical engineering, and in woodworking and woodturning.

- **1 Types**
    - 1.1 Inside caliper
    - 1.2 Outside caliper
    - 1.3 Divider caliper
    - 1.4 Oddleg caliper
    - 1.5 Vernier calipers
    - 1.6 Dial caliper
    - 1.7 Digital caliper

Types

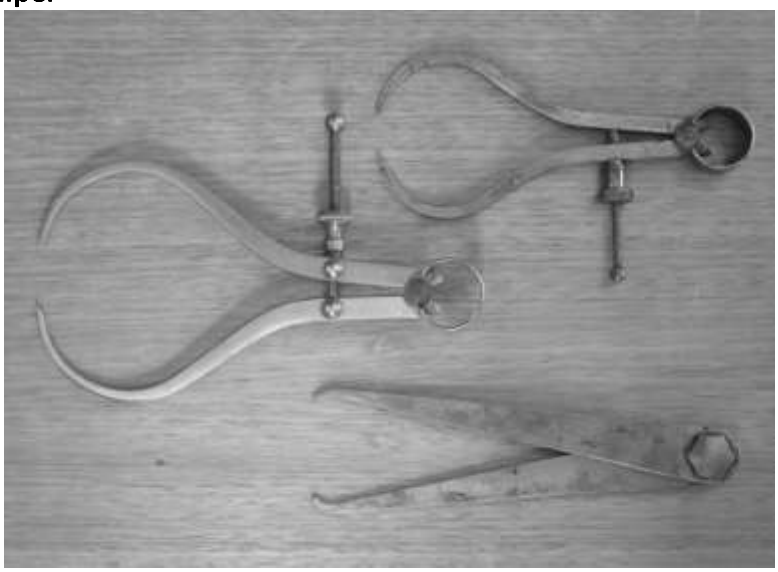
1.1 Inside caliper



Two inside calipers

• The upper caliper in the image requires manual adjustment prior to fitting, fine setting of this caliper type is performed by tapping the caliper legs lightly on a handy surface until they will almost pass over the object. A light push against the resistance of the central pivot screw then spreads the legs to the correct dimension and provides the required, consistent feel that ensures a repeatable measurement.
• The lower caliper in the image has an adjusting screw that permits it to be carefully adjusted without removal of the tool from the workpiece.

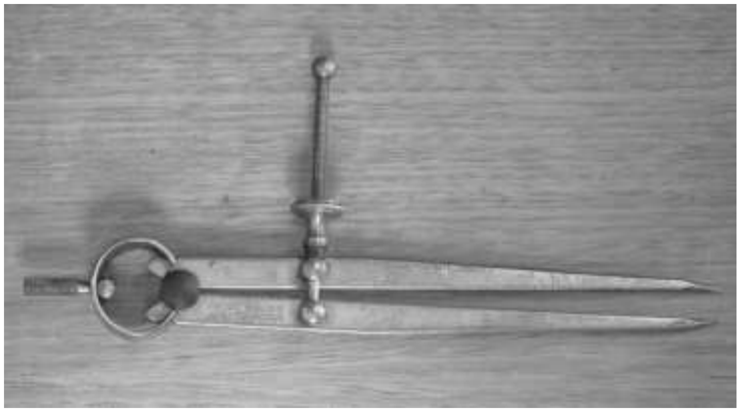
1.2 Outside caliper



Outside calipers

Outside calipers are used to measure the external size of an object.
The same observations and technique apply to this type of caliper, as for the above Inside caliper. With some understanding of their limitations and usage these instruments can provide a high degree of accuracy and repeatability. They are especially useful when measuring over very large distances, consider if the calipers are used to measure a large diameter pipe. A vernier caliper does not have the depth capacity to straddle this large diameter while at the same time reach the outermost points of the pipes diameter.

1.3 Divider caliper



In the metalworking field divider calipers are used in the process of marking out suitable workpieces. The points are sharpened so that they act as scribers, one leg can then be placed in the dimple created by a center or prick punch and the other leg pivoted so that it scribes a line on the workpiece's surface, thus forming an arc or circle.

A divider caliper is also used to measure a distance between two points on a map. The two caliper's ends are brought to the two points whose distance is being measured. The caliper's opening is then either measured on a separate ruler and then converted to the actual distance, or it is measured directly on a scale drawn on the map. On a nautical chart the distance is often measured on the latitude scale appearing on the sides of the map: one minute of arc of latitude is approximately one nautical mile or 1852 metres.

1.4 Odd leg calipers

Oddleg calipers, Hermaphrodite calipers or Oddleg jennys, as pictured at left, are generally used to scribe a line a set distance from the edge of workpiece. The bent leg is used to run along the workpiece edge while the scriber makes its mark at a predetermined distance, this ensures a line parallel to the edge.

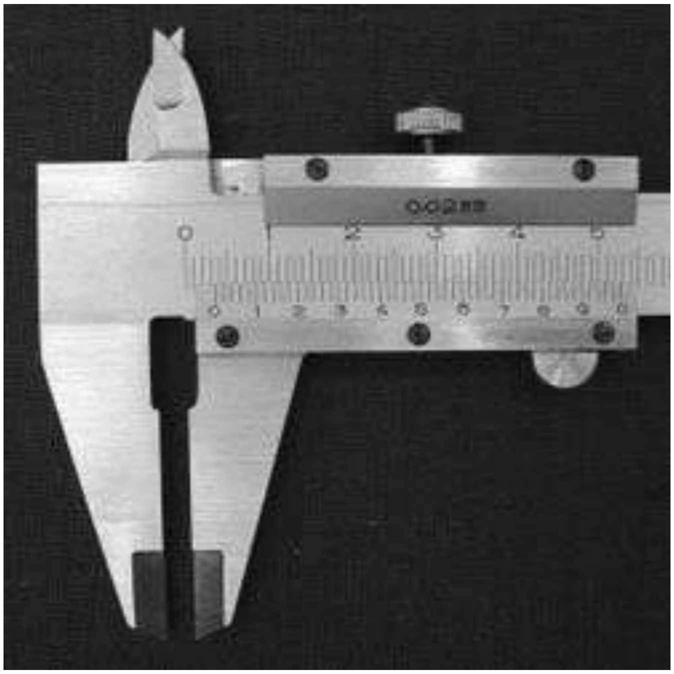
The uppermost caliper has a slight shoulder in the bent leg allowing it to sit on the edge more securely, the lower caliper lacks this feature but has a renewable scriber that can be adjusted for wear, as well as being replaced when excessively worn.

1.5 Vernier calipers

Parts of a vernier caliper:

1. Outside jaws: used to measure external lengths
2. Inside jaws: used to measure internal lengths
3. Depth probe: used to measure depths
4. Main scale (cm)
5. Main scale (inch)

6. Vernier (cm)
7. Vernier (inch)
8. Retainer: used to block movable part to allow the easy transferring a measurement



Using the vernier caliper

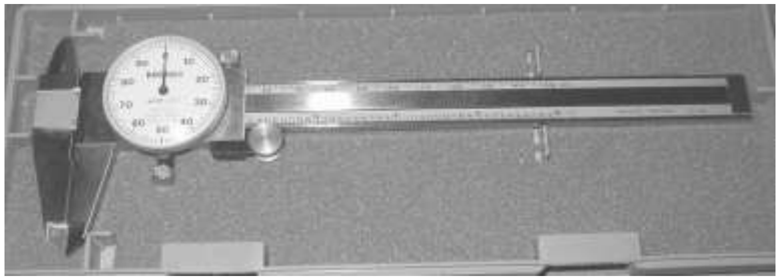
A variation to the more traditional caliper is the inclusion of a vernier scale, this makes it possible to directly obtain an accurate measurement.

Vernier calipers can measure internal dimensions (using the uppermost jaws in the picture at right), external dimensions using the pictured lower jaws, and depending on the manufacturer, depth measurements by the use of a probe that is attached to the movable head and slides along the centre of the body. This probe is slender and can get into deep grooves that may prove difficult for other measuring tools.

The vernier scales will often include both metric and English measurements on the upper and lower part of the scale.

Vernier calipers commonly used in industry provide a precision to a hundredth of a millimetre (10 micrometres), or one thousandths of an inch.
A more accurate instrument used for the same purpose is the micrometer.

1.6 Dial caliper



A further refinement to the vernier caliper is the dial caliper.
In this instrument, a small gear rack drives a pointer on a circular dial. Typically, the pointer rotates once every inch, tenth of an inch, or 10 millimetres, allowing for a very accurate and direct reading without the need to interpolate a vernier scale (although one still needs to add the basic inches or tens of millimeters value read from the slide of the caliper). The dial is usually arranged to be rotatable beneath the pointer, allowing for easy "differential" measurements (the measuring of the difference in size between two objects, or the setting of the dial using a master object and subsequently being able to read directly the plus-or-minus variance in size of subsequent objects relative to the master object).

The slide of a dial caliper can usually also be locked at a setting using a small lever; this allows simple go/no-go checks of part sizes.

1.7 Digital caliper

A refinement now popular is the replacement of the analog dial with an electronic digital display. This version of the caliper finally allows simply reading the value directly from a single display. Many digital calipers can also be switched between metric and imperial units and all provide for zeroing the display at any point along the slide, allowing the same sort of differential measurements as with the dial caliper but without the need to read numbers that may be upside down.

Digital calipers may also contain some sort of "reading hold" feature, allowing the reading of dimensions even in very awkward locations where the display cannot be directly seen.

Increasingly, digital calipers are offering a serial data output to allow them to be interfaced with a personal computer. This means measurements to be taken and instantly stored in a spreadsheet or similar piece of software, significantly decreasing the time taken to take and record a series of measurements. The output of non name brand calipers is usually 24 bit 90 kHz synchronous. A suitable interface to convert the output to RS232 levels and format can be easily built or purchased.
Like dial calipers, the slide of a digital caliper can usually be locked using a lever or thumb-screw.

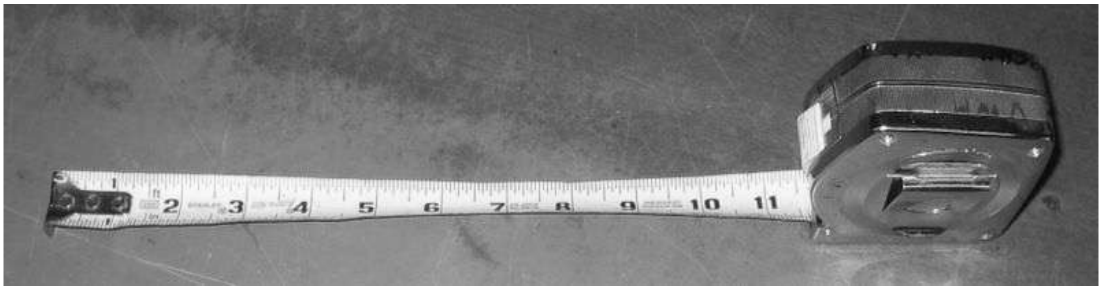
Use of Calipers
A caliper must be properly applied against the part in order to take the desired measurement. For example, when measuring the thickness of a plate a vernier caliper must be held at right angles to the piece. Some practice may be needed to measure round or irregular objects correctly.

Accuracy of measurement when using a caliper is highly dependent on the skill of the operator. Regardless of type, a caliper's jaws must be forced into contact with the part being measured. As both part and caliper are always to some extent elastic, the amount of force used affects the indication. A consistent, firm touch is correct. Too much force results in an under indication as part and tool distort; too little force gives insufficient contact and an over indication. This is a greater problem with a caliper incorporating a screw, which lends mechanical advantage.

Simple calipers are un-calibrated; the measurement taken must be compared against a scale. Whether the scale is part of the caliper or not, all analog calipers -- verniers and dials -- require good eyesight in order to achieve the highest precision. Digital calipers have the advantage in this area.

Calibrated calipers may be mishandled, leading to loss of zero. When a calipers' jaws are fully closed, it should of course indicate zero. If it does not, it must be recalibrated or discarded. It might seem that a vernier caliper cannot get out of calibration but a drop or knock can be enough. Sometimes a careful tap is enough to restore zero. Digital calipers have zero set buttons.

Measure Tape



A measuring tape is a ribbon of cloth, plastic, or metal with linear-measure markings, often in both imperial and metric units. Surveyors use tape measures in lengths on the order of hectometres. It is a convenient measuring tool. Its flexibility allows for a measure of great length to be easily carried in pocket or toolkit and permits one to measure around curves or corners.

Tape measures intended for use in tailoring or dressmaking are typically made of flexible cloth or plastic, while those designed for carpentry or construction often use a stiff, curved metallic ribbon that can remain stiff and straight when extended, but retracts into a coil for convenient storage. This type of tape measure will have a floating tang on the end to aid measuring. The tang will float a distance equal to its thickness, to allow accurate measurement whether the tape is in tension or compression. A tape measure of 25 or even 100 feet can wind into a relatively small container.

For many purposes tape measures are indispensable. Almost any home or shop can be expected to have several of one sort or another.

Micrometer

A micrometer is a widely used device in mechanical engineering for precisely measuring thickness of blocks, outer and inner diameters of shafts and depths of slots. Appearing frequently in metrology, the study of measurement, micrometers have several advantages over other types of measuring instruments like the Vernier caliper - they are easy to use and their readouts are consistent.

The first ever micrometric screw was invented by William Gascoigne in the 17th century, as an enhancement of the Vernier; it was used in a telescope to measure angular distances between stars. Its adaptation for the measurement of the small dimension was made by Jean-Louis Palmer; this device is therefore often called palmer in France. In 1888 Edward Williams Morley added to the precision of micrometric measurements and proved their accuracy in a complex series of experiements.

Types

There are mainly three common types of micrometers, the names are based on their application:

- External Micrometer
- Internal Micrometer
- Depth Micrometer

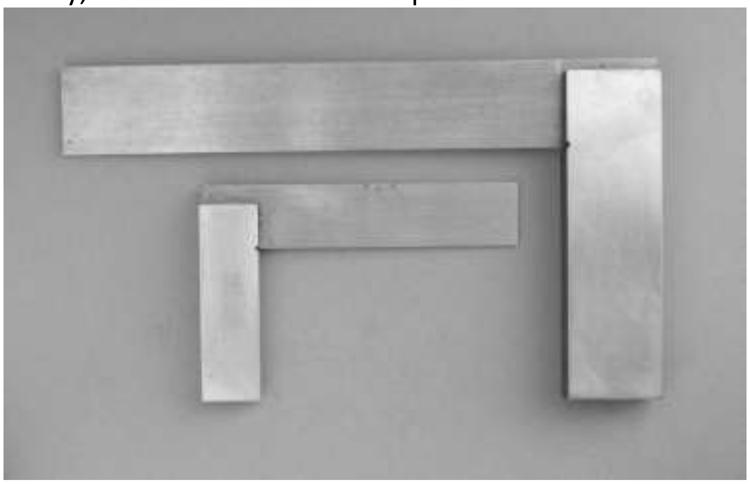
An external micrometer is typically used to measure wires, spheres, shafts and blocks. An internal micrometer is used to measure the opening of holes, and a depth micrometer typically measures depths of slots and steps.

The precision of a micrometer is achieved by a using a fine pitch screw mechanism.

An additional interesting feature of micrometers is the inclusion of a spring-loaded twisting handle. Normally, one could use the mechanical advantage of the screw to force the micrometer to squeeze the material, giving an inaccurate measurement. However, by attaching a handle that will ratchet at a certain torque, the micrometer will not continue to advance once sufficient resistance is encountered.

Machinist square

A machinist square or engineer's square is the metalworkers' equivalent of a try square. It consists of a steel blade inserted and either welded or pinned into a heavier body at an angle of 90°. In the accompanying image, there is evidence of pinning at the intersection of the blade and body, where the heads of two pins are visible as dark circles.



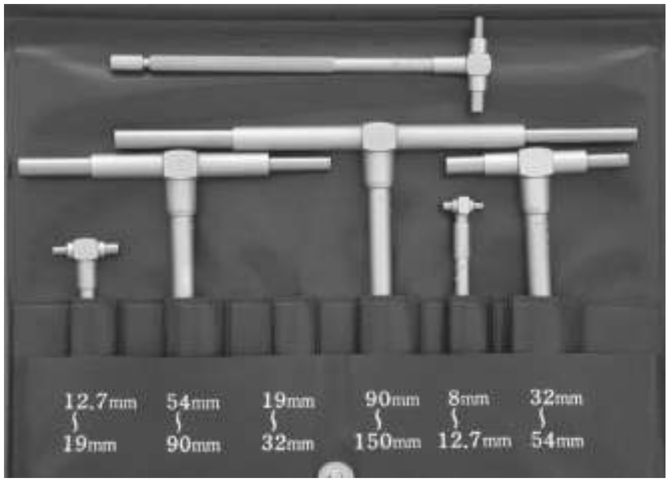
In use the body is aligned against the one edge of the object and the blade is presented to the end or body of the object. If the end is being checked, then a strong light source behind the square will show any mismatch between the blade of the square and the end of the object. The purpose of this action is to either check for squareness or to mark out the body of the workpiece.

Bore gauge

A bore gauge is a convenient term for the measuring or transfer tools that are used in the process of accurately measuring holes.

Telescopic gauges

These are a range of gauges that are used to measure a bore's size, by transferring the internal dimension to a remote measuring tool. They are a direct equivalent of inside calipers and require the operator to develop the correct feel to obtain repeatable results.



The gauges are locked by twisting the knurled end of the handles, this action is performed to exert a small amount of friction on the telescopic portions of the gauge (the smaller diameter rods found at the T head of the gauge). Once gently locked to a size slightly larger than the bore, the gauges are inserted at an angle to the bore and slowly brought to align themselves radially, across the hole. This action compresses the two anvils where they remain locked at the bores dimension after being withdrawn.
The gauge is then removed and measured with the aid of a micrometer or vernier caliper.

Small hole gauges
A set of tools, shown in the image below, which cover the smaller sizes — 3 mm (0.125") to 13 mm (0.5").

They require a slightly different technique to the telescopic gauges, the small hole gauge is initially set smaller than the bore to be measured. It is then inserted into the bore and adjusted by rotating the knurled knob at the base, until light pressure is felt when the gauge is slightly moved in the bore. Measurement is again by external means.

Dial bore gauge
Is a Dial indicator type gauge that will measure a range of holes directly. The tool consists of

- A range of interchangeable anvil pieces (for the telescopic part of the gauge) that transfer their movement to a freely moving rod.
- A body that includes a transfer mechanism (the movable rod)
- A dial indicator mounted at the remote end (to measure the axial movement of the rod).

This combination allows the bore size to be accurately read from the instrument with the minimum of effort. The fixed end of the anvil piece has pressure fingers on either side of it that assist correct placement in the bore, this reduces the reliance on feel by the operator, as required when using the telescopic gauge.

Gauge blocks
Gauge blocks (also known as gage blocks, Johansson gauges, or slip gauges) are precision ground and lapped measuring standards. They are used as references for the setting of measuring equipment such as micrometers, sine bars, dial indicators (when used in an inspection role).

They are available in various grades depending on their intended use

- reference (AAA) — high tolerance (± 0.00005mm or 0.000002")
- calibration (AA) — (tolerance +0.00010mm to -0.00005mm)
- inspection (A) — (tolerance +0.00015mm to -0.0005mm)
- workshop (B) — low tolerance (tolerance +0.00025mm to -0.00015mm)

More recent grade designations include:

- 0.5 — generally equivalent to grade AAA
- 1 — generally equivalent to grade AA
- 2 — generally equivalent to grade A+
- 3 — compromise grade between A and B

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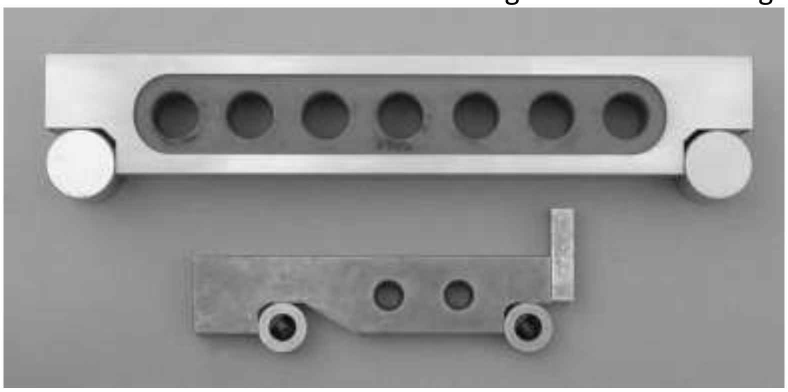
Sine bar
A sine bar is a tool used to measure angles in metalworking.



It consists of a hardened, precision ground body with two precision ground cylinders fixed at each end. The distance between the centers of the cylinders is precisely controlled, and the top of the bar is parallel to a line through the centers of the two rollers. The dimension between the two rollers is chosen to be a whole number (for ease of later calculations) and forms the hypotenuse of a triangle when in use. The image shows a 10 inch and a 100 mm sine bar.

When a sine bar is placed on a level surface the top edge will be parallel to that surface. If one roller is raised by a known distance then the top edge of the bar will be tilted by the same amount forming an angle that may be calculated by the application of the sine rule.
The hypotenuse is a constant dimension — (100 mm or 10 in in the examples shown).
The height is obtained from the dimension between the bottom of one roller and the table's surface.

The angle is calculated by using the sine rule. $\sin(angle) = \frac{opposite}{hypotenuse}$

Angles may be measured or set with this tool. For precision measurements where the bar must be set at an angle, gauge blocks are traditionally used.

Types
Sine centre
A special type of sine bar is sine centre which is used for conical objects having male and female parts.it cannot measure the angle more than 45 degree.

Sine table

Sine table is used to measure angles of large workpieces

Compound sine angle

It is used to measure compound angles of large workpieces.In this case,two sine tables are mounted one over the other at right angles.The tables can be twisted to get the required alignment.

Feeler gauge

They consist of a number of small lengths of steel of different thicknesses with measurements marked on each piece. They are flexible enough that, even if they are all on the same hinge, several can be stacked together to gauge intermediate values. It's common to have two sets for imperial units and metric measurements although the pictured set has both measurements recorded on each blade.

A similar device with wires of specific diameter instead of flat blades is used to set the gap in spark plugs to the correct size; this is done by increasing or decreasing the gap until the gauge of the correct size just fits inside the gap.

The lengths of steel are sometimes called *blades*, although they have no sharp edge.

Feeler gauge

A feeler gauge is a simple tool used to measure gap-widths. Feeler gauges are mostly used in engineering to measuring the clearance between two parts.

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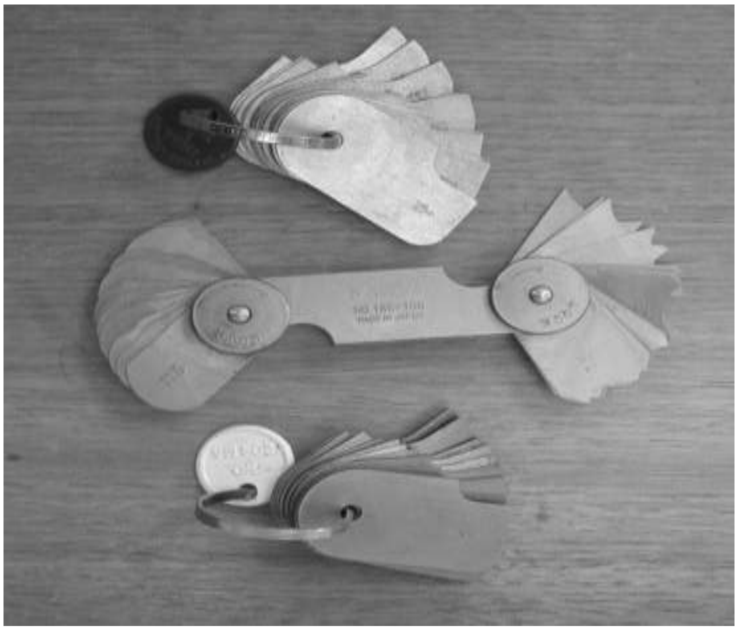
Thread pitch gauge
Threading gauges, pictured on the right, are also referred to as pitch gauges and are used to measure the pitch or lead of screw threads. The uppermost gauge in the image is an ISO metric pitch gauge, The larger gauge in the center is for measuring the Acme Thread Form, and the lower gauge is for imperial screws.

Thread pitch gauges are used as a reference tool in determining the pitch of a thread that is on a screw or in a tapped hole. This tool is not used as a precision measuring instrument. This device allows the user to determine the profile of the given thread and quickly categorize the thread by shape and pitch. This device also saves time, in that it removes the need for the user to measure and calculate the thread pitch of the threaded item.

Radius gauge



A radius gauge is a tool used to measure the radius of an object.
Radius gauges require a bright light behind the object to be measured. The gauge is placed against the edge to be checked and any light leakage between the blade and edge indicates a mismatch that requires correction.
A good set of gauges will offer both convex and concave sections, and allow for their application in awkward locations.

Go-NoGo gauge

A Go NoGo gauge (or Go/no go) refers to an inspection tool used to check a workpiece against its allowed tolerances. Its name derives from its use: the gauge itself has two tests; the check involves the workpiece's having to pass one test(*Go*) and 'fail' the other (*No Go*).

It is an integral part of the quality process that is used in the manufacturing industry to ensure interchangeability of parts between processes, or even between different manufacturers.

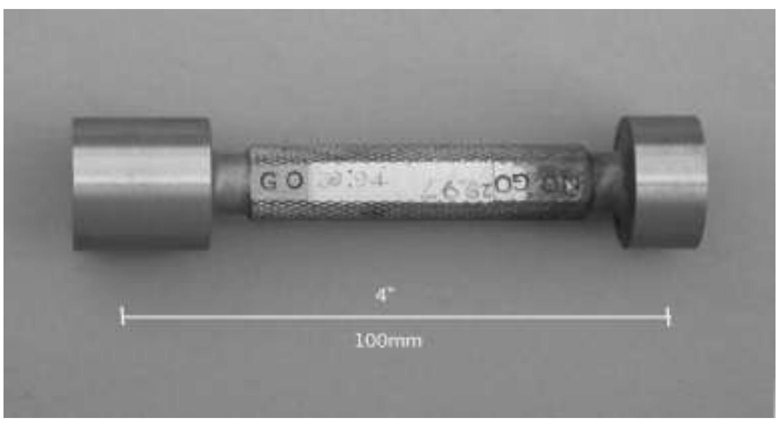
A Go NoGo gauge is a measuring tool that does not return a *size* in the conventional sense, but instead returns a *state*. The *state* is either acceptable (the part is within tolerance and may be used) or it is unacceptable (and must be rejected).

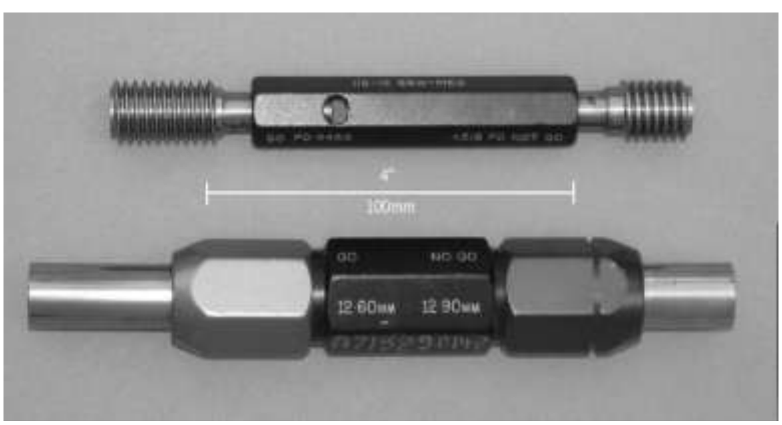
They are well suited for use in the production area of the factory as they require little skill or interpretation to use effectively and have few, if any, moving parts to be damaged in the often hostile production environment.

Plug gauge

These gauges are referred to as plug gauges; they are used in the manner of a plug. They are generally assembled from standard parts where the gauge portion is interchangeable with other gauge pieces (obtained from a set of pin type gauge blocks) and a body that uses the collet principle to hold the gauges firmly. To use this style of gauge, one end is inserted into the part first and depending on the result of that test, the other end is tried.

Hardened and ground plug gauge

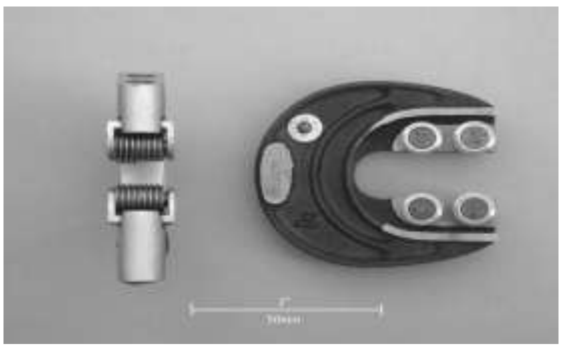


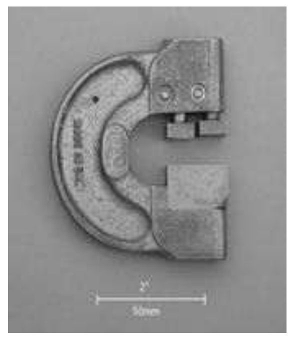


Replaceable thread and plug gauges

The lower gauge is a thread gauge that is screwed into the part to be tested, the labeled *GO* end will enter into the part fully, the *NOT GO* end should not. The top image is a plain plug gauge used to check the size of a hole, the green end is the *GO*, red is the *NO GO*. The tolerance of the part this gauge checks is 0.30mm where the lower size of the hole is 12.60mm and the upper size is 12.90mm, every size outside this range is *out of tolerance*.

Gap gauge





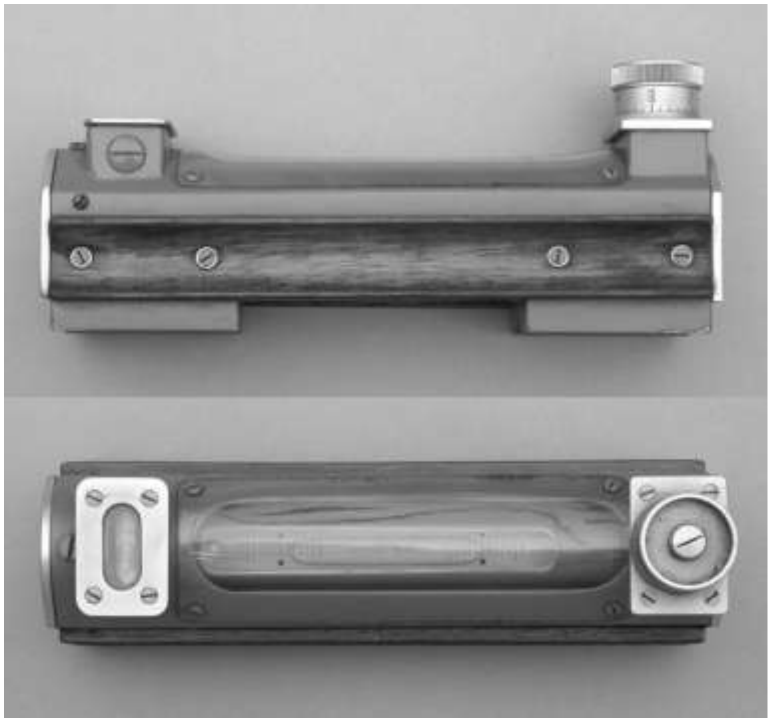
These images illustrate an alternative type of gauge. The gap gauge has four *anvils* or *jaws*, the first one or pair (outermost) are set using the upper limit (tolerance) of the part and the inner set adjusted to the lower limit of the part.

The usage of this gauge may be more intuitive than the plug type. A correctly machined part will pass the first set of jaws and stop at the second — end of test. In this manner a part may be checked in one action, unlike the plug gauge that needs to be used in the correct sequence and flipped to access the second gauge.

The left image is a plain gap gauge used to measure outside distances (diameters), the right hand image shows two views of a thread gap gauge.

Spirit level

An **engineers spirit level** is generally used to level machines, although they may be used to level large workpieces on machines such as planers. Spirit levels are also used in building construction, by carpenters and masons.



Both levels have The upper image is a *plain* precision level used in the engineering field to level machines or workpieces, the lower image shows an adjustable precision level that has an accuracy of 1:10000. The adjustable nature of this level can also be used to measure the inclination of an object.

The accuracy of a spirit level can be checked by placing it on any flat surface, marking the bubble's position and rotating the level 180°. The position of the bubble should then be symmetrical to the first reading.
a "vee" groove machined along the base which enables the level to sit on a round bar while remaining parallel with the bars axis. They also have a smaller cross level to enable the second axis to be roughly checked or corrected.

While a precision level may be used to check and correct the twist in a machine (or workpiece), its presence does not necessarily need to be corrected.

- A machine such as a mill or lathe does not have to be perfectly level to operate correctly but may in fact have a known twist introduced to the machines bed. This twist is often introduced to ensure that a worn lathe turns parallel work, by realigning the bed (that is worn) to the spindle axis (unworn).
- Levelling a ships lathe would be pointless due to the nature of the ships base - floating on water. Correcting any twist in the bed however would be essential for accurate work to be reproduced from the lathe.

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CHAPTER 5
NON DESTRUCTIVE TESTING (NDT)

Non destructive testing (NDT) is one of the important topic in day today life. Though NDT techniques are used in industries, certain techniques like X-ray, ultrasonic testing is used in medical field. It is very interesting to know that X-rays were first used in medical field, later in industry. In this module various NDTs / NDE are listed out but NDTs, which are most commonly used are explained in little detail to familiar with NDTs.

INTRODUCTION

The field of Nondestructive Testing (NDT) is a very broad, interdisciplinary field that plays a critical role in assuring that structural components and systems perform their function in a reliable and cost effective fashion. NDT techniques that locate and characterize material conditions and flaws that might otherwise result in failure of pressure vessels, pipelines or machinery components. These tests are performed in a manner that does not affect the future usefulness of the object or material. In other words, NDT allows parts and materials to be inspected and measured without damaging them. Because it allows inspection without interfering with a product's final use, NDT provides an excellent balance between quality control and costeffectiveness.

Generally speaking, NDT applies to industrial inspections. While technologies are used in NDT that are similar to those used in the medical industry, typically nonliving objects are the subjects of the inspections.

NON DESTRUCTIVE EVALUATION

Nondestructive Evaluation (NDE) is a term that is often used interchangeably with NDT. However, technically, NDE is used to describe measurements that are more quantitative in nature. NDE method would not only locate a defect, but it would also be used to measure something about that defect such as its size, shape, and orientation. NDE may be used to determine material properties such as fracture toughness, formability, and other physical characteristics.

NDT / NDE METHODS

The number of NDT methods that can be used to inspect components and make measurements is large and continues to grow. There are six NDT methods that are used most often. These methods are visual inspection, penetrant testing, magnetic particle testing, electromagnetic or eddy current testing, radiography, and ultrasonic testing. These methods and a few others are briefly described below.

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1. VISUAL OR OPTICAL TESTING (VT)

Visual inspection involves using an inspector's eyes to look for defects. The inspector may also use special tools such as magnifying glasses, mirrors, boroscopes or fibroscopes to gain access and more closely inspect the subject area. Visual examination involves procedures that range from simple to very complex.

2. LIQUID PENETRANT TESTING (LPT)

Liquid penetrant Testing (LPT) is one of the most widely used nondestructive evaluation (NDE) method. Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. LPT can be used to inspect almost any material provided that its surface is not extremely rough or porous. Materials that are commonly inspected using LPT include the following:

- Metals (aluminum, copper, steel, titanium, etc.)
- Glass
- Many ceramic materials
- Rubber
- Plastics

LPT offers flexibility in performing inspections because it can be applied in a large variety of applications ranging from automotive spark plugs to critical aircraft components. Penetrant material can be applied with a spray can or a cotton swab to inspect for flaws known to occur in a specific area or it can be applied by dipping or spraying to quickly inspect large areas.

Liquid penetrant inspection is used to inspect of flaws that break the surface of the sample. Some of these flaws are listed below:

- Fatigue cracks
- Quench cracks
- Grinding cracks
- Overload and impact fractures
- Porosity
- Laps
- Seams
- Pin holes in welds
- Lack of fusion or braising along the edge of the bond line

As mentioned above, one of the major limitations of a penetrant inspection is that flaws must be open to the surface.

In LPT, a liquid penetrant (contrast colour dye or fluorescent) is applied over the thoroughly cleaned and dry surface, which is having flows(discontinuities) those are open surface due to capillary action. Sufficient time is allowed so that the penetrant can enter in narrow discontinuities. Excess penetrant is removed by cleaning and developer (a fluffy chalk like powder) is applied over the surface.

Due to blotting nature of the developer, entrapped penetrant in the discontinuities flows out and gives an indication, which can be viewed either in normal light for contrast dye or in “black light” (UV light) for fluorescent dye. The indication is always greater than the discontinuity due to diffusion of the penetrant in the developer.

ADVANTAGES AND DISADVANTAGES OF LPT

Like all nondestructive inspection methods, liquid penetrant inspection has both advantages and disadvantages. The primary advantages and disadvantages when compared to other NDE methods are summarized below.

PRIMARY ADVANTAGES

- The method has high sensitive to small surface discontinuities.
- The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- Parts with complex geometric shapes are routinely inspected.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Aerosol spray cans make penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

PRIMARY DISADVANTAGES

- Only surface breaking defects can be detected.
- Only materials with a relative nonporous surface can be inspected.
- Precleaning is critical as contaminants can mask defects.
- Metal smearing from machining, grinding, and grit or vapor blasting must be removed prior to LPT.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed and controlled.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling and proper disposal is required.

3. MAGNETIC PARTICLE TESTING (MPT)

MPT is a fast and relatively easy to apply and part surface preparation is not as critical as it is for some other NDT methods. These characteristics make MPT one of the most widely utilized nondestructive testing methods.

MPT uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components. The only requirement from an inspectability standpoint is that the component being inspected must be made of a ferromagnetic material such iron, nickel, cobalt, or some of their alloys. Ferromagnetic materials are materials that can be magnetized to a level that will allow the inspection to be effective.

Magnetic particle testing (MPT) is a relatively simple concept. It can be considered as a combination of two nondestructive testing methods: magnetic flux leakage testing and visual testing. Consider a bar magnet. It has a magnetic field in and around the magnet. Any place that a magnetic line of force exits or enters the magnet is called a pole. A pole where a magnetic line of force exits the magnet is called a north pole and a pole where a line of force enters the magnet is called a south pole. This NDT method is accomplish by inducing a magnetic field in a ferromagnetic material and then dusting the surface with iron particles (either dry or suspended in liquid). Surface and near-surface imperfections distort the magnetic field and concentrate iron particles near imperfections, previewing a visual indication of the flaw.

4. ELECTROMAGNETIC (ET) OR EDDY CURRENT TESTING

Electrical currents are generated in a conductive material by an induced alternating magnetic field. The electrical currents are called eddy currents because they flow in circles at and just below the surface of the material. Interruptions in the flow of eddy currents, caused by imperfections, dimensional changes, or changes in the material's conductive and permeability properties, can be detected with the proper equipment.

5. RADIOGRAPHIC TESTING (RT)

X-rays were discovered in 1895 by Wilhelm Conrad Roentgen (1845-1923) who was a Professor at Wuerzburg University in Germany. Working with a cathode-ray tube in his laboratory, Roentgen observed a fluorescent glow of crystals on a table near his tube. He concluded that a new type of ray was being emitted from the tube. This ray was capable of passing through the heavy paper covering and exciting the phosphorescent materials in the room. He found the new ray could pass through most substances casting shadows of solid objects. Roentgen also discovered that the ray could pass through the tissue of humans, but not bones and metal objects.

In 1922, industrial radiography took another step forward with the advent of the 200,000-volt X-ray tube that allowed radiographs of thick steel parts to be produced in a reasonable amount of time. In 1931, General Electric Company developed 1,000,000 volt X-ray generators, providing an effective tool for industrial radiography. That same year, the American Society of Mechanical Engineers (ASME) permitted X-ray approval of fusion welded pressure vessels that further opened the door to industrial acceptance and use.
Radiography involves the use of penetrating gamma or X-radiation to examine parts and products for imperfections. An X-ray generator or radioactive isotope is used as a source of radiation. Radiation is directed through a part and onto film or other imaging media. The resulting shadowgraph shows the dimensional features of the part. Possible imperfections are indicated as density changes on the film in the same manner as a medical X-ray shows broken bones.

6. ULTRASONIC TESTING (UT)

Sound in the range of 20 Hz to 18000 Hz is in audible ranges of human ear. Sound beyond this range cannot be heard by human and called as ultrasonic sound. However, some mammals can hear well above this. For example, bats and whales use echo location that can reach frequencies in excess of 100,000Hz.

Ultrasonic testing is based on time-varying deformations or vibrations in materials, which is generally referred to as acoustics. All material substances are comprised of atoms, which may be forced into vibrational motion about their equilibrium positions. Many different patterns of vibrational motion exist at the atomic level, however, most are irrelevant to acoustics and ultrasonic testing. Acoustics is focused on particles that contain many atoms that move in unison to produce a mechanical wave. When a material is not stressed in tension or compression beyond its elastic limit, its individual particles perform elastic oscillations. When the particles of a medium are displaced from their equilibrium positions, internal (electrostatic) restoration forces arise. It is these elastic restoring forces between particles, combined with inertia of the particles, that leads to oscillatory motions of the medium. In solids, sound waves can propagate in four principle modes that are based on the way the particles oscillate. Sound can propagate as longitudinal waves, shear waves, surface waves, and in thin materials as plate waves. Longitudinal and shear waves are the two modes of propagation most widely used in ultrasonic testing.

Ultrasonic testing uses transmission of high-frequency sound waves into a material to detect imperfections or to locate changes in material properties. The most commonly used ultrasonic testing technique is pulse echo, wherein sound is introduced into a test object and reflections (echoes) are returned to a receiver from internal imperfections or from the part's geometrical surfaces.

CHAPTER- 6

THE FORMAT FOR COLLECTING TECHNICAL SPECIFICATIONS FOR MACHINES TOOLS & FACTORY EQUIPMENT FROM CLIENTS

(a) Capstan Lathe:

Capacity:
Maximum swing:
Over bed covers and under overhead support bar
Over bed within 160 mm of cross slide
Close to cross slide
Over cross slide
Largest bar admitted by dead length bar chuck:
Round, dia.
Hexagon, A/F
Square, A/F
Largest bar admitted by geared draw-in chuck:
Round, dia.
Hexagon, A/F
Square, A/F
Maximum length of bar
Power of main motor
Spindle:
Diameter of spindle bore
Diameter of spindle flange
Saddle and cross slide:
Maximum longitudinal traverse
Maximum cross traverse
Height of tools for square turret and rear tool post
Capstan slide:
Maximum stroke of capstan slide
Diameter of tool holes in hexagonal turret
Centre of tool holes to top of capstan slide
Speeds and feeds:
Number of reversible spindle speeds
Spindle speeds
Number of automatic feeds to saddle and capstan slide
Automatic feed rate, per revolution
Miscellaneous:
Floor space occupied:

Chuck work machine
Bar work machine
Gross weight:
Chuck work machine
Bar work machine

(b) Centre Lathe:

Capacity:
Height of centre
Type of bed
Swing over bed
Swing over carriage wings
Swing over cross slide
Swing in gap
Distance between centres
Headstock:
Spindle nose/bore
Spindle socket taper
Speed range:
Forward
Reverse
Feeds and Threads:
Feed range longitudinal
Feed range cross
Lead screw pitch
Metric threads
Inch threads
Module threads
Carriage:
Cross slide travel
Top slide travel
Tool shank size
Tailstock:
Sleeve diameter/ taper
Sleeve travel
Power of main motor

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(c) Combination Turret Lathe:

Capacity:
Maximum Swing:
Under overhead support bar
Over saddle
Over cross slide
Spindle flange to hex-turret face:
Maximum
Minimum
Diameter of spindle bore
Diameter of spindle flange
Main spindle motor power
Quick power traverse motor
Saddle and cross slide:
Stroke of turret slide
Diameter of tool holes in turret
Centre of tool holes to top of turret slide
Turret face size
Speeds and feeds:
Number of spindle speeds
Range of spindle speeds
Number of automatic feeds to saddle and turret slide
Automatic feed rate per rev.:
Fine feed range
Coarse feed range
Miscellaneous:
Minimum floor space occupied
Minimum floor space for machine with bar guard
Gross weight of machine

CVSRTA

(d) CNC High Performance Vertical Lathe:

Capacity:
Table diameter
Maximum swing
Maximum turning diameter
Maximum turning height
Maximum weight of workplace
Maximum torque of table
Maximum cutting force
Table speed:
No. of range
Speed range:
Low
High
Cross-rail:
Height under cross-rail
Maximum
Minimum
Crossrail positioning step
Tool head:
Vertical travel
Horizontal travel:
To right from table centre
To left from table centre
Tool holder shank size
Ram size (square)
Feeds:
Feed
Feed rate
Traverse rate:
Rapid traverse
Elevating speed of cross-rail:
50 Hz
60 Hz

(e) **CNC Turn Mill Centre:**

Capacity:
Type of bed
Swing over carriage wins
Maximum turning dia. over cross slide
Distance between centres
Maximum turning dia. of chucking job
Maximum turning length
Spindle:
Spindle nose
Hole through spindle
Spindle socket taper
Spindle indexing
Speeds and feeds:
Spindle speed range
Selection of speeds
Type of spindle drive
Longitudinal feed drive:
Feed range
Rapid traverse rate
Stroke
Cross feed drive:
Feed range
Rapid traverse rate
Stroke
Tailstock:
Tailstock spindle dia.
Spindle stroke (HYD)
Spindle taper
Turrent:
No. of tools (external/internal)
Turret indexing positions
Turning tool shank size
Turret actuation
Maximum boring bar size
Capacity of driven tools:
No. of rotating tools on turret
Maximum tool capacities on steel for:
a. Drilling
b. End milling

c. Face milling
d. Tapping
Speed and Power
Maximum speed
Type of tool drive
Spindle drive motor
Hydraulic power pack motor
Coolant pump motor
Input supply to voltage stabiliser
Total connected load
CNC System
Accuracies
Positioning
Repeatability

(f) Shaping machine:

Maximum length of stroke
Maximum horizontal traverse of table
Maximum vertical traverse of table
Maximum distance table to ram
Minimum distance table to ram
Length and width of table top
Depth of table side
Floor space
No. of speeds to ram
Range of speeds
Range of table feed
No. of table feeds
Power of driving motor
'T' slot size on table top
Net weight of the machine

(g) Planing machine:

Capacity:
Width of planing
Length of planing
Height of planing
Clamping surface of table (width * length)
Stroke of toolpost slide

Number of infeed and reverse speeds
First version:
Range of infeed and reverse speeds from 5 to 25 m/min
Maximum draw through force
Output of the machine motor
Second version:
Range of infeed and reverse speeds from 6.3 to 31.5 m/min
Maximum draw through force
Output of the machine motor
Third version:
Range of infeed and reverse speeds from 8 to 40 m/min
Maximum draw through force
Output of the machine motor
Feeds, weight and load:
Feeds of cross-rail heads
Feeds of side heads
Feeds of tool post slides
Output of the motor for cross-rail rapid traverse
Output of the motor for rapid traverse of heads
Weight of the machine with standard equipment/length of planing
Weight of 1 m of the length of planing
Volumetric content of boxes for 1 m length of planing
Maximum load to table by work piece per 1 m length of planing
Maximum load to cross-rail head
Maximum load to side head
Maximum length of planing
Maximum speed
Floor space occupied by machine/ length of planing

(h) Radial Drilling Machine:

Maximum size of hole drilled:
Maximum size of hole drilled without pre-drilling in steel of 60 kp per sq.mm tensile strength
Maximum size of hole drilled in cast iron of 25 kp per sq.mm tensile strength
Maximum size of hole bored in steel of 60 kp per sq.mm tensile strength
Maximum thread size cut in steel of 60 kp per sq.mm tensile strength
Maximum thread size cut in cast iron of 25 kp per sq.mm tensile strength
Main dimensions:
Maximum distance between spindle axis and outer column
Minimum distance between spindle axis and outer column

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Maximum pitch circle of holes drilled
Minimum pitch circle of holes drilled
Maximum and minimum distance between spindle and base
Outer column dia.
Vertical travel of arm along column
Horizontal travel of headstock on arm
Range of arm swivel on column
Spindle:
Spindle nose dia.
Inner taper in spindle
Spindle dia.
Spindle travel
Spindle speeds and feeds:
No. of speeds
Speed range, standard
Speed range, increased
No. of feeds
Feed range
Base:
Clamping area
Base height
Number, width and distance of clamping slots
Drive:
Spindle driving motor
Clamping motor
Coolant pump motor
Dimensions:
Overall length
Overall width
Overall height
Overall weight
Overall input of machine

(i) Horizontal Boring and Milling Machine:

Type
Headstock:
Diameter of work spindle
Taper in spindle (CSN 22 0429)
Protrusion of work spindle
External diameter of connecting of hollow spindle (CSN 22 0431)
Vertical adjustment of headstock
Horizontal protrusion of head stock
Range of speed of work and hollow spindle in 26 steps (in line R 20/2)
Output and speed of motor for spindle drive
Maximum torsional moment on hollow spindle
Horizontal headstock feeds:
1^{st} Range- steplessly
2^{nd} Range- steplessly
Rapid traverse of headstock in horizontal direction
Work spindle feeds in horizontal direction and headstock feeds in vertical direction:
1^{st} Range- steplessly
2^{nd} Range- steplessly
Rapid traverse of work spindle and headstock
Minimum distance of spindle centre line from bed guiding surfaces
Output and speed of motor of hydraulic set for feed drive
Upright:
Upright traverse along the bed
Length of standard bed
Upright feeds:
1^{st} Range- steplessly
2^{nd} Range- steplessly
Rapid traverse
Output of all installed motors

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(j) Hacksaw:

Capacity:
Size
Cuts round material upto maximum
Cuts square material upto maximum
Length and breadth of saw blade
Angular cuts at 45 degree
Stroke per minute
Length of the stroke
Load
Weight

(k) Circular Saw:

Capacity:
Maximum diameter
Saw blade
Table size
Height of the table
Spindle speed
Power required

(l) Cylindrical Grinding Machine:

Capacity:
Height of centre
Swing over table
Distance between centres
Maximum grinding length
Grinding wheel:
Maximum diameter
Minimum diameter
Work Head:
Taper bore in spindle
Tail stock:
Centre
Quill movement
Table head:
Maximum table traverse
Swivel of table in either direction

Wheel head:
Cross travel of wheel head
Wheel feed/ revolution of hand wheel
Wheel spindle speed (single)
Work spindle speed (single)
Steps of speed for table traverse
General:
Wheel head motor
Work head motor
Table drive motor
Machine overall dimensions
Weight of the machine

(m) Tool and Cutter Grinder:

Capacity:
Centre distance maximum
Centre height maximum
Movement of table maximum
Angle adjustment
Axial adjustment of grinding wheel
Vertical adjustment of grinding support
RPM of grinding wheel
Swing of grinding support to right and left
Diameter of grinding wheel
Grinding motor power requirement
Table motor power requirement
Power requirement for suction motor
Power requirement for water cooling
Net weight of machine
Indexing plate:
No. of Index

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(n) EDM Machine (spark erosion machine):

Table Tank:
Table size
Travel size
Tank size
Job weight
Linearity of movement
Work hesad:
Vertical travel
Platen
Platen to table:
Maximum
Minimum
Electrode weight (maximum)
Linearity of movement
Dielectric:
Reservoir
Pump
Filter
Feed system
Generator:
Output voltage (volts)
Output current (maximum amps)
Pulse time (microseconds)
Pause time (microseconds)

(o) Lift:

Load capacity
Operating speed
Platform size
Hoist way opening available
Landings
Openings
Operation
Car enclosure
Car gate opening

(p) Electric overhead travelling crane:

Safe working load:
Main
Auxiliary
Span Auxiliary
Height of lift
Speeds:
Main hoist
Auxiliary hoist
Cross travel
Long travel
Wire rope:
Diameter:
Main
Auxiliary
Rope drum dia. (Main)
Length
Material of construction
Rope drum dia. (Aux.)
Length
Material of construction
Wheel:
C.T./ DD dia.
Rail size
L.T./ DD dia.
Rail size
Motors:
Main hoist:
HP
Rating
RPM
Type
Insulation
Long travel:
HP
Rating
RPM
Type
Insulation
Cross travel:

HP
Rating
RPM
Type
Insulation
Auxiliary hoist:
HP
Rating
RPM
Type
Insulation
Brake:
Hoist
Cross travel
Long travel
Auxiliary hoist
Hook block:
Main hoist:
Falls
Capacity
Auxiliary hoist:
Falls
Capacity
Gearboxes:
Main hoist:
Size
Ratio
Type
Cross travel:
Size
Ratio
Type
Long travel:
Size
Ratio
Type
Auxiliary hoist:
Size
Ratio
Type

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(q) Belt conveyor:

Type
Horizontal portion
Inclined portion
Height
Height at discharge end
Belt
Speed
Drive
Gearbox:
Type
Ratio

(r) Bucket elevator for lifting and conveying:

Type
Bulk density and size
Conveying rate
Height- centre to centre
Speed
Bucket size
Bucket spacing
Type of bucket
Bucket plate thickness
Chain
Sprocket
Head sprocket shaft dia.
Boot sprocket shaft dia.
Materials of construction:
Bucket
Pin and bush
Links
Sprocket
Shaft
Casing:
Type
Size
Thickness of head and boot section
Thickness of mid-section
Inlet

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Outlet
Materials of construction:
Head and boot section
Mid-section
Drive
Gearbox:
Type
Ratio
Coupling guard
Type of take up

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IV. Factory Equipment - material handling -fire protection etc.

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Lifting & Transport Vehicles

In day to day manufacturing, right from the stage of raw material "Inward" to the product "dispatch" , the material is required to be handled in various ways. In this chapter we will discuss the lifting & transportation arrangements being used in the industry. In the first part you will be introduced to some of the "Lifting" devices. The later part deals with the "Engineering Vehicles"

Crane

A crane is a tower or derrick equipped with cables and pulleys that can be used both to lift and lower materials and to shift them horizontally. Cranes are commonly employed in the construction industry and in manufacturing heavy equipment. Construction cranes are usually temporary structures, either fixed to the ground or mounted on a purpose-built vehicle. Cranes may either be controlled from an operator in a cab that travels with the crane, by a pushbutton pendant control station, or by infrared or radio control. Where a cab operator is employed, workers on the ground will communicate with the operator through a system of standardised hand-signals or, in larger installations, radio systems; an experienced crew can position loads with great precision using only these signals.

Listed under are the types of cranes used. Please note that the list includes some of the ancient cranes also. Though these cranes are not used now a days, however they are briefly discussed here for acadamic interest.

1 Types of cranes

1.1 Ancient Greek cranes
1.2 Ancient Roman cranes
1.3 Railroad cranes
1.4 Mobile crane
1.5 Telescopic crane
1.6 Tower crane
1.7 Truck-mounted crane
1.8 Rough terrain crane
1.9 Crawler crane
1.10 Loader crane
1.11 Gantry crane
1.12 Overhead crane

1.13 Stacker crane
1.14 Floating crane
1.15 Aerial crane
1.16 Winch (Crane for special purpose)

Ancient Greek cranes

The crane for lifting heavy loads was invented by the ancient Greeks in the late 6th century BC.

[1] The archaeological record shows that no later than c.515 BC distinctive cuttings for both lifting tongs and Lewis irons begin to appear on stone blocks of Greek temples. Since these holes point at the use of a lifting device, and since they are to be found either above the centre of gravity of the block, or in pairs equidistant from a point over the centre of gravity, they are regarded by archaeologists as the positive evidence required for the existence of the crane.

[2] The introduction of the winch and pulley hoist soon lead to a widespread replacement of ramps as the main means of vertical motion. Although the exact circumstances of the shift from the ramp to the crane technology remain unclear, it has been argued that the volatile social and political conditions of Greece were more suitable to the employment of small, professional construction teams than of large bodies of unskilled labour, making the crane more preferable to the Greek polis than the more labour-intensive ramp which had been the norm in the autocratic societies of Egypt or Assyria.

Ancient Roman cranes

The heyday of the crane in ancient times came under the Roman Empire, when construction activity soared and buildings reached enormous dimensions. The Romans adopted the Greek crane and developed it further. We are relatively well informed about their lifting techniques thanks to rather lengthy accounts by the engineers Vitruvius and Heron of Alexandria.

The simplest Roman crane, the Trispastos, consisted of a single-beam jib, a winch, a rope, and a block containing three pulleys. Having thus a mechanical advantage of 3:1. Heavier crane types featured five pulleys (Pentaspastos) or, in case of the largest one, a set of three by five pulleys (Polyspastos) and came with two, three or four masts, depending on the maximum load. In case the winch was replaced by a treadwheel, the maximum load even doubled at only half the crew, since the treadwheel possesses a much bigger mechanical advantage due to its larger diameter.

Cranes in the Middle Ages were used to build Europe's cathedrals. The crane would be fixed on top of a wall as it was being constructed and was powered by men running inside two large wheels on each side. Also cranes were used in Medieval ports and shipyards e.g. Żuraw in Gdańsk, Poland.

Railroad cranes

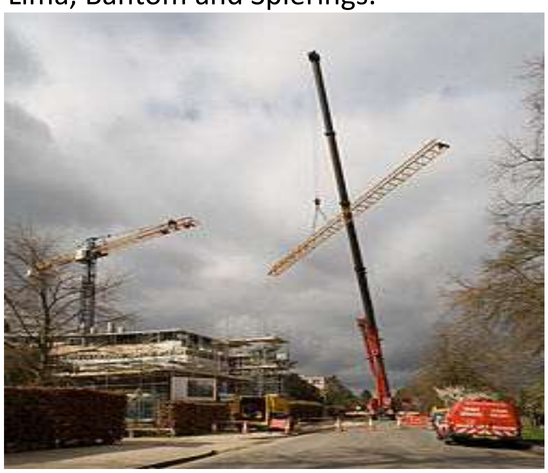
A railroad crane is a crane that is mounted on a railroad car or on a flatcar.

Mobile crane

The most basic type of crane consists of a steel truss or telescopic boom mounted on a mobile platform, which may be rail, wheeled (including "truck" carriers) or caterpillar tracks. The boom is hinged at the bottom, and can be raised and lowered by cables or by hydraulic cylinders. A hook is suspended from the top of the boom by cables and pulleys.

The cables are operated by whatever prime movers the designers have available, operating through a variety of transmissions. Steam engines, electric motors and internal combustion engines (IC) have all been used.

International Manufacturers include: Koehring, Manitowoc, American Hoist and Derrick, NCK-Rapier, Bucyrus-Erie, Ruston-Bucyrus, Jones, Sumitomo, Hitachi, Mannesman Dematic (Demag), Liebherr, Sennebogen, Northwest, Lorain, Grove, P&H, PPM, Terex, Favelle Favco, Link Belt, Lima, Bantom and Spierings.



Telescopic crane

A type of crane whose boom consists of a number of tubes fitted one inside the other. A hydraulic mechanism extends or retracts the tubes to increase or decrease the length of the boom. is used on many constuction projects

Tower crane

The tower crane is a modern form of balance crane. Fixed to the ground, tower cranes often give the best combination of height and lifting capacity and are used in the construction of tall buildings. To save space and to provide stability the vertical part of the crane is often braced onto the completed structure which is normally the concrete lift shaft in the center of the building. A horizontal boom is balanced asymmetrically across the top of the tower. Its short arm carries a counterweight of concrete blocks, and its long arm carries the lifting gear. The crane operator either sits in a cabin at the top of the tower or controls the crane by radio remote control from the ground, usually standing near the load. In the first case the operator's cabin is located at the top of the tower just below the horizontal boom. The boom is mounted on a slewing bearing and is rotated by means of a slewing motor. The lifting hook is operated by a system of pulleys.

A tower crane is usually assembled by a telescopic crane of smaller lifting capacity but greater height and in the case of tower cranes that have risen while constructing very tall skyscrapers, a smaller crane will sometimes be lifted to the roof of the completed tower to dismantle the tower crane afterward. A self-assembling tower crane has been demonstrated, which lifts itself off the ground using jacks, allowing the next section of the tower to be inserted at ground level.

Truck-mounted crane

A crane mounted on truck carrier which provides the mobility for the crane. Outriggers that extend horizontally and vertically are used to level and stabilize the crane for hoisting.

Rough terrain crane

A crane mounted on an undercarriage with four rubber tires that is designed for pick-and-carry operations and for off-road and "rough terrain" applications. Outriggers that extend horizontally and vertically are used to level and stabilize the crane for hoisting. These telescopic cranes are single-engine machines where the same engine is used for powering the undercarriage as is used for powering the crane, similar to a crawler crane. However, in a rough terrain crane, the engine is usually mounted in the undercarriage rather than in the upper, like the crawler crane.

Crawler crane

A crawler is a crane mounted on an undercarriage with a set of tracks that provide for the stability and mobility of the crane. Crawler cranes have both advantages and disadvantages depending on their intended use. The main advantage of a crawler is that they can move on site and perform lifts with very little set-up, as the crane is stable on its tracks with no outriggers. In addition, a crawler crane is capable of moving with a load. The main disadvantage of a crawler crane is that they are very heavy, and cannot easily be moved from one job site to the next without significant expense. Typically, a large crawler must be disassembled or moved by barge in order to be transported.

Loader crane

Almost invariably called a "Hiab" by its operators, this is a hydraulically-powered articulated arm fitted to a trailer, used to move goods onto or off of the trailer. Unlike most cranes the operator must move around to be able to view his load; hence he will have a portable cabled or radio linked control system. The numerous jointed sections can be folded into a small space when the crane is not in use. One or more of the sections may be telescopic. Often the crane will have a degree of automation and be able to unload or stow itself without an operator's instruction. Manufacturers of loader cranes include the Swedish company Hiab (Hydrauliska Industri AB) and the Danish company HMF .

Gantry crane

A Gantry crane has a hoist in a trolley which runs horizontally along gantry rails, usually fitted underneath a beam spanning between uprights which themselves have wheels so that the whole crane can move at right angles to the direction of the gantry rails. These cranes come in all sizes, and some which are extremely large for use in shipyards or industrial installations can move very heavy loads. A special version is the Portainer crane for loading and unloading ship-borne containers of freight.

Gantry cranes at Harbour

Overhead crane

These are widely used in large factory manufacturing or assembly area.

Also known as a "suspended crane", this type of crane works in the same way as a gantry crane but without uprights. The hoist is on a trolley which moves in one direction along one or two beams, which move at right angles to that direction along elevated tracks, often mounted along the side walls of an assembly area in a factory. Some of them can lift very heavy loads.

Stacker crane

A crane with a forklift type mechanism used in automated (computer controlled) warehouses (known as an automated storage and retrieval system (AS/RS)). The crane moves on a track in an aisle of the warehouse. The fork can be raised or lowered to any of the levels of a storage rack and can be extended into the rack to store and retrieve product. The product can in some cases be as large as an automobile. Stacker cranes are often used in the large freezer warehouses of frozen food manufacturers. This automation avoids requiring forklift drivers to work in below freezing temperatures every day.

Floating crane

Floating cranes are used mainly in bridge building and port construction, but they are also used for occasional loading and unloading of especially heavy or awkward loads on and off ships. Some floating cranes are mounted on a pontoon, others are specialized crane barges with a lifting capacity exceeding 10,000 tonnes and have been used to transport entire bridge sections. Floating cranes have also been used to salvage sunken ships.

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Crane vessels are often used in offshore construction. The largest revolving cranes can be found on SSCV Thialf, which has two cranes with a capacity of 7100 metric tons each

Aerial crane

Aerial cranes usually extend from helicopters to lift large loads. Helicopters are able to travel to and lift in areas that are more difficult to reach by a conventional crane. Aerial helicopter cranes are most commonly used to lift units/loads onto shopping centers, multi-story buildings, highrises, etc. However, they can lift basically anything within their lifting capacity, (i.e. cars, boats, swimming pools, etc.). They also work as disaster relief after natural disasters for clean-up, and during wild-fires they are able to carry huge buckets of water over fires to put them out.

Mechanical principles of Crane

There are two major considerations that are taken into account in the design of cranes. The first is that the crane must be able to lift a load of a specified weight and the second is that the crane must remain stable and not topple over when the load is lifted and moved to another location.

Lifting capacity

Cranes illustrate the use of one or more simple machines to create mechanical advantage.

•***The lever.*** A balance crane contains a horizontal beam (the lever) pivoted about a point called the fulcrum. The principle of the lever allows a heavy load attached to the shorter end of the beam to be lifted by a smaller force applied in the opposite direction to the longer end of the beam. The ratio of the load's weight to the applied force is equal to the ratio of the lengths of the longer arm and the shorter arm, and is called the mechanical advantage.

•***The pulley.*** A jib crane contains a tilted strut (the jib) that supports a fixed pulley block. Cables are wrapped multiple times round the fixed block and round another block attached to the load. When the free end of the cable is pulled by hand or by a winding machine, the pulley system delivers a force to the load that is equal to the applied force multiplied by the number of lengths of cable passing between the two blocks. This number is the mechanical advantage.

•***The hydraulic cylinder.*** This can be used directly to lift the load (as with a HIAB), or indirectly to move the jib or beam that carries another lifting device.

Cranes, like all machines, obey the principle of conservation of energy. This means that the energy delivered to the load cannot exceed the energy put in to the machine. For example, if a pulley system multiplies the applied force by ten, then the load moves only one tenth as far as the applied force. Since energy is proportional to force multiplied by distance, the output energy is kept roughly equal to the input energy (in practice slightly less, because some energy is lost to friction and other inefficiencies).

Stability of crane

In order for a crane to be stable the sum of all moments about any point such as the base of the crane must equate to zero. In practice the magnitude and combination of anticipated loads is increased so that a crane should have a factor of safety against toppling of about ten times. As an accessor one has to be very careful about the safety factors in such criticle equipments.

Winch (Crane for special purpose)

A winch is a mechanical device that is used to wind up a rope or wire rope (also called "cable"). In its simplest form it consists of a spool and attached crank. More elaborate designs have gear assemblies and can be powered by electric, hydraulic, pneumatic or internal combustion drives. Some may include a solenoid brake and/or a mechanical brake or ratchet that prevents it from unwinding.

Besides industrial applications (e.g. in cranes), winches are used for towing cars, boats, or gliders. There are several winches on almost every boat or ship where they are used to pull anchor or mooring lines, halyards, and sheets.

The rope is usually stored on the winch, but a similar machine that does not store the rope is called a capstan.

Winches are frequently used as elements of backstage mechanics to move scenery in large theatrical productions. Winches are often embedded in the stage floor and used to move large set pieces on and off.

Bulk material handling

Bulk Material Handling is an engineering field that is centred around the design of equipment (civil, structural, mechanical, electrical and control) used for the transportation of materials such as ores and cereals in loose bulk form. It can also relate to the handling of mixed wastes.

Bulk material handling systems are typically comprised of moveable items of machinery such as conveyors, stackers, reclaimers, shiploaders, unloaders and various shuttles, hoppers and diverters combined with storage facilities such as stockyards, storage silos or stockpiles.

The purpose of a bulk material handling facility is generally to transport material from one of several locations (i.e. a source) to an ultimate destination. Providing storage and inventory control and possibly material blending is usually part of a bulk material handling system.

Bulk material handling systems can be found on mine sites, ports (for loading or unloading of cereals, ores and minerals) and processing facilities (such as iron and steel, coal fired power stations refineries).

In ports handling large quantities of bulk materials continuous ship unloaders are replacing gantry cranes.

Conveyor belt

A conveyor belt or belt conveyor consists of two pulleys, with a continuous loop of material that rotates about them. The pulleys are powered, moving the belt and the material on the belt forward. Conveyor belts are extensively used to transport industrial and agricultural materials, such as grain, coal, ores, etc. Material flowing over the belt may be weighed in transit using a beltweigher. Belts with regularly spaced partitions, known as elevator belts, are used for transporting loose materials up steep inclines. Conveyor belts are used in self-unloading bulk freighters and in live bottom trucks. This technology is also used in conveyor transport such as moving sidewalks or escalators, as well as on many manufacturing assembly lines. Stores often have conveyor belts at the check-out counter to move shopping items. Ski areas also use conveyor belts to transport skiers up the hill. A wide variety of conveying machines are available, different as regards principle of operation, means and direction of conveyance, including screw conveyors, the moving floor system, which uses reciprocating slats to move cargo, and roller conveyor system, which uses a series of powered rollers to convey boxes or pallets. This is widely used in industries for movement of work in progress or finished goods to storage area.

The longest conveyor belt in the world is in Western Sahara. It is 100 km long, from the phosphate mines of Bu Craa to the coast south of El-Aaiun. The longest single belt conveyor runs from Meghalaya in India to Sylhet in Bangladesh. It is 17 km long and conveys limestone and shale.

Conveyor mechanisms are used as components in automated distribution and warehousing. In combination with computer controlled pallet handling equipment this allows for more efficient retail, wholesale, and manufacturing distribution. It is considered a labor saving system that allows large volumes to move rapidly through a process, allowing companies to ship or receive higher volumes with smaller storage space and with less labor expense.

Engineering vehicles
Engineering vehicles are heavy-duty vehicles, specially designed for executing engineering tasks.

These vehicles can be put under various catagories depending on where the material is handled or how it is handled.

- Caterpillar vehicles
- Excavators
- Forklift truck
- Tractors

Caterpillar vehicles
The Caterpillar vehicle group includes the Bulldozers, JCBs etc which are used for earth moving, excavation or bulldozing use.

For use in a rough or hazadous tarrien, these combat engineering vehicles combine the earth moving capabilities of the bulldozer with armor which gives the vehicle and its operator protection when operating in or around a combat situation. In most cases they are civilian models that have been modified by the addition of armor and military equipment but there have been cases where a tank has been stripped of its armament and fitted with a dozer blade as in the British Centaur of the Second World War which were used at the Normandy landings alongside armored versions of the Caterpillar D8 bulldozer. Tanks have been fitted with bulldozer blades while retaining their armament but this does not make them armored bulldozers as such.

Bulldozer

A bulldozer is a very powerful crawler (caterpillar tracked tractor) equipped with a blade. The term "bulldozer" is often used to mean any heavy engineering vehicle, but precisely, the term refers only to a tractor (usually tracked) fitted with a dozer blade. That is the meaning used herein.

The first bulldozers were built by a man by the name of William "Willy" Kern. It was his love for engines and their inability to perform under the harsh "hole-digging" presure that he put on them that eventually gave Willy the push to adapt farm Holt tractors that were used to plough fields into what we today call "bulldozers", Their versatility in soft ground for logging and road building lead directly to them becoming the armoured tank in the first war.

By the 1920s, tracked vehicles became common, particularly the Caterpillar 60. To dig canals, raise earth dams, and do other earthmoving jobs, these tractors were equipped with a large thick metal plate in front. This thick metal plate (it got its curved shape later) is called a "blade". The blade peels layers of soil and pushes it forward as the tractor advances. Several specialised blades have been developed: for high volume loads such as coal, rakes to remove only larger boulders, or blades with razor sharp edges to cut tree stumps. In some early models the driver sat on top in the open without a cabin. These attachments, home built or by small equipment manufacturers of attachments for wheeled and crawler tractors and trucks, appeared by 1929, widespread acceptance of the bull-grader does not seem to appear before the mid-1930's, and the addition of powered down force made them the preferred excavation machine for large and small contractors alike by the 1940's, by which time the term "bulldozer" referred to the entire machine and not just the attachment.

CVSRTA

Over the years, when engineers needed equipment to complete large scale earthworks, firms like the CAT, Komatsu, Fiat-Allis, John Deere, International Harvester, Case, Liebherr, Terex and JCB started to manufacture large tracked-type earthmoving machines. They were large, noisy, and powerful, and therefore nicknamed "bulldozer".

Through the years, bulldozers got bigger, more powerful, and more sophisticated. Important improvements include more powerful engines, more reliable drive trains, better tracks, raised cabins, and hydraulic (instead of early models' cable operated) arms that enable more precise manipulation of the blade and automated controls. As an option, bulldozers can be equipped with a rear ripper claw to loosen rocky soils or to break up pavement (roads).

Description

Most often, bulldozers are large and powerful tracked engineering vehicles. The tracks give them excellent ground hold and mobility through very rough terrain. Wide tracks help distribute the bulldozer's weight over large area (decreasing pressure), thus preventing it from sinking in sandy or muddy ground. Extra wide tracks are known as 'swamp tracks'. Bulldozers have excellent ground hold and a torque divider designed to convert the engine's power into dragging ability , letting the bulldozer use its own weight to push very heavy things and remove obstacles that are stuck in the ground. The Caterpillar D9, for example, can easily tow tanks that weigh more than 70 tons. Because of these attributes, bulldozers are used to clear areas of obstacles, shrubbery, burnt vehicles, and remains of structures.

Sometimes a bulldozer is used to push another piece of earthmoving equipment known as a "scraper". The towed Fresno Scraper, invented in 1883 by James Porteous, was the first design to enable this to be done economically, removing the soil from the cut and depositing it elsewhere on shallow ground (fill). Many dozer blades have a reinforced center section with this purpose in mind, and are called "bull blades."
The bulldozer's primary tools are the blade and the ripper.

Compact excavator

A compact hydraulic excavator is a tracked or wheeled vehicle with an approximate operating weight of 6 metric tons (13,228 lbs). It generally includes a standard backfill blade and features independent boom swing. The compact hydraulic excavator is also referred to as a mini excavator.

The compact hydraulic excavator is somewhat unique from other construction equipment in that all movement and functions of the machine are accomplished through the transfer of hydraulic fluid. The compact excavator's work group and blade are activated by hydraulic fluid acting upon hydraulic cylinders. The excavator's slew (rotation) and travel functions are also activated by hydraulic fluid powering hydraulic motors.

In recent years, hydraulic excavator capabilities have expanded far beyond excavation tasks. With the advent of hydraulic powered attachments such as breakers, clamps, augers and compactors, the excavator is frequently used in many applications other than excavation and actually serves as an effective attachment tool carrier. Many excavators feature quick-attach mounting systems for simplified attachment mounting, dramatically increasing the machine's utilization on the jobsite.

Loader

A loader, also called a front end loader, bucket loader, scoop loader or shovel, is a type of tractor, usually wheeled, that uses a wide square tilting bucket on the end of movable arms to lift and move material. The loader assembly may be a removable attachment or permanently mounted. Often the bucket can be replaced with other devices or tools—like forks to lift heavy pallets or shipping containers, hydraulically-opening "clamshell" bucket allows a loader to act as a light dozer or scraper. The bucket can also be augmented with devices like a bale grappler for handling large bales of hay/ straw.

Large loaders, such as the Caterpillar 950G/966G, Volvo L120E or Hitachi ZW310 usually have only a front bucket and are called Front Loaders, whereas small loader tractors are often also equipped with a small backhoe and are called backhoe loaders or loader backhoes.

Loaders are used mainly for uploading materials into trucks, laying pipe, clearing rubble, and digging. A loader is not the most efficient machine for digging as it cannot dig very deep below the level of its wheels, like a backhoe can. Their deep bucket can usually store about 3-6 cubic meters (exact number varies with the model) of earth.

The front loader's bucket capacity is much bigger than a bucket capacity of a backhoe loader. Loaders are not classified as earthmoving machinery, as their primary purpose is other than earthmoving.

In construction areas loaders are also used to transport building materials - such as bricks, pipe, metal bars, and digging tools - over short distances.

Loaders are also used for snow removal, using their bucket or a snowbasket but usually they use a snowplow attachment. They clear snow from streets and highways and also parking lots. They sometimes load the snow into dump trucks which haul it away.
Unlike most bulldozers, some loaders are wheeled and not tracked. However, track loaders do exist. They are sucessful where sharp edged materials or nails in construction debris would damage rubber wheels. Wheels provide better mobility and speed and do not damage paved roads as much as tracks, but this comes at the cost of reduced traction.

Unlike backhoes or standard tractors fitted with a front bucket, many large loaders do not use automotive steering mechanisms. Instead, they steer by a hydraulically actuated pivot point set exactly between the front and rear axles. This is referred to as "articulated steering" and allows the front axle to be solid, allowing it to carry a heavier weight. Articulated steering also gives reduced turning radius (and therefore higher maneuverability) for a given wheelbase. Since the front wheels and attachment rotate on the same axis, the operator is able to "steer" his load in an arc after positioning the machine, which can come in handy. The problem is that when the machine is "twisted" to one side and a heavy load is lifted high, it has a bigger risk of turning over to the "wide" side.

Forklift truck

A forklift truck, a lift truck or a forklift is a powered industrial truck used to lift and transport materials, normally by means of steel forks inserted under the load. Forklifts are most commonly used to move loads stored on pallets. The forklift was developed in the 1920s by various companies including the transmission manufacturing company Clark (today known as Clark Material Handling Company) and the hoist company Yale & Towne Manufacturing (Today known as Yale Materials Handling Corporation)[1]. It has since become an indispensable piece of equipment in manufacturing and warehousing operations.

Following is the list of the more common truck types, from the smallest to the biggest:

- Hand pallet truck
- Walkie low lift truck
- Rider low lift truck
- Towing tractor
- Walkie stacker
- Rider stacker
- Reach truck
- Electric counterbalanced truck
- IC counterbalanced truck
- Telescopic handler
- Slip Sheet machine
- Walkie Order Picking truck
- Rider Order Picking truck

The names of the trucks themselves are indicative of the type. All the description given under, singularly or collectively can describe a typical forklift:

- The truck proper, which is a motive machine with wheels and/or tracks powered through a drive train
- An LPG, gasoline or diesel fueled internal combustion engine, or an electric motor(s) either Direct Current or Alternating Current powered by either a battery or fuel cells.
- The mast, which is the vertical assembly that does the work of raising, lowering, and tilting the load; the mast is either hydraulically operated consisting of one or cylinder(s) and interlocking rails for lifting and lowering operations and for lateral stability, or it may be chain operated with a hydraulic motor providing motive power.
- The carriage, which comprises flat metal plate(s) and is moved along the mast either by means of chains, or by being directly attached to the hydraulic cylinder.
- The cab, which may contain a seat for the operator, along with the control pedals, steering wheel, levers, and switches for controlling the machine and a dashboard containing operator readouts. The cab may be open, or closed, but is bounded by the cage-like overhead guard assembly.
- Counterbalance machines have a counterweight, which is a heavy iron mass attached to the rear of the machine, necessary to compensate for the load. In an electric forklift, the large lead-acid battery itself may serve as part of the counterweight.

Control and capability

Forklift trucks are available in many variations and load capacities. In a typical warehouse setting most forklifts used have load capacities of around one to five tons, though machines of over 50 tonnes capacity have been built and operated.

In addition to a control to raise and lower the forks (also known as blades or tines), the operator can tilt the mast to compensate for a load's tendency to angle the blades toward the ground and risk slipping off the forks. Tilt also provides a limited ability to operate on non-level ground. Some machines also allow the operator to move the tines and backrest laterally(side-shift), allowing easier placement of a load. To aid the handling of skids that may have become excessively tilted and other specialty material handling needs, some forklifts are fitted with a mechanism that allows the tines to be rotated. In addition, a few machines offer a hydraulic control to move the tines together or apart, removing the need for the operator to get out of the cab to manually adjust for a differently sized load.

Roll and Barrel Clamp attachments for handling barrels, kegs, or paper rolls also have a control to operate the Clamp pads that grab the load, such attachments also usually have a rotate function so that a vertically stored paper roll can be inserted into the horizontal intake of a printing press.

Another variation, used in some manufacturing facilities, utilizes forklift trucks with a clamp attachment that the operator can open and close around a load, instead of forks. Products such as cartons, boxes, etc., can be moved with these trucks. The product to be moved is squeezed, lifted, and carried to its destination. These are generally referred to as "clamp trucks".

Tractor

A tractor is a device intended for drawing, towing or pulling something which cannot propel itself and, often, powering it too. Most commonly the word is used to describe a vehicle intended for pulling some other vehicle or object.

In Britain and India the word "tractor" usually means "farm tractor", and the use of the word "tractor" to mean other types of vehicles is familiar to the vehicle trade but unfamiliar to much of the general public. In Canada and the US the word is also used to refer to a road tractor .

The word comes from the Latin trahere "to pull". A conflicting history of the name suggests that steam tractors were originally referred to as traction engines, with the word "tractor" eventually deriving from a contraction of 'traction' and 'motor'.

Farm tractor

The most common use of the term is for the vehicles used on farms. The farm tractor is used for pulling or pushing agricultural machinery or trailers, for plowing, tilling, disking, harrowing, planting, and similar tasks.

The classic farm tractor is a simple open vehicle, with two very large driving wheels on an axle below and slightly behind a single seat (the seat and steering wheel consequently are in the center), and the engine in front of the driver, with two steerable wheels below the engine compartment. This basic design has remained unchanged for a number of years, but enclosed cabs are fitted on almost all modern models, for reasons of operator safety and comfort.

There are also lawn tractors. Cub Cadet, Husqvarna, John Deere, Massey Ferguson and Toro are some of the better known brands.

Farm implements can be attached to the rear of the tractor by either a drawbar or a three-point hitch. The three-point hitch was invented by Harry Ferguson and has been standard since the 1960s. Equipment attached to the three-point hitch can be raised or lowered hydraulically with a control lever. The equipment attached to the three-point hitch is usually completely supported by the tractor. Another way to attach an implement is via a Quick Hitch, which is attached to the three-point hitch. This enables a single person to attach an implement quicker and put the person in less danger when attaching the implement.

Engineering tractors

The durability and engine power of tractors made them very suitable for engineering tasks. Tractors can be fitted with engineering tools such as dozer blade, bucket, hoe, ripper, and so on. The most common attachments for the front of a tractor are dozer blade or a bucket. When attached with engineering tools the tractor is called an engineering vehicle.

A bulldozer is a track-type tractor attached with blade in the front and a rope-winch behind. Bulldozers are very powerful tractors and have excellent ground-hold, as their main tasks are to push or drag things.

Bulldozers have been further modified over time to evolve into new machines which are capable of working in ways that the original bulldozer can not. One example is that loader tractors were created by removing the blade and substituting a large volume bucket and hydraulic arms which can raise and lower the bucket, thus making it useful for scooping up earth, rock and similar loose material to load it into trucks.
A front-loader or loader is a tractor with an engineering tool which consists of two hydraulic powered arms on either side of the front engine compartment and a tilting implement. This is usually a wide open box called a bucket but other common attachments are a pallet fork and a bale grappler.

Other modifications to the original bulldozer include making the machine smaller to let it operate in small work areas where movement is limited. There are also tiny wheeled loaders, officially called Skid-steer loaders but nicknamed "Bobcat" after the original manufacturer, which are particularly suited for small excavation projects in confined areas.

EPA tractor

During World War II there was a shortage of tractors in Sweden and this led to the invention of a new type of tractor called the EPA tractor (EPA was a chain of discount stores and it was often used to signify something lacking in quality). An EPA tractor was simply an automobile, truck or lorry, with the passenger space was cut off behind the front seats, equipped with two gearboxes in a row. When done to an older car with a ladder frame, the result was not dissimilar to a tractor and could be used as one.

Other types of tractors

Road tractors or tractor units

Heavy-duty vehicles with large engines and several axles. These tractors are designed to pull long semi-trailers, most often for the transport of freight of some kind over a significant distance (see also semi-trailer truck). In England this type of "tractor" is often called an "artic cab".

Locomotive tractors (engines) or Rail car movers

The amalgamation of machines, electrical generators, controls and devices that comprise the traction component of railway vehicles. In large industrial units these are deployed for movement of railway wagons in the yard.

Artillery tractors

Vehicles used to tow artillery pieces of varying weights. For movement of large equipments and crane booms, these tractors are used in industries.

Fire Control & Alarm Equipments

Fire extinguisher

A fire extinguisher is an active fire protection device to extinguish or control a fire, often in emergency situations. Typically a fire extinguisher consists of a handheld cylindrical pressure vessel containing an agent that when discharged, can extinguish a fire.

In order to use a packaged commercial fire extinguisher, you must first make sure it is suitable to the type of fire. If it is not a suitable type, it may not be effective or it may cause additional dangers. For example, water on a kitchen oil fire might splash the flaming oil over a wide area. Water on an active electrical fire might create a shock danger.

If the fire extinguisher is suitable, the typical steps to use it are:
(P) Pull the safety pin
(A) Aim the nozzle at the base of the fire, from a safe distance (about six feet away)
(S) Squeeze the handle
(S) Sweep the extinguisher from side to side while aiming at the base of the fire
Since the fire might try to start up again, make SURE it stays out!

According to the standard BS EN 3, fire extinguishers in the United Kingdom are predominately red, and a band or circle of a second color covering at least 5% of the surface area of the extinguisher indicates the contents. Before 1997, the entire body of the fire extinguisher was colour coded according to the type of extinguishing agent.

Type	Old Code	BS EN 3 Colour Code	Fire Class
Water	Signal Red	Signal Red	A
Foam	Cream	Red with a Cream panel above the operating instructions	A, B and sometimes E
Dry Powder	French Blue	Red with a Blue panel above the operating instructions	A, B, C,E/B,C,E
Carbon Dioxide CO_2	Black	Red with a Black panel above the operating instructions	A(Limited),B,E
Halon	Emerald Green	Pre-03- Signal red with a green panel	A,B,E
Wet Chemical	No F Class	Red with a Canary Yellow panel above the operating instructions	A, F
Class D Powder	French Blue	Red with a Blue panel above the operating instructions	D

The UK recognizes six fire classes. Class A fires involve organic solids such as paper and wood. Class B fires involve flammable liquids. Class C fires involve flammable gases. Class D fires involve metals, Class E fires involve live electrical items and Class F fires involve cooking fat and oil. Fire extinguishing capacity is rated by fire class using numbers and letters such as 13A, 55B.

Chemistries

A fire extinguisher may emit a solid, liquid, or gaseous chemical.

Water

Water is the most common chemical for class A fires and if available in sufficient volume can be quite effective. Water extinguishes flame by cooling the fuel surfaces and thereby reduces the pyrolysis rate of the fuel. The effectiveness against the combustion sustaining effect of burning gases is minor for extinguishers, but water fog nozzles used by fire departments creates water droplets small enough to be able to extinguish flaming gases as well. The smaller the droplets, the greater the effectiveness water has against burning gases.

Most water based extinguishers also contain traces of other chemicals to prevent the extinguisher from rusting. Some also contain surfactants which help the water penetrate deep into the burning material and cling better to steep surfaces.

Water may or may not help extinguish class B fires. It depends on whether or not the liquid's molecules are polar molecules. If the liquid that is burning is polar (such as alcohol), then water can be an effective means of extinguishment. If the liquid is nonpolar (such as large hydrocarbons, like petroleum or cooking oils), the water will merely spread the flames around.

Similarly, water sprayed on an electrical fire (US: Class C, UK: Class E) increases the likelihood that the operator will receive an electric shock. However, if the power can be reliably disconnected and a carbon dioxide or halon extinguisher is not available, clean water actually causes less damage to electrical equipment than will either foam or dry powders. Special spray nozzles called fog nozzles, equipped with tiny rotating devices called spiracles replace the continuous water jet with a succession of droplets, greatly increasing the resistivity of the jet. These should however be used by skilled personnel, since these complex nozzle assemblies may difficult to use effectively without training.

Foams

fighting a petrol fire with a foam extinguisher

Foams are commonly used on class B fires, and are also effective on class A fires. These are mainly water based, with a foaming agent so that the foam can float on top of the burning liquid and break the interaction between the flames and the fuel surface. Ordinary foams work better if "poured" but it is not critical.

A "protein foam" was used for fire suppression in aviation crashes until the 1960s development of "light water", also known as "Aqueous Film-Forming Foam" (or AFFF). Carbon dioxide (later sodium bicarbonate) extinguishers were used to knock down the flames and foam used to prevent re-ignition of the fuel fumes. "Foaming the runway" can reduce friction and sparks in a crash landing, and protein foam continue to be used for that purpose, although FAA regulations prohibit reliance upon its use for reduction of the risk of ignition in gear up landing.

AFFF in concentrations less than 3% is not acceptable to the FAA for use on airports. The 1% concentrate that is available should not be used in ARFF applications because of the difficulty in consistently providing an accurate mixture. Any attempt to use 1% foam would necessitate the installation of a computer-controlled system and each load would have to be checked carefully.

Ordinary foams are designed to work on nonpolar flammable liquids such as petrol (gasoline), but may break down too quickly in polar liquids such as alcohol or glycol. Facilities which handle large amounts of flammable polar liquids use a specialized "alcohol foam" instead. Alcohol foams must be gently "poured" across the burning liquid. If the fire cannot be approached closely enough to do this, they should be sprayed onto an adjacent solid surface so that they run gently onto the burning liquid.

Alcohol type foams are typically used by city and industrial fire departments because they are effective on both hydrocarbons, such as gasoline, and polar solvents such as alcohol. Most fire department will only carry only one type of foam on their trucks if they use alcohol type foams.

Dry Powder ("Dry Chemical" in the US)

For classes B and C, a dry powder is used. There are two main dry powder chemistries in use:

- BC powder is either sodium bicarbonate or potassium bicarbonate, finely powdered and propelled by carbon dioxide or nitrogen. Similarly to almost all extinguishing agents the powders acts as a thermal ballast making the flames too cool for the chemical reactions to continue. Some powders also provide a minor chemical inhibition, although this effect is relatively weak. These powders thus provide rapid knockdown of flame fronts, but may not keep the fire suppressed. Consequently, they are often used in conjunction with foam for attacking large class B fires. BC extinguishers are often kept in small vehicles since they provide good knockdown of a rapidly flaring class B fire, from a small package. BC Powder has a slight saponification effect on cooking oils & fats due to its alkalinity & sometimes used to be specified for kitchens prior to the invention of Wet Chemical extinguishers.

Where an extremely fast knockdown is required potassium bicarbonate (Purple K) extinguishers are used. A particular blend also containing urea (Monnex) decrepitates upon exposure to heat increasing the surface area of the powder particles and providing very rapid knockdown.

- ABC powder is monoammonium phosphate and/or ammonium sulphate. As well as suppressing the flame in the air, it also melts at a low temperature to form a layer of slag which excludes the gas and heat transfer at the fuel surface. For this reason it can also be effective against class A fires. ABC powder is usually the best agent for fires involving multiple classes. However it is less effective against three-dimensional class A fires, or those with a complex or porous structure. Foams or water are better in those cases.

Both types of powders can also be used on electrical fires, but provide a significant cleanup and corrosion problem that is likely to make the electrical equipment unsalvageable.

Wet potassium salts ("Wet Chemical")

Most class F (class K in the US) extinguishers contain a solution of potassium acetate, sometimes with some potassium citrate or potassium bicarbonate. The extinguishers spray the agent out as a fine mist. The mist acts to cool the flame front, while the potassium salts saponify the surface of the burning cooking oil, producing a layer of foam over the surface. This solution thus provides a similar blanketing effect to a foam extinguisher, but with a greater cooling effect. The saponification only works on animal fats and vegetable oils, so class F extinguishers cannot be used for class B fires. The misting also helps to prevent splashing the blazing oil.

Carbon dioxide

Carbon dioxide extinguisher

Carbon dioxide (CO_2) also works on classes B and C/E and works by suffocating the fire. Carbon dioxide will not burn and displaces air. Carbon dioxide can be used on electrical fires because, being a gas, it does not leave residues which might further harm the damaged equipment. (Carbon dioxide can also be used on class A fires when it is important to avoid water damage, but in this application the gas concentration must usually be maintained longer than is possible with a hand-held extinguisher.) Carbon dioxide extinguishers have a horn on the end of the hose. Due to the extreme cold of the carbon dioxide that is expelled from an extinguisher, it should not be touched.

Halons

Halons are very versatile extinguishers. They will extinguish most types of fire except class D & K/F and are highly effective even at quite low concentrations (less than 5%). Halon is a poor extinguisher for Class A fires, a nine pound Halon extinguisher only receives a 1-A rating and tends to be easily deflected by the wind. They are the only fire extinguishing agents that are quite suitable for discharge in aircraft (as other materials pose a corrosion hazard to the aircraft). Halon fire-suppression systems are also incorporated into some armored fighting vehicles, such as the M1 Abrams tank. The major extinguishing effect is by disturbing the thermal balance of the flame, and to a small extent by inhibiting the chemical reaction of the fire. Halons are chlorofluorocarbons causing damage to the ozone layer and are being phased out for more environmentally-friendly alternatives. Halon fire extinguishers may cost upwards of Rs 50000 due to production and import restrictions.

Halon extinguishers used to be widely used in vehicles and computer suites. It is mildly toxic in confined spaces, but to a far less extent than its predecessors such as carbon tetrachloride, chlorobromomethane and methyl bromide.

Since 1992 the sale and service of Halon extinguishers has been made illegal in Canada due to environmental concerns except for in a few rare cases, as per the Montreal Protocol.

In the UK and Europe Halons were made illegal at the end of 2003, except for certain specific aircraft and law enforcement uses. This appears to be at least partially in response to the Montreal Protocol and effort by the United Nations Environment Programme (UNEP) to combat release of quantities of harmful chemicals into the atmosphere.

Phosphorus tribromide

Like Halon, phosphorus tribromide is a flame chemistry poison, marketed under the brand name PhostrEx. PhostrEx is a liquid which needs a propellant, such as compressed nitrogen and/or helium, to disperse onto a fire. As a fire extinguisher, PhostrEx is much more potent than Halon, making it particularly appealing for aviation use as a lightweight substitute. Unlike Halon, PhostrEx reacts quickly with atmospheric moisture to break down into phosphorous acid and hydrogen bromide, neither of which harms the earth's ozone layer.

High concentrations of PhostrEx can cause skin blistering and eye irritation, but since so little is needed to put out flames this problem is not a significant risk, especially in applications where dispersal is confined within an engine compartment. Any skin or eye contact with PhostrEx should be rinsed with ordinary water as soon as practical. PhostrEx is not especially corrosive to metals, although it can tarnish some. The U.S. EPA and FAA both approved PhostrEx, and the substance will find its first major use in Eclipse Aviation's jet aircraft as an engine fire suppression system.

Fluorocarbons

Recently, DuPont has begun marketing several nearly saturated fluorocarbons under the trademarks FE-13, FE-25, FE-36, FE-227, and FE-241. These materials are claimed to have all the advantageous properties of halons, but lower toxicity, and zero ozone depletion potential. They require about 50% greater concentration for equivalent fire quenching.

Specialised materials for Class D

Class D fires involve extremely high temperatures and highly reactive fuels. For example, burning magnesium metal breaks water down to hydrogen gas and excites the fire; breaks halon down to toxic phosgene and fluorophosgene and may cause a rapid phase transition explosion; and continues to burn even when completely smothered by nitrogen gas or carbon dioxide (in the latter case, also producing toxic carbon monoxide). Consequently, there is no one type of extinguisher agent that is approved for all class D fires; rather, there are several common types and a few rarer ones, and each must be compatibility approved for the particular hazard being guarded. Additionally, there are important differences in the way each one is operated, so the operators must receive special training. Some example class D chemistries include:

- Granulated sodium chloride and graphite applied by a shaker, scoop or shovel. Suitable for sodium, potassium, magnesium, titanium, aluminium, and most other metal fires.
- Powdered graphite, applied with a long handled scoop, is preferred for fires in fine powders of reactive metals, where the blast of pressure from an extinguisher may stir up the powder and cause a dust explosion. Graphite both smothers the fire and conducts away heat.
- Finely powdered copper propelled by compressed argon is the currently preferred method for lithium fires. It smothers the fire, dilutes the fuel, and conducts away heat. It is capable of clinging to dripping molten lithium on vertical surfaces. Graphite can also be used on lithium fires but only on a level surface.
- Other materials sometimes used include powdered sodium carbonate, powdered dolomite and argon gas.
- As a very poor last resort dry sand may be used to smother a metal fire if nothing else is available, applied with a long-handled shovel to avoid the operator receiving flash burns. Sand is, however, notorious for collecting moisture, and even the smallest trace of moisture may result in a steam explosion, spattering burning molten metal around.

Fire sprinkler

Fire sprinklers are an active fire protection measure subject to stringent bounding. They are connected to a fire suppression system that consists of overhead pipes fitted with sprinkler heads throughout the coverage area. Fire sprinkler systems for high-rises are usually also equipped with a fire pump, and a jockey pump and are tied into the fire alarm system. Although historically only used in factories and large commercial buildings, home and small building systems are now available at a relatively cost-effective price.

Each sprinkler head is held closed independently by heat-sensitive seals. These seals prevent water flow until a design temperature is exceeded at the individual sprinkler heads.

Each sprinkler activates independently when the predetermined heat level is reached. The design intention is to limit the total number of sprinklers that operate, thereby providing the maximum water supply available from the water source to the point of fire origin.

Typical "wet" systems are simple and passive. They have water already pressurized in the pipes held back by the sprinkler head. These systems require no manual controls to activate, so long as adequate water supplies are provided.

Specialty systems called "dry" systems, designed for unheated spaces, have a low "maintenance" air pressure in the pipes. Water is fed into the system when the sprinkler "fuses" allowing the maintenance air pressure to reach the minimum pressure point. "Pre-action" systems are highly specialized for locations where accidental activation is unacceptable such as museums with rare art works, manuscripts, or books. Pre-action valves are connected to fire alarm initiating devices such as smoke detectors or heat detectors and virtually eliminate the possibility of accidental water flow.

"Deluge" systems are "pre-action" systems that have open sprinklers, i.e. the fusible link is removed, so that every sprinkler served by the system will discharge water. This ensures a large and simultaneous application of water over the entire hazard. These systems are used for special hazards where rapid fire spread is a concern.
Other specialty systems may have foam instead of water suppression agents for fire protection in occupancies with flammable liquids, such as airport hangars. "Clean agent" gaseous systems, such as Argon/CO2/Nitrogen mixtures can be used in very small spaces where water cannot be used for suppression.

A sprinkler activation will do less damage than a fire department hose, as the fire department's hose streams provide around 250 US gallons per minute (15 L/s) whereas an activated sprinkler head generally discharges around 23 US gallons per minute (1.5 L/s). In addition, the sprinkler will activate immediately; whereas a fire appliance takes some time to reach an incident. This delay can result in substantial damage from the fire before the appliance arrives and will the fire will be much larger; requiring much more water to extinguish.

Most sprinkler systems installed today are designed using an area and density approach. First the building use and building contents are analyzed to determine the level of fire hazard. Usually buildings are classified as light hazard, ordinary hazard group 1, ordinary hazard group 2, extra hazard group 1, or extra hazard group 2. After determining the hazard classification, a design area and density can be determined by referencing tables in the National Fire Protection Association (NFPA) handbooks. The design area is a theoretical area of the building representing the worst case area where a fire could burn.

The design density is a measurement of how much water per square foot of floor area should be applied to the design area. For example, in an office building classified as light hazard, a typical design area would be 1500 square feet and the density would be 0.1 gallons per minute per square foot or a minimum of 150 gallons per minute applied to the 1500 square foot design area. Another example would be a warehouse classified as ordinary hazard group 2 where a typical design area would be 1500 square feet and the density would be 0.2 gallons per minute per square foot or a minimum of 300 gallons per minute applied to the 1500 square foot design area.

After the design area and density have been determined, calculations are performed to prove that the system can deliver the required amount of water to the required design area. These calculations account for all of the pressure that is lost or gained between the includes pressure that is lost due to friction inside the piping, pressure that is lost or gained due to elevation differences between the source and the discharging sprinklers, and sometimes momentum pressure from water velocity inside the piping is also calculated.

Fire alarm system

Fire alarm systems have devices connected to them to detect the fire/smoke or to alert the occupants of an emergency. Below is a list of common devices found on a fire alarm.

- **Manual pull stations/manual call points** - Devices to allow people to manual activate the fire alarm. Usually located near exits.
  A fire alarm pull station is an active fire protection device, usually wall-mounted, that, when activated, initiates an alarm on a fire alarm system. In its simplest form, the user activates the alarm by pulling the handle down, which completes a circuit and locks the handle in the activated position, and sending an alarm to the fire alarm control panel. Fire alarm pull station are often reset using a key, which allows the handle to go back up to its normal position.
  Many fire alarm pull stations are single action and only require the user to pull down the handle. Other fire alarm pull stations are dual-action, and as such require the user to perform a second task before pulling down, such as lifting up or pushing in a panel on the station, or shattering a glass panel. The Fire-Lite BG-10 and the Cerberus Pyrotronics (Siemens) MS-501 are examples of this design. Perhaps the most recognizable pull station is the T-bar style pull. The style is so named because the handle is shaped like the letter "T". This style was first manufactured by Simplex, and is now manufactured by many other companies.

- **Manual call points**

  In Europe, a manual call point, usually referred to as an MCP within the fire protection industry, and as a "break glass" in the UK, is used to allow building occupants to signal that a fire or other emergency exists within the building. They are usually connected to a central fire alarm panel which is in turn connected to an alarm system in the building, and often to a local fire brigade dispatcher as well. The first MCP (as we know it) arrived in Europe in 1972 and was invented by KAC. [1]

  MCP's would historically be printed with FIRE as a title above a glass element, where the element would be glass which would be covered with plastic. This element design would be the old British Standard. The new European Standard EN54 says that the title should be the House Flame symbol, and the glass would appear differently. The glass will still be covered with plastic on the printed side.
- **Smoke detectors –** Smoke detectors, as the name suggest, detects the smoke in the vicinity and sends signal to the control panel. There are many types in use. Main types being - Spot type: Photoelectric and Ionization; Line type: Projected Beam Smoke Detector; Air-Sampling type: Cloud Chamber
- **Water Flow Switches –** On receipt of comand from the control panel, if there is a sprinkler system, the water flow switch will be activated. It detects & controls the water flowing through the fire sprinkler system
- **Rate-of-Rise and Thermostat (heat) Detectors -** Detect heat changes. These are used in addition to smoke detectors. Heat generated may be prior to full fledge fire can also be detected by this units. On sensing a predetermined heat, a signal is sent to control
- **Valve Position Switch -** Indicates that a fire sprinkler system valve that is required to be open, is now closed (off-normal).
- **Carbon Monoxide Detectors –** In case of fire, there is all possibility that the fire may starve of oxygen. This lack of oxygen will result in production of Carbon Monoxide gas (instead of Carbon Dioxide) This is highly poiseneous gas. It is more dangerous because it is without any colour or odour (smell). The CO detectors detects poisonous carbon monoxide gas and gives alarm.
- **Horns/Strobes -** Visual and Audible devices to alert people of system activation.
- **Magnetic Door Holder -** Doors are allowed to close when the fire alarm is activated.
- **Control Panel -** The control panel is the main analysing and commanding unit of the system. It receives signal from various sensor devices and actuating devices listed above. On recept of this signal, it gives out appropriate command for various acts like – audiable / visual alarm, activation of automatic fire fighting system like sprinklers, closure of doors for isolation of effected area for prevention of spreading of fire etc. The control panel also gives repeat alarm to area panels situated in stratagic locations like medical unit, control room, HODs office etc.

CVSRTA

Telecommunication

Telecommunication is the transmission of signals over a distance for the purpose of communication. In modern times, this process almost always involves the sending of electromagnetic waves by electronic transmitters

The basic elements of a telecommunication system are:

- a transmitter that takes information and converts it to a signal for transmission
- a transmission medium over which the signal is transmitted
- a receiver that receives and converts the signal back into usable information

Signals can either be analogue or digital. In an analogue signal, the signal is varied continuously with respect to the information. In a digital signal, the information is encoded as a set of discrete values (e.g. 1's and 0's). Telecommunications devices convert different types of information, such as sound and video, into electrical or optical signals. Electrical signals typically travel along a medium such as copper wire or are carried over the air as radio waves. Optical signals typically travel along a medium such as strands of glass fibers. When a signal reaches its destination, the device on the receiving end converts the signal back into an understandable message, such as sound over a telephone, moving images on a television, or words and pictures on a computer screen

A collection of transmitters, receivers or transceivers that communicate with each other is known as a network. Digital networks may consist of one or more routers that route data to the correct user. An analogue network may consist of one or more switches that establish a connection between two or more users. For both types of network, a repeater may be necessary to amplify or recreate the signal when it is being transmitted over long distances. This is to combat attenuation that can render the signal indistinguishable from noise.

In a conventional telephone system, the caller is connected to the person they want to talk to by the switches at various exchanges. The switches form an electrical connection between the two users and the setting of these switches is determined electronically when the caller dials the number based upon either pulses or tones made by the caller's telephone. Once the connection is made, the caller's voice is transformed to an electrical signal using a small microphone in the telephone's receiver. This electrical signal is then sent through various switches in the network to the user at the other end where it transformed back into sound waves by a speaker for that person to hear. This person also has a separate electrical connection between him and the caller which allows him to talk back.

Today, the fixed-line telephone systems in most residential homes are analogue — that is the speaker's voice directly determines the amplitude of the signal's voltage. However although short-distance calls may be handled from end-to-end as analogue signals, increasingly telephone service providers are transparently converting signals to digital before converting them back to analogue for reception. The advantage being that digitized voice data can travel side-by-side with data from the Internet and that digital signals can be perfectly reproduced in long distance communication as opposed to analogue signals which are inevitably impacted by noise.

Mobile phones have had a significant impact on telephone networks. Mobile phone subscriptions now outnumber fixed-line subscriptions in many markets. Sales of mobile phones in 2005 totalled 816.6 million with that figure being almost equally shared amongst the markets of Asia/Pacific (204 m), Western Europe (164 m), CEMEA (Central Europe, the Middle East and Africa) (153.5 m), North America (148 m) and Latin America (102 m). In terms of new subscriptions over the five years from 1999, Africa has outpaced other markets with 58.2% growth. Increasingly these phones are being serviced by digital systems such as GSM or W-CDMA with many markets choosing to depreciate analogue systems such as AMPS.

There have also been dramatic changes in telephone communication behind the scenes. Starting with the operation of TAT-8 in 1988, the 1990s saw the widespread adoption of systems based upon optic fibres. The benefit of communicating with optic fibres is that they offer a drastic increase in data capacity. TAT-8 itself was able to carry 10 times as many telephone calls as the last copper cable laid at that time and today's optic fibre cables are able to carry 25 times as many telephone calls as TAT-8This drastic increase in data capacity is due to several factors. First, optic fibres are physically much smaller than competing technologies. Second, they do not suffer from crosstalk which means several hundred of them can be easily bundled together in a single cableLastly, improvements in multiplexing have lead to an exponential growth in the data capacity of a single fibreAssisting communication across these networks is a protocol known as Asynchronous Transfer Mode (ATM) that allows the side-by-side data transmission mentioned in the first paragraph. The importance of the ATM protocol is chiefly in its notion of establishing pathways for data through the network and associating a traffic contract with these pathways.

The traffic contract is essentially an agreement between the client and the network about how the network is to handle the data, if the network cannot meet the conditions of the traffic contract it does not accept the connection. This is important because telephone calls can negotiate a contract so as to guarantee themselves a constant bit rate, something that will ensure a caller's voice is not delayed in parts or cut-off completely. Now a days Multiprotocol Label Switching (MPLS) is better option than ATM.

Multiprotocol Label Switching (MPLS) is a type of data-carrying technique for high-performance telecommunications networks. MPLS directs data from one network node to the next based on short path labels rather than long network addresses, avoiding complex lookups in a routing table.

V. Utility Equipment used as engineering services in an Industry

by

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Utility Equipment used as engineering services in an Industry

Prologue:

The effort here is to learn about basic study of utility equipment used as engineering services in an industry. We shall study the basic principal of engineering and some of the popular variance of the standard equipment.

The entire subject is divided in five sections or units.

The first unit deals with “Energy Generation”.- i.e. how energy is generated for utilization in an industry. It broadly covers various types of boilers. heaters, fittings and devices associated with boilers,

The second unit – “ Energy Consuming Devices” discuses some of the important equipment like different types of pumps, compressors and prime movers.

Third unit “Energy Utilisation” – adapts various equipment deployed for utilization of the energy generated earlier. It covers the systems to condition (heat or cool) the mediums, humidifiers / de humidifiers, circulating and distributing equipment like ducts, diffusers, grills, dampers, fans, air cleaning system etc.

The fourth unit is dedicated to various aspects of “Electrical Installations” starting with what is electricity, basic theory of electricity, basic machines and distribution network. It also overviews the basic control, application & protection equipment like switchgear, motors, drives etc. It also deals with various statutory requirements (including that for boilers)

An effort is made so that after studying all the four units, the student will understand the basic plant installation and the machinery installed in it. Having understood the basic working and the type of usage, a valuer can judge the value of the equipment in question by putting his valuation practices in use. The fifth unit deals with some typical practical aspects of valuations.

I wish to put on record the valuable guidance received from Mr Kirit Budhbhatti to make this work more beneficial to the students. I also thank Prof Oza & Prof AM Shaikh for suggestions to improve contents & Mr Muni Bhatt for checking the language part.

Hemant Vasavada

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UNIT 01
ENERGY GENERATION

PROCESS BOILERS AND PIPEWORK INSTALLATIONS

Definition of a Boiler

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care.

The process of heating a liquid until it reaches its gaseous state is called evaporation. Heat is transferred from one body to another by means of

(1) Radiation, which is the transfer of heat from a hot body to a cold body without a conveying medium,
(2) Convection, the transfer of heat by a conveying medium, such as air or water and
(3) Conduction, transfer of heat by actual physical contact, molecule to molecule.

Boiler Specification

The heating surface is any part of the boiler metal that has hot gases of combustion on one side and water on the other. Any part of the boiler metal that actually contributes to making steam is heating surface. The amount of heating surface of a boiler is expressed in square meters. The larger the heating surface a boiler has, the more efficient it becomes.

The quantity of the steam produced is indicated in tons of water evaporated to steam per hour.

Maximum continuous rating is the hourly evaporation that can be maintained for 24 hours.

F & A means the amount of steam generated from water at 100 °C to saturated steam at 100 °C.

Indian Boiler Regulation

The Indian Boilers Act was enacted to consolidate and amend the law relating to steam boilers. Indian Boilers Regulation (IBR) was created in exercise of the powers conferred by section 28 & 29 of the Indian Boilers Act.

Typical Boiler Specification
Boiler Make & Year : XYZ & 2003
MCR(Maximum Continuous Rating) : 10TPH (F & A 100°C)
Rated Working Pressure : 10.54 kg/cm2(g)
Type of Boiler : 3 Pass Fire tube
Fuel Fired : Fuel Oil

IBR Steam Boilers means any closed vessel exceeding 22.75 liters in capacity and which is used expressively for generating steam under pressure and includes any mounting or other fitting attached to such vessel, which is wholly, or partly under pressure when the steam is shut off.

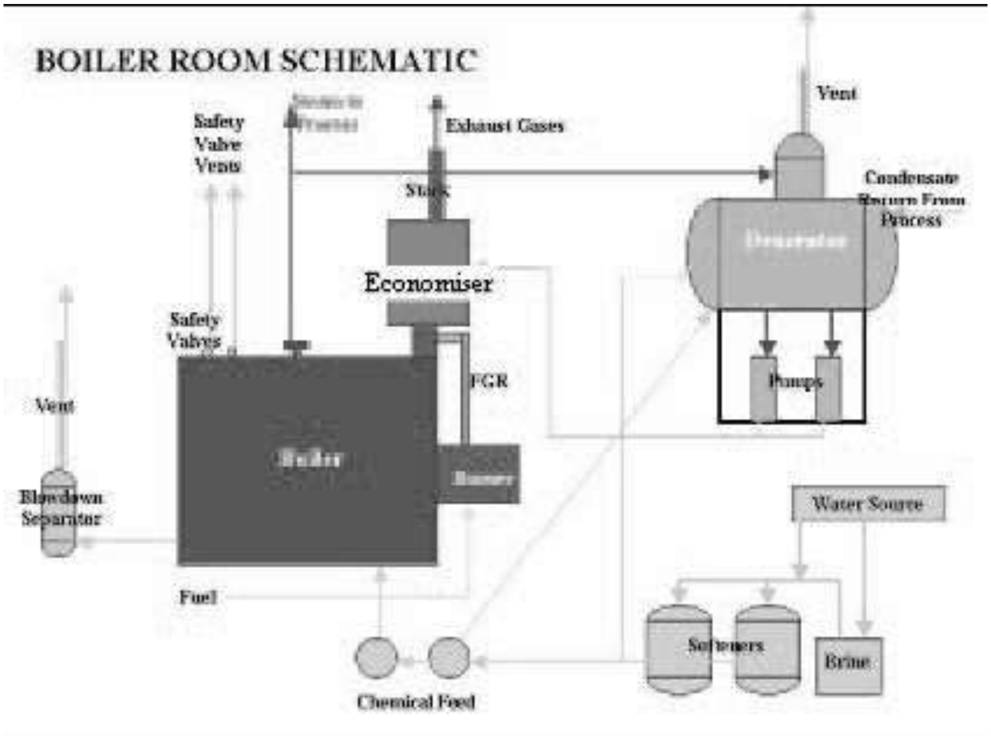
IBR Steam Pipe means any pipe through which steam passes from a boiler to a prime mover or other user or both, if pressure at which steam passes through such pipes exceeds 3.5 kg/cm2 above atmospheric pressure or such pipe exceeds 254 mm in internal diameter and includes in either case any connected fitting of a steam pipe.

Boiler Systems

The boiler system comprises of: feed water system, steam system and fuel system.
The **feed water system** provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair.

The **steam system** collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges.

The **fuel system** includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system. A typical boiler room schematic is shown in Figure



The water supplied to the boiler that is converted into steam is called **feed water**.

The two sources of feed water are:
(1) **Condensate** or condensed steam returned from the processes and
(2) **Makeup water** (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, the feed water is preheated by economizer, using the waste heat in the flue gas.

Boiler Types and Classifications

There are virtually infinite numbers of boiler designs but generally they fit into one of two categories:
1. Fire tube or "fire in tube" boilers: contain long steel tubes through which the hot gasses from a furnace pass and around which the water to be converted to steam circulates.

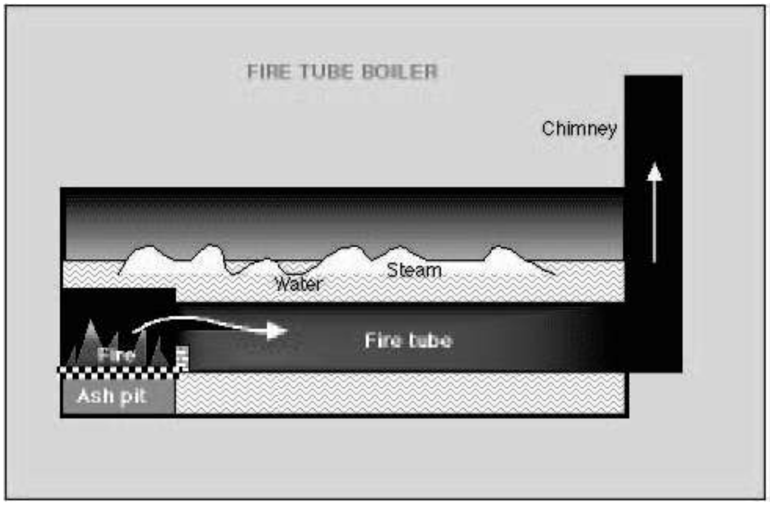


Fig: Fire Tube Boiler

Fire tube boilers, typically have a lower initial cost, are more fuel efficient and easier to operate, but they are limited generally to capacities of 25 tons/hr and pressures of 17.5 kg/cm2.

2. Water tube or “water in tube” boilers: in which the conditions are reversed with the water passing through the tubes and the hot gasses passing outside the tubes

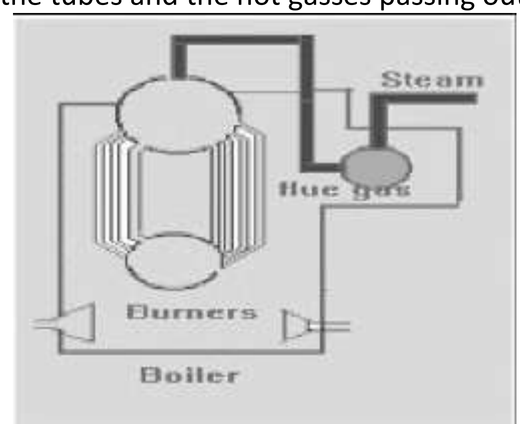


Fig: Water Tube Boiler

These boilers can be of single- or multiple-drum type. These boilers can be built to any steam capacities and pressures, and have higher efficiencies than fire tube boilers. **Packaged Boiler:** The packaged boiler is so called because it comes as a complete package. Once delivered to site, it requires only the steam, water pipe work, fuel supply and electrical connections to be made for it to become operational.

Fig: Package Boiler

Package boilers are generally of shell type with fire tube design so as to achieve high heat transfer rates by both radiation and convection.

The features of package boilers are:

- Small combustion space and high heat release rate resulting in faster evaporation.
- Large number of small diameter tubes leading to good convective heat transfer.
- Forced or induced draft systems resulting in good combustion efficiency.
- Number of passes resulting in better overall heat transfer.
- Higher thermal efficiency levels compared with other boilers.

These boilers are classified based on the number of passes – the number of times the hot combustion gases pass through the boiler. The combustion chamber is taken, as the first pass after which there may be one, two or three sets of fire-tubes. The most common boiler of this class is a three-pass unit with two sets of fire-tubes and with the exhaust gases exiting through the rear of the boiler.

Boilers can be classified in various ways, by its:

(1) Type of construction : cast-iron and steel boilers

(2) Fuel of combustion (or means of heating) : gas, oil, coal, waste fuel (such as wood waste and biogases) and electricity

(3) Heat transfer medium : hot water, steam and organic fluids

For the study purpose let us classify the boilers by its type of construction. The classifications are as follows:

A. Cast-iron Boilers

(i) Sectional boilers (vertical)

(ii) Sectional boilers (horizontal)

B. Steel Boilers

(i) Fire-tube boilers
The products of combustion pass through the inside of tubes with water surrounding the tubes.

(ii) Water-tube boilers
The water passes through the tubes and the products of combustion pass around the tubes.

(iii) Other and special application boilers including electric boilers, hot water high temperature systems, waste heat boilers, waste fuel boilers and fluidized bed boilers (and a subsection on pulverized coal firing)

C. Under **Pipe work Installations,** the study has considered the various fittings, connections or devices that are attached directly to the boiler so that the units can be operated safely and efficiently, as well as auxiliary equipment to the system:

(i) Safety valves

(ii) Water columns, gauge classes and gauge cocks

(iii) Valves and piping

(iv) Steam traps

(v) Pressure gauges

(vi) Feed water heaters and other devices

(vii) Auxiliary equipment including bag house filters, gas scrubbers and electrostatic precipitators

A. Cast Iron Boilers:

The cast-iron boiler is basically a water tube boiler because the water is inside the cast sections (There are no tubes and the products of combustion are on the outside)

Cast-iron is a term applied to many iron-carbon alloys, which can be cast in a mould to make a particular shape. But for cast-iron boilers, grey cast iron is generally used.

Cast-iron process boilers are built to various shapes and sizes, but can be grouped into the two following broad classifications:

1. Sectional boilers (vertical) consist of sections assembled front to back, with sections standing vertically and assembled by means of push nipples or screwed nipples to form waterway passages.
2. Sectional boilers (horizontal) consist of assembled sections stacked like pancakes. Here, each section is laid flat in relation to the base. This type of vertical stacking may be supplemented by having three vertically stacked boilers side-by-side and interconnected to gain additional capacity.

   These sections can be connected to build a boiler up to 1.8MW capacity.

They require refractory combustion chambers and insulated/air or water cooled hearths designed to limit boiler house floor temperatures to a max. of 65°C. They also require adequate suction in the combustion chamber provided by chimney or induced draught fan. Designs are now produced with fully water-cooled combustion chambers requiring no brickwork and these are independent of chimney draught to some extent. Such later designs are at present taken up to ratings of 4MW and are suited to solid, liquid or gaseous fuel firing.

Fig: Cast Iron Boiler

All such boilers can be installed in sites with limited access and can be extended to meet future requirements. They are suitable for LTHW (low temperature hot water) systems and low-pressure steam up to maximum gauge pressure of 4 bar. Certain units can withstand a gauge pressure of 10 bar.

B. **Steel Boilers:**

(I) **Fire-tube boilers**

Type and Arrangements

Fire-tube boilers are classified into horizontal return – tubular (HRT), economic type, locomotive firebox-type, scotch-marine-type, vertical tubular and vertical tubeless boilers. The scotch marine (SM) design is the dominant fire tube type for both heating and industrial process use up to 35,000 lb/hr capacity and 300psi pressure. Above this capacity water tube boilers are generally used.

Horizontal-Return-Tubular Boilers

The HRT boiler consists of a cylindrical shell, fusion-welded, with tubes of identical diameter running the length of the shell throughout the water space.

The HRT boiler is simple in construction, has a fairly low initial cost and is a good steamer. It is more economical than the vertical tubular or locomotive types, but the scotch marine boiler, is replacing it.

Horizontal-return-tubular boilers are not very practical in shell sizes over 96” in diameter or for pressure exceeding 200psi.

Economic Boiler

The economic boiler is an adaptation of the HRT boiler, giving somewhat greater heating surface per square foot of floor space. An added advantage is that the required amount of brickwork is much less since the boiler is self-supporting in its special casing. But this type has the same size and pressure limitations as the HRT boiler.

The economic-type boiler is considered to be an externally fired, fire-tube design because its steel-encased combustion chamber is not a pressure part of the boiler. They are compact in design and are usually shipped as a unit.

Locomotive Firebox Boilers

The locomotive firebox boiler, like the vertical tubular and scotch-marine types, is an internally fired fire-tube unit. But, its shell is horizontal and the firebox is not contained within the cylindrical portion of the boiler.

The locomotive firebox boiler is limited as to pressure and capacity, just as the HRT boiler.

Scotch Marine Boilers

The largest number of boilers in use today for commercial and small industrial plants is the scotch marine (SM) boilers. This boiler was originally used for marine service because the furnace forms and integral part of the boiler assembly, permitting very compact construction that requires a small space for the capacity produced. The SM boiler is sold as a package consisting of the pressure vessel, burner, controls, draught fan, draught controls and other components assembled into a fully factory-fire-tested unit.

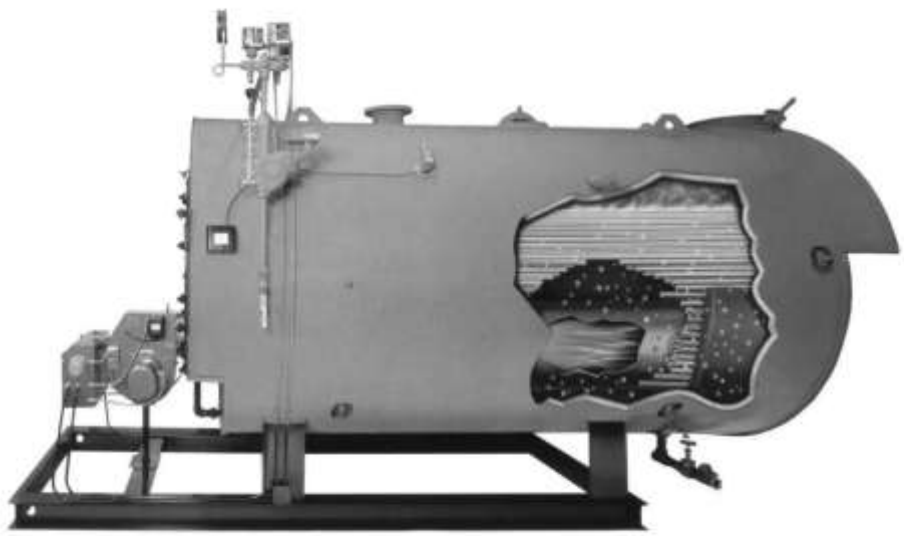


Fig. Scotch Marine Boilers

The SM boiler is built either as a wetback furnace or as a dry-back. It consists of an outer cylinder shell, a furnace; front and rear tube sheets and a crown sheet. The hot gases from the furnaces pass into a refractory-lined combustion chamber at the back and are returned through the fire tubes to the front of the boiler and then to the uptake. This boiler is suitable for coal, gas and oil firing.

In the wetback design, the shell, tube and furnace combustion are similar to the dry-back type, but the combustion chamber, being inside the shell, is surrounded by water. Thus, no outside setting or combustion-chamber refractory is needed. The dry-back type is a quick steamer because of its large heating surface. It is also compact and easily set up and shows fairly good economy.

The SM boiler may be by far the largest in diameter of any fire-tube boiler, being built up to about 15 feet diameter. In boilers of large diameter, it is the practice to use more than one furnace. Two, three or even four furnaces are used in the large boilers of this type

Vertical Tubular Boiler

The vertical fire-tube boiler is used where floor space is at a premium and the pressure and capacity requirements come within the scope of this type of boiler. The vertical tubular (VT) boiler is an internally fired fire-tube unit. It is a self-contained unit requiring little or no brickwork. It is popular for portable service, such as cranes, pile drivers, hoisting engines, and similar construction equipment. Vertical tubular boilers are used for stationary service where moderate pressures and capacity are required for process work, such a pressing, drying-roll applications in various small laundries in the plastics industry.

The coil-type water-tube boiler is a competitor of the VT boiler for small capacities and lower pressures to 150psi. But the VT boiler is limited in capacity and pressure even more than the horizontal fire-tube boiler. For this reason, most VT boilers of the fire-tube type seldom exceed 300hp or about 10,000 1b/hr capacity with a maximum pressure of 200psi.

The advantages of VT fire-tube boilers are:

1. Compactness and portability
2. Low initial cost
3. Very little floor space required per boiler horsepower
4. No special setting required
5. Quick and simpler installation

The disadvantages are:

1. The interior is not easily accessible for cleaning, inspection or repair
2. The water capacity is small, making it difficult to keep a steady steam pressure under varying load.
3. The boiler is liable to prime (carry over with steam) when under heavy load because of the small steam space
4. The efficiency is low in smaller sizes because hot gases have a short, direct path to the stack, so much of the heat goes to waste.

Lancashire and Cornish Boilers

These boilers are very rarely in use nowadays. They are essentially fire-tube boilers, but unlike the conventional ones, they do not have tubes within the boiler. Its construction is quite basic, comprising a pressure vessel with two furnaces normally fired by either gas or coal fuel. The rating of these boilers is in the range of 5,000 – 10,000 lb/hr at 100psi. These boilers can still be found in use for supplying hot water to pit head baths in coal mines and for process drying in old cotton and yarn manufacturing textile processing house. It has also found it's application, in dairy industry. In dairy industry, the cleanliness and sterilization is an integral & essential part of the manufacturing. These boilers are used for providing steam to sterilize milk in autoclaves.

(ii) Water-Tube Boilers

As mentioned earlier, water tube boilers are normally rated above 35,000 lb/hr capacity and 300psi pressure.

Bent Tube Water Tube Boilers

The Sterling boiler was one of the first types of bent-tube boilers to come into common use. Boilers of this general type were usually designed for pressures from 160 to 1000psi and capacities ranging from 7500 to 350,000 lb/hr of steam.

Modern bent tube boilers come in packaged units and typical example is the "Combustion Engineering" VU steam generator. It is cross drum bent-tube boiler with self-contained furnace. Great flexibility of operation, as well as compactness and high efficiency, is afforded by the ample combustion space and adequate heating surfaces offered to the radiant heat. This boiler is designed especially to burn fuels in suspension with interfuse-type burners.

Coal-Fired Packaged Boilers

Stoker-fired, water-tube boilers generally are built up to about the 250,000 lb/hr rating. Above this rating, pulverized-coal and cyclone-fired units are generally used. Modern stoker-fired boilers are usually of the two-drum type. Long-drum and cross-drum designs are used with bent tubes. On a long drum boiler, the flue gases flow lengthwise to the drums, while on a cross drum, they flow across or perpendicular to the drum.

Coil Boilers

Coil boilers, were developed to satisfy industry's needs for a compact, fast-steaming, factory-assembled packaged boiler. They find special application where a process requires high-pressure steam in one part of the process flow and the capacities required are moderate. A packaged unit is placed where the load need exists and this makes it unnecessary to operate large, centralized boilers at reduced capacity during periods of operation when other parts of the plant may have low demand. Several packaged boilers can be placed close to the steam loads of a plant at widely separate locations, thus avoiding long steam-line losses that may exist with a centralized steam plant.

Coil-type boilers are used over packaged fire-tube types when high pressure and capacities may be required. Pressures up to 900psi are possible with coil-type water tube boilers. Capacities generally are below 10,000 1b/hr, but units of greater size are available.

Utility Boilers

Utility boilers are used to generate electric power at the lowest heat rate possible, which is generally defined as the net Btu of fuel needed to generate one kilowatt of electricity. The trend has been to install single-boiler steam turbine arrangements that include a need to coordinate boiler-turbine start-up and loading.

Depending on the design for pressure, capacity and final temperature, a modern, large steam generator will have water walls, super heater, economizer, reheater and air-heater tubes. The basic purpose of these tubes is to extract all possible heat from the fuel input, thus lowering the exit temperature going up the stack. Utility boilers are classified as sub critical and supercritical, and are determined by whether a unit is operated above or below the critical pressure of 3206.2psia. Further classification is also made to indicate whether the boiler has natural circulation or forced (controlled) circulation.

(iii) Other and Special Application Boilers

Electric Boilers

Two basic types of electric boilers are available. First, units for low capacity and voltage generally consist of the resistance type. In the resistance type, current generates heat by flowing through resistance elements. This is wire, encased in an insulated metal sheath and these are submerged in water to generate usually moderate pressure steam at low capacities. These types do not depend on the conductivity or resistance of the water for generating heat. Second, in electrode boilers, the current flows through the water and not through wires. The liquid in the boilers converts electric energy to heat energy.

The energy crisis and air pollution regulations have created a demand for higher-output electric boilers above the 10,000 lb/hr ratings. A high voltage unit is classified as boilers with energy input between 2,300 Volts and 15,000 Volts.

Electrode boilers are packaged and they come fully equipped with controls and safety devices. Most boilers have controllers to maintain conductivity within the manufacturer's limits by monitoring the water and adding prescribed chemicals as needed, as well as blowing down the boiler when necessary.

High -Temperature Hot-Water Boilers

A high-temperature hot-water (HTHW) system is a heat utilization boiler that uses water at an elevated temperature, usually over 300°F with no specific pressure limitations. The HTHW system usually is not designed for temperatures exceeding 500°F. Operating temperatures within the range of 350° to 450°F are the most frequently encountered. Above 500°F, other fluids are used to obtain high temperature, such as Dowtherm and similar organic fluids.

At these temperatures, water in its liquid form can exist only at pressures above the corresponding saturation pressures.

The HTHW systems have widespread use for supplying the heating needs of large airports, military bases, office buildings, hospitals, colleges and other large multi building complexes. The application of HTHW systems has been extended to many industrial processes in the fields of chemistry, plastics, rubber, metal plating, paper and textiles.

Advantages of HTHW Systems

For many applications, HTHW systems are claimed to have distinct advantages over steam systems. The major advantages are:

1. Because of its large heat-storage capacity, an HTHW system permits very close control of temperature, which is important with many process applications.
2. The large quantity of heat in the system forms a heat reserve so that fluctuating loads have a minimal effect on the boiler, permitting use of a lower capacity boiler unit.
3. The absence of return-line corrosion in HTHW system, which is frequently a problem in a steam system is advantageous.
4. No traps, pumps, receivers, vents or other condensate-return equipment are needed on HTHW systems, thus producing lower initial cost, less maintenance and no steam losses.
5. A small amount of make-p is required; thus there is no need for an expensive feed water treatment system.

Disadvantages of HTHW Systems

There are several disadvantages, one of the most important being the large water content of the system. This produces the following disadvantages:

1. The system takes longer to heat up initially.
2. More time is needed for cool down when a repair or alteration has to be made and much water has to be discharged.
3. If a pipe or pressure-vessel break occurs, the water content, being above the atmospheric boiling point, will partly flash into steam with a powerful disruption effect. Even a relatively small leak can result in considerable water damage before the system can be depressurized.

Both fire-tube and water-tube boilers are used for HTHW systems. The main advantage of fire-tube boilers for this application is that they are generally less expensive in the smaller sizes below 600hp. Above this size, water tube boilers are used.

Water tube hot water generators are available in packaged ratings up to 150 million Btu/hr for water temperatures up to 650°F. The combustion equipment used is the same as that used for steam boilers. All types of fuels can be used.

High Temperature Heat-Transfer Liquid and Vapour Organic Fluids

Thermal fluids such as oils, silicates, glycols and similar liquids with high boiling points are used where higher temperatures are demanded by process requirements but at low operating pressures. Uses include drying of fabrics, clay, wood, paint, etc., which previously many have been done by direct firing of natural gas. Temperature up to 1000°F is now practical with thermal fluids.

Where HTHW systems can be used, they are preferred to thermal liquids, because they have about twice the heat capacity, do not deteriorate in use and are cheap.

Thermal-liquid systems also can be used in conjunction with steam systems. Plants that require high-pressure steam for specific applications can apply thermal liquids economically for other uses as well by installing a thermal liquid-to-steam heat exchanger and use part of its output to generate steam. This eliminates installation of a separate gas or oil-fired boiler.

When an organic substance is in the liquid state, the heating unit is referred to as a heater and if it is vapourised, it is called a vapouriser. The heating may be performed in a electric-fired units, up to about 1 million Btu/hr, with units above this size generally being fired by gas, oil and even coal. Units are generally packaged for automatic operation to a maximum capacity of 30 million Btu/hr. Multiple units are used for greater capacities as a rule.

The systems used can be classified as follows:

1. Vapour systems are generally of the fire-tube type using either gravity returns or pumped condensate return
2. Liquid systems use water-tube boilers with either natural circulation or the more pronounced forced circulation,

Among the organic fluids used are Dowtherm, Avoclor, Therminol FR and Tetralin. Since many of these fluids are hydrocarbons, a tube failure can create a fire hazard in the unit. Some fire insurance inspection departments require a steam smothering device or an inert-gas smothering system to be installed to smother a fire in the unit from a leaking pressure part. Safety controls should include a high-temperature cutout, pressure cutout and safety relief valves set to the maximum allowable pressure of the unit.

Waste-Heat, Combined-Cycle and Co-Generation Systems

Waste-Heat Boilers

There are a number of manufacturing processes that give off considerable quantities of high-temperature gases. Common among these are the exhaust from gas turbines or diesel engines. The value of heat recovery depends primarily on three considerations:

1. The cost of producing an equivalent amount of heat by other means
2. The cost of heat recovery equipment
3. The operating and maintenance cost of the waste heat recovery equipment

Steam boilers may be designed to use waste heat as all or part of the steam-generating medium. Since the gas temperature is usually 500 to 800°F, whereas combustion products in the conventionally fired installation may enter generating passes at about 2000°F, some means of compensating for the lower gas temperature must be employed. Otherwise, to have an appreciable steam generating capacity, the boiler would have to be beyond all reason in size. Other factors to consider besides pressures and temperatures of available waste gasses are the physical and chemical properties of the gas, their effect on boiler parts, the effect on the heat recovery system by plant-process disturbances and similar considerations involving continuity of service. Recovery of exhausted heat from industrial processes and combustion equipment can often reduce overall plant fuel consumption with minimal capital investment.

Supplementary firing is used when the waste-heat gases do not have sufficient heat to produce the desired final pressure or temperature of the steam.

Depending on the properties of the waste gases and the pressure and capacity needed, the following waste-heat boilers are used:

1. Fire-tube boilers, both the vertical and horizontal types, if waste gas is relatively clean.
2. Straight-tube water-tube boilers, for clean or moderately dust-laden waste gas
3. Water tube of the bent-tube type for very heavy dust loadings
4. Positive circulation boilers, for clean, low temperature gases
5. Pressurised or supercharged boilers, for gas turbine exhaust (Velox type).

Special material and other design factors are considered in the application of a waste-heat boiler because waste gases quite often have inert gases and solid entrapped particles in the mixture.

A Combined-Cycle generating system which utilizes a gas turbo generator or diesel with the exhaust heat going to either an unfired or a partially fired waste-heat boiler can be used to recover sensible heat and thus lower the Btu's required to generate one kilowatt of electricity. The boilers that can be used are generally water tube type of either natural or forced circulation design. Cogeneration produces electric power from a combined cycle usually, but also provides for process steam needs with the use of an extraction steam turbine.

Waste-Fuel Boilers

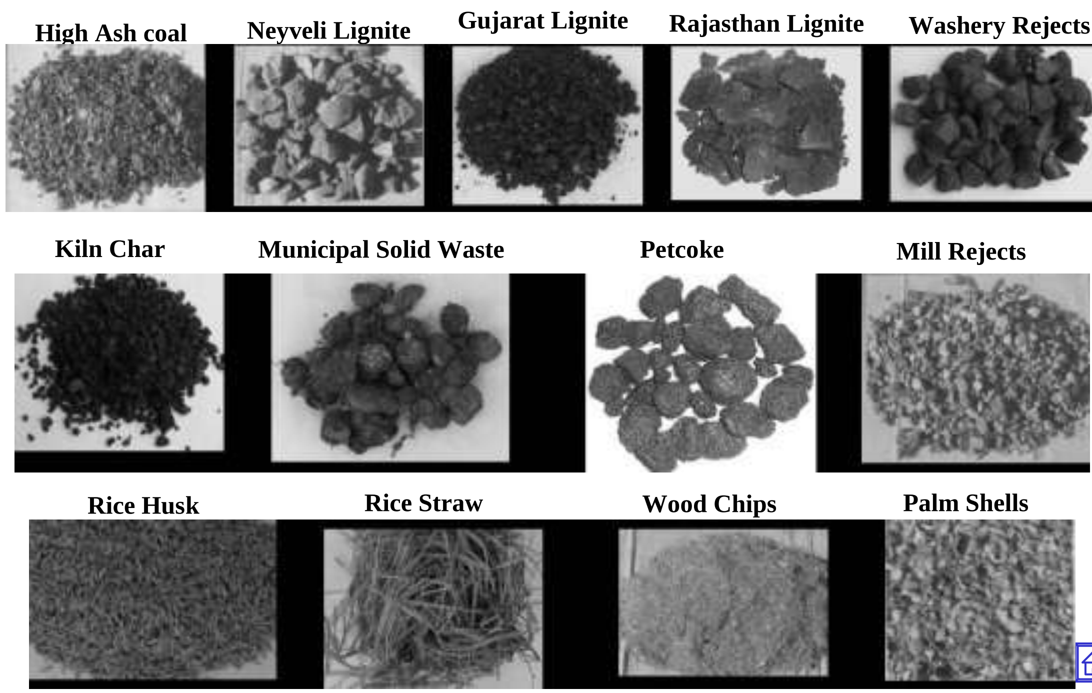
Escalating fuel costs and shortages that may develop in the future have caused industry and governments to re-examine the potential of waste-fuels of all types as a combustive alternate to the once-plentiful supply of fuels such as oil and gas.

Solid fuels in this category of waste fuels are many. Among them are wood chips, sawdust, hulls from coffee and nuts, corncobs, bagasse (waste product from sugar cane), coal char (residue from low-temperature carbonization of coal) and petroleum coke (final solid residue from a refinery). Each product must be handled in a special manner because of differences in moisture content, consistency, specific weight and heat content.

The furnace rather than the steam generator is affected when these special fuels are used. Products like bagasse, which has about 50 percent moisture, require a Dutch oven. The Wad furnace is a popular design for bagasse. Here, bagasse is partly dried and burned in refractory cells below a radiant arch. The combustion of gases is completed above the arch. Spreader stokers can also be used.

In refining sugar from cane, the juice squeezed out of the cane eventually is processed into sugar. The remaining fibrous, tenacious and bulky crushed cane is called bagasse. It is also moist. Depending on where it is grown and efficiency of the juice extractor, bagasse contains 30 to 50 percent wood fiber and 40 to 60 percent water. Heating value is 8000 to 8700 Btu/1b as a dry solid, with a yield of about 4500 Btu/1b at around 45 percent moisture content.

Fuel Samples



The steel industry has large quantities of gaseous by-product energy available. Heat content varies from less than 100 Btu/ft^3 for blast-furnace gas to 525 to 600 Btu/ft^3 for coke-oven gas. The main problem is getting this gas clean enough to avoid fouling the burners.

Oil refineries (catalytic cracking of crude petroleum) produce large volumes of gas as a by-product of catalytic regeneration. This gas contains 5 to 8% CO (carbon monoxide) about twice that much CO_2 (carbon dioxide) and air. The gas temperature is around 500°F, with a heat content of about 145 Btu/1b. Increasingly, refineries reclaim this energy by burning the gas together with oil or gas and additional air, in a carbon monoxide steam generator.

Liquid fuels in this category of waste fuels, include residue from chemical processes such as tar and pitch. These can be handled in conventional oil burners, but for satisfactory results, they must be heated to maintain viscosity at the proper level. Filtration is also required to remove and solid contaminants. High moisture can be poured off (decantation) or emulsified.

Black-Liquor Boilers

Black liquor is a by-product of wood pulp processing in the papermaking industry. Chips of wood are cooked in steam in a solution of sodium sulphide and sodium hydroxide in a large tank known as a "digester". Strong liquor from the digester flows to a storage tank where it is joined by weak liquor from pulp washers. In order that this liquor may sustain combustion, it is then concentrated by evaporation and crushed salt cake is added until if contains over 58 percent solids.

The concentrated liquor is pumped at about 220°F through oscillating burners which spray it onto the furnace walls; deposits of combustible char build up until they are heavy enough to drop to the furnace floor, where combustion is assisted by primary air nozzles. The gases and a small percentage of fuel particles rise to the upper part of the furnace where secondary air is admitted to complete the combustion process.

A considerable percentage of chemicals, a form of soda ash is recoverable from the ash of this process. Thus, the combustion of this black liquor is twofold, namely, steam generation and for soda-ash recovery. The capacity of a black-liquor recovery boiler is also expressed in the amount of tons of dry solids it can burn in 24 hours. As an example, a nit designed for 1600 psi with a capacity of 392,000 lb/hr of steam is rated at the same time as being able to burn 800 tons/day of black liquor. The major manufacturers are Babcock Energy, NEI International Combustion and Foster Wheeler.

The deposited liquor dries, forms char and falls to the hearth where sodium chemicals are smelted and the char are turned to gas which burns in the furnace. The smelted chemicals drain down the sloping floor through the water-cooled spout and then into the dissolving tank. The bottom of the furnace in the unit is flat and is called a decanting furnace. Most other boiler details are similar for the two manufacturers' design.

The black liquor recovery boiler is used in the paper making industry where hydrogen sulphide is used as the chemical to break up the lignin in wood that is cooked in digesters. The process is considered alkaline. Another process is called the red-liquor acid process. Red liquor with a concentration of about 50 percent solids is fired with steam-atmoizing burners. The red liquor burns in suspension and forms little or no slag in the furnace.

Magnesium oxide ash is removed from the furnace floor as well as from the flue gas. Sulphur dioxide is also recovered from the fuel gas by passage of the flue gas through absorption towers where magnesia oxide slurry absorbs the sulphur dioxide. The result is a cooking acid that is reused in the digesters.

Black and red liquors do not burn alike; thus, the steam generators used are not alike. Black liquor in the kraft process is very difficult to burn. Large furnaces are needed to keep the temperature relatively low because the liquor has a high content of low-fusion temperature ash. Smelt collects on the refractory sloping hearth, and a reducing atmosphere must be maintained in the lower part of the furnace or chemical conversion. Also, since super-heater and boiler surfaces have a tendency to coat with slag, they operate at low absorption rates i.e. reducing the efficiency. Thus frequent soot blowing and hot cleaning of heating surfaces is necessary.

Red liquor in the MgO (magnesia oxide) process on the other hand burns completely in suspension, making little or no slag. Thus a smaller steam generator can be used for an equivalent amount of steam production.

Fluidized-Bed Boilers

Fluidized-bed boilers are developed to take advantage of the large coal deposits that exist as well as overcome the pollution problem that exists in burning coal. The merits in using fluidised-bed combustion are the following:

1. High-sulphur fuels can be burned without resorting to flue-gas treatment. This is accomplished by injecting limestone into the bed, which absorbs the sulphur dioxide;
2. Higher combustion efficiencies are obtainable in fluidized-bed burning;
3. Lower combustion temperatures are possible which minimize nitrogen oxide and furnace slag formation;
4. The waste product formed at a lower bed temperature is easier to handle and dispose.
5. Low quality, high moisture content fuel can be burnt efficiently.

These are combination water-tube and fire-tube boiler designed for fluidised-brd burning. Particles being carried by the flue gas can be captured by conventional electrostatic precipitators or bag house filters. Fluidised-bed burning boilers approach the oil burning boiler in size because the former have heat-release rates of 100,000btu/(hr/ft^3) whereas, a conventional coal-fired steam generator has a heat release rate of around 20,000bt/hr/ ft^3).

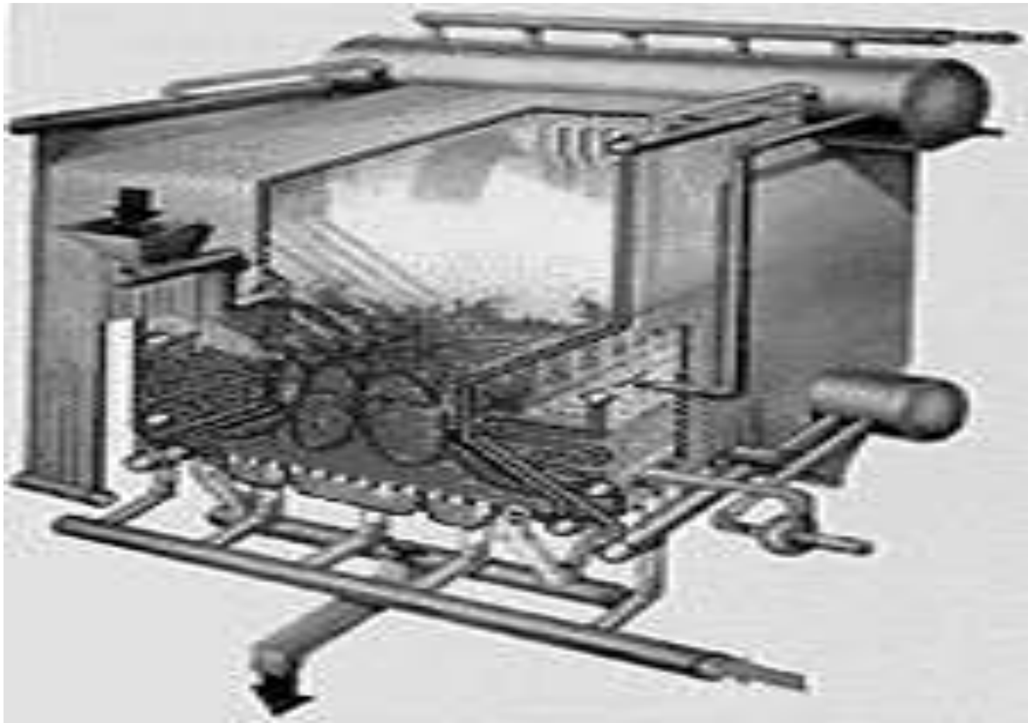


Fig. Fluidised Bed Boiler

Pulverized Coal Firing

Pulverized coal firing is the most widely used method for burning coal in large boilers. The system requires coal to pass from feed bunkers through scales or feeders to the pulverizer. The grinding of the coal exposes the fuel elements in the coal to rapid oxidation (burning) as the ignition temperature is reached. More complete burning is thus possible than with fuel-bed burning.

In general, pulverizers (sometimes called mills) may be classified as attrition or impact types. To these might be added the shearing type, which is a form of the attrition type, impact type or both. The impact mills generally have some attrition action. And conversely, while attrition may be the primary action of a mill, impact is usually present as a secondary action. Thus we have impact mills, including ball mills and hammer mills and attrition mills, including bowl mills and ball and race mills.

C. Pipe Work Installations, Mountings & Accessories:

Under pipe work installation, we shall consider various fittings, connections or devices that are attached directly to the boiler so that the units can be operated safety and efficiently, as well as other auxiliary equipment to the system. The mountings are primarily attached on the body of the boiler for smooth & safe operation with ease of controls. The Accessories are attached to increase the efficiency of the boilers.

(i) Safety Valves

The function of a safety valve is to prevent excessive pressure from building up in a steam boiler. The safety valve is set at or below the maximum safe working pressure for the boiler it protects.

(ii) Water Columns, Gauge Glasses and Gauge Cocks

The gauge glass and gage cocks are essential appliances for indicating the level of the boiler water. The water column is installed between the gauge glass and the boiler. It serves to eliminate excessive fluctuations of water-level indication in the glass due to rapid boiler circulation or ebullition and thus acts as a steadying medium.

(iii) Valves and Piping

Valves on boilers include steam valves on the main headers, feed valves on the water feed to a boiler; drain valves on water columns, gauge glass and drain connections; blow down valves for both surface blow off and bottom sediment blow off; check and valves on feed lines; and non return valves on steam mains. Materials for power plant piping are mostly carbon steels or stainless steel. Electrical Heat Traced piping is an electrical means of supplying heat to the piping and thus aid the flow of fluids through the piping to various equipment. Insulation can be provided to piping to reduce heat loss via the piping to the environment, thus maintaining the temperature of the fluids at a certain temperature.

(iv) Steam Traps

Steam traps are installed in lines wherever condensation must be drained, as rapidly as it accumulates and wherever condensate must be recovered for heating, for hot-water needs, or for return to boilers. They are a “must” for steam piping, separators and all steam-heated or steam operated equipment. Now a days steam traps are also viewed as an energy saving device.

(v) Pressure Gauges

Pressure gauges are used to indicate pressure in a system. The two main types of pressure gauges used are Bourdon tube and the diaphragm type.

CVSRTA

(vi) Feed water Heaters and Other Devices

Feed water Heaters are used to bring feed water nearer to the temperature of the boiler water. Each 10°F in feed water temperature, increases the overall boiler efficiency by about 1 percent, owing to savings in fuel that would have been required to heat the boiler water an equal amount. An added advantage is that temperature stresses in the boiler may be avoided.

Evaporators are used to remove solids from feed water by use of heat. The evaporator is one in which raw (impure) water is evaporated into steam. This steam is condensed into pure condensate for feed water.

Deaerators are also an important section of the boiler. Air, oxygen, carbon dioxide or other such entrained gases are carried by water into a boiler. These may come from raw water, from leakages within a system or by chemical reactions of water and metals in a boiler loop system. The deaerator's main function is to remove these gases from the boiler water so as to prevent corrosion of metal parts in the boiler loop. Water de-ionising units are used to soften hard water by removing certain types of salt impurities in the water.

Pressure reducing valve, sometimes known as pressure regulators, are used to supply steam at a desired constant pressure lower than that of the supply. Their applications include supply for manufacturing processes, low-pressure feed water or fuel oil heaters and other auxiliaries.

(vii) Auxiliary Equipment to the System

Coal burning and other solid fuel burning boilers require auxiliary equipment to remove fly ash and other particulates being emitted to the surrounding atmosphere. The equipment commonly used includes the following:

1. Bag house employing fabric filters now usually made of fiberglass that can withstand flue-gas temperatures of 275 to 550°F.
2. Scrubbers that wash particulate emissions such as sulphur dioxide out of the flue gas and form a sludge that is disposed of in a landfills. They are economical only for large industrial and power plants. The fuel gas, after being cleaned in the precipitator, enters the bottom of the scrubber tower and passes up through the limestone slurry, which is being sprayed into the tower from above. The chemical reaction removes the SO_2 from the flue gas. The sludge formed must be disposed of in approved landfill sites.
3. Electrostatic precipitators. Induced / forced-draught fans are necessary to keep steam generators operating. The forced-draught fan supplies air for combustion of fuel as well as draught, while the I.D. fan pulls the flue gas out of the boiler and into a stack. Centrifugal and axial fans are used for F.D. & I.D. fans, gas recirculation and primary air fans.

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Exercise :

1. Define a boiler.
2. Describe significance of “Boiler Specifications”
3. What is IBR ? Where it is applicable.
4. Describe the classification of boilers by the type of construction.
5. Write note & describe the following :
    a. Fire Tube Boilers
    b. Scotch Marine Boilers
    c. Lancashire Boilers.
    d. Utility Boilers.
    e. High temperature Hot Water Boilers with Advantages & Dis advantages.
    f. High temperature heat transfer methods.
    g. Waste Heat Boilers.
    h. Waste fuel Boilers.
    i. Fluidised Bed Boilers.
6. Describe the components of pipe work installations for boilers.

UNIT – 02

ENERGY CONSUMING DEVICES

Pumps & Compressors

In any industry, pump is essential and vital equipment. It's basic function is to transportation / movement of fluid from one location to another in a system. Increasing the pressure from one level to another does this. Depending on various factors the increase in pressure can be from fraction of a bar in laboratory equipment to tens of thousands in a hydrocarbon industry.

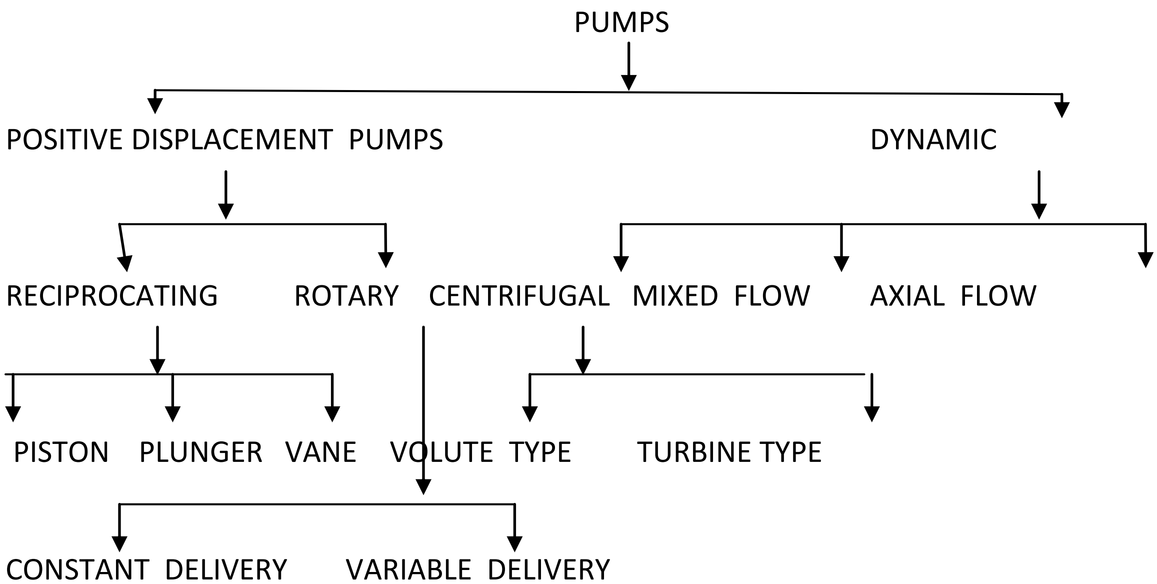
The fluid to be handled can be in liquid form or vapour / gas form. All machines, which handle liquid for transportation, are termed as pumps while as the compressors handle vapours.

While as the basic principal of the construction is similar in both the cases, the design and the internal components change due to :

- The volume handled. Compressor handles a huge volume as compared to the pump since vapour occupies large space. E.g. 1 cubic ft of water at room temperature becomes 1700 cubic feet of vapor at same temperature
- Due to difference in density and volume, the backpressure while the volume is being pressed varies. This calls for variation in clearances.
- The possibility of leakage is different in both the cases and hence the components to check and arrest leaks like seals or gland are different.

Pumps:

As we know, there are various types of liquids, which are to be handled in various industries. Also the parameters like temperature, pressure, head, flow etc etc vary from industry to industry and even within same industry it can vary from case to case. There are several types of pumps available for various applications.



The selection of the right type of pump for a particular application is very essential. Following are some of the important technical factors :

- SERVICE (WATER/HYDROCARBON/ACID………)
- DRIVER (MOTOR/TURBINE)
- CAPACITY NORMAL / RATED
- DUTY CONDITIONS (CONTINUOUS/INTERMITTENT
- DIFFERENTIAL HEAD
- SUCTION PRESSURE/TEMPERATURE
- VISCOSITY / SPECIFIC GRAVITY (DENSITY)
- SEAL TYPE

After careful consideration of all the factors, a particular pump is considered for a select application.
For our study purpose, we will find out how the most popular of them, i.e. centrifugal pump works & what are the important parts involved.

Centrifugal Pumps: Basic Concepts of Operation,
Introduction to Working Mechanism of a Centrifugal Pump

A centrifugal pump is one of the simplest pieces of equipment in any process plant. Its purpose is to convert energy of a prime mover (a electric motor or a turbine) first into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped. The energy changes occur by virtue of two main parts of the pump, namely, the impeller and the volute or diffuser. The impeller is the rotating part that converts driver energy into the kinetic energy. The volute or diffuser is the stationary part that converts the kinetic energy into pressure energy.

Note: All of the forms of energy involved in a liquid flow system are expressed in terms of feet of liquid i.e. head.

Generation of Centrifugal Force

The process liquid enters the suction nozzle and then into eye (center) of a revolving device known as an impeller. When the impeller rotates, it spins the liquid sitting in the cavities between the vanes outward and provides centrifugal acceleration. As liquid leaves the eye of the impeller a low-pressure area is created causing more liquid to flow toward the inlet. Because the impeller blades are curved, the fluid is pushed in a tangential and radial direction by the centrifugal force. This force acting inside the pump can be better explained by an analogy. This force is the same one that keeps water inside a bucket that is rotating at the end of a string. Figure 1 below depicts a side cross-section of a centrifugal pump indicating the movement of the liquid inside and also the major components of the pump.

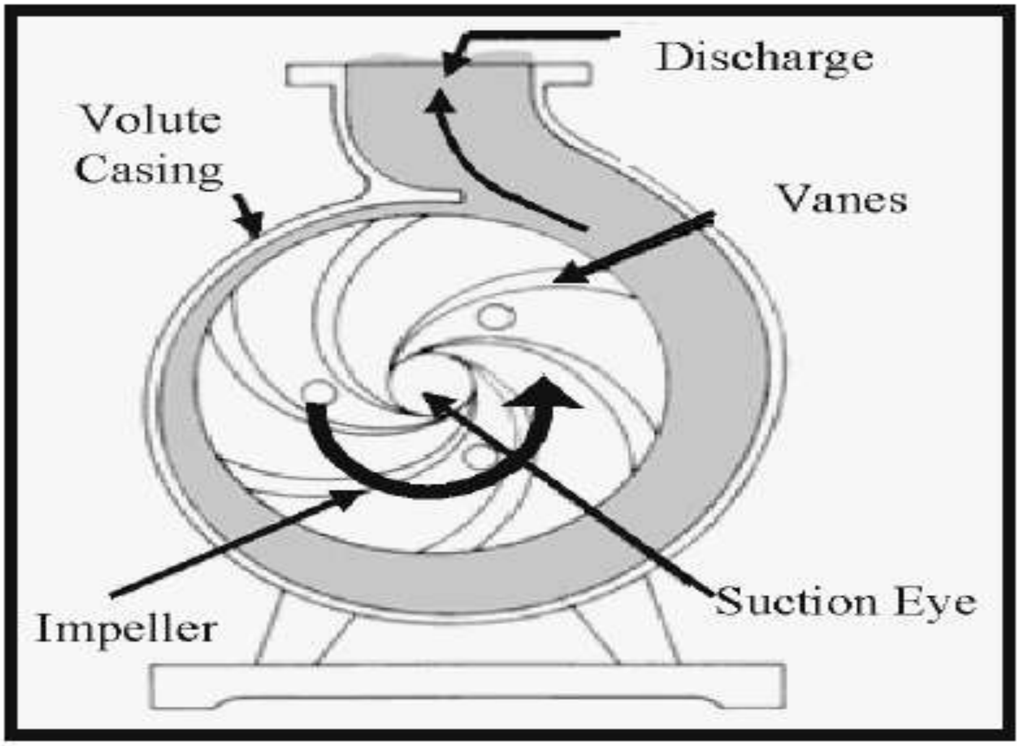


Figure : Liquid flow path inside a centrifugal pump

Conversion of Kinetic Energy to Pressure Energy

The key idea is that the energy created by the centrifugal force is *kinetic energ*y. The amount of energy given to the liquid is proportional to the *velocity* at the edge or vane tip of the impeller. The faster the impeller revolves or the bigger the impeller is, then the higher will be the velocity of the liquid at the vane tip and he greater the energy imparted to the liquid.

This kinetic energy of a liquid coming out of an impeller is harnessed by creating a *resistance* to the flow. The first resistance is created by the pump volute (casing) that catches the liquid and slows it down. In the discharge nozzle, the liquid further decelerates and its velocity is converted to pressure according to Bernoulli's principle. Therefore, the head (pressure in terms of height of liquid) developed is approximately equal to the velocity energy at the periphery of the impeller.

One fact that must always be remembered: A pump does not create pressure, it only provides flow. Pressure is a just an indication of the amount of resistance to flow.

General Components of Centrifugal Pumps

A centrifugal pump has two main components:

I. A rotating component comprised of an impeller and a shaft

II. A stationary component comprised of a casing, casing cover, and bearings.

The general components, both stationary and rotary, are depicted in Figure below. The main components are discussed in brief below. These parts are also shown on a photograph of a pump in the field.

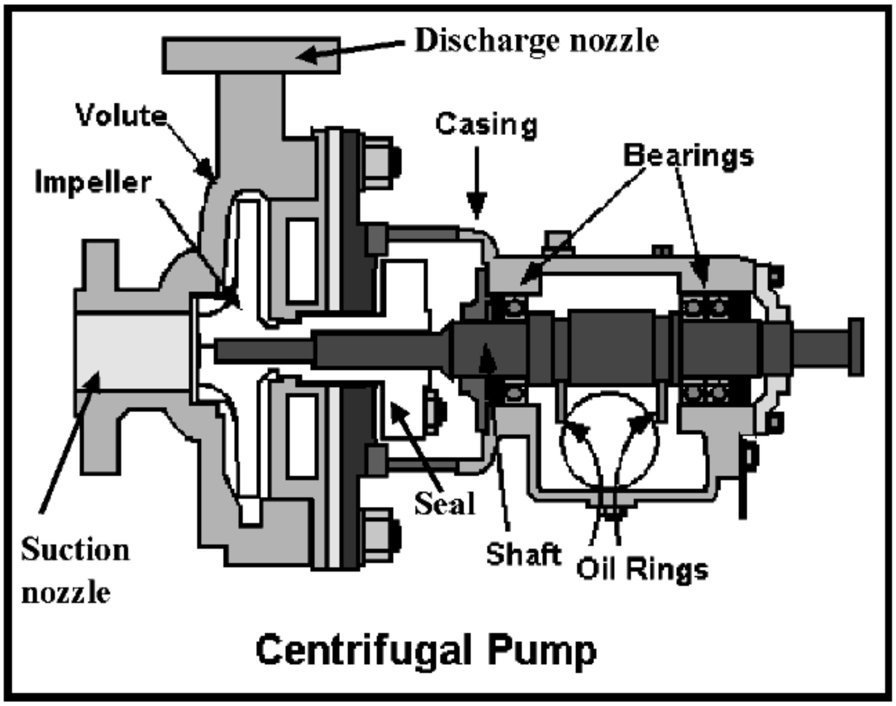


Figure: General components of Centrifugal Pump.

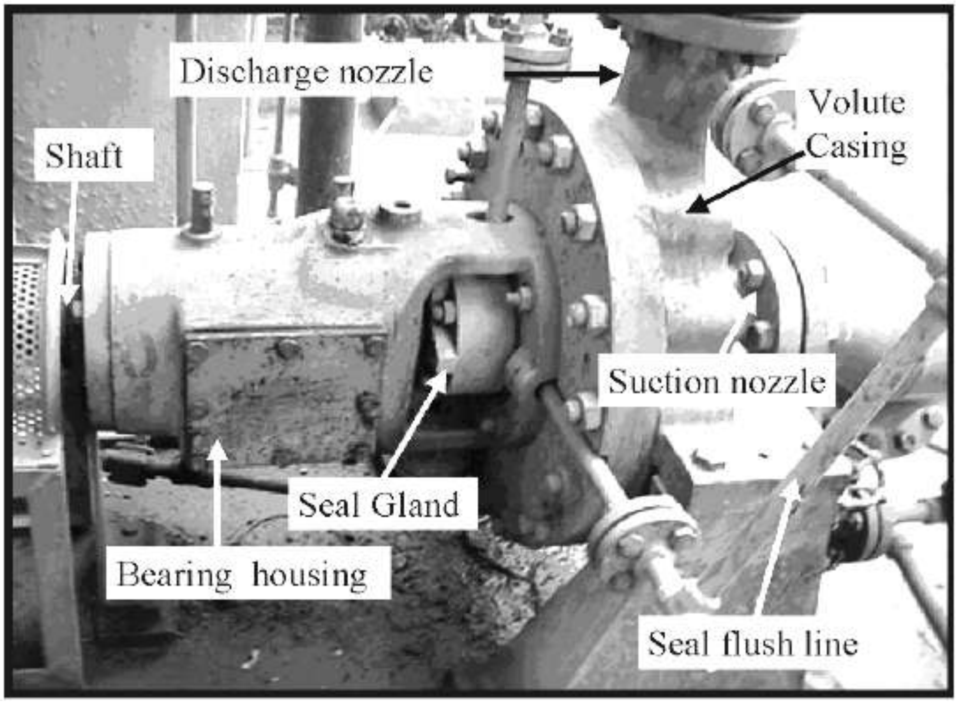


Figure: General components of a Centrifugal Pump – A photograph of Stationary Components

Casing

Casings are generally of two types: volute and circular. The impellers are fitted inside the casings.

Volute casings build a higher head; *circular casings* are used for low head and high capacity.

* A *volute* is a curved funnel increasing in area to the discharge port. As the area of the cross-section increases, the volute reduces the speed of the liquid and increases the pressure of the liquid..

Circular casing have stationary diffusion vanes surrounding the impeller periphery that convert velocity energy to pressure energy. Conventionally, the diffusers are applied to multi-stage pumps.

* The casings can be designed either as solid casings or split casings.

Solid casing implies a design in which the entire casing including the discharge nozzle is all contained in one casting or fabricated piece.

Split casing implies two or more parts are fastened together. When the casing parts are divided by horizontal plane, the casing is described as horizontally split or axially split casing. When the split is in a vertical plane perpendicular to the rotation axis, the casing is described as vertically split or radially split casing.

Suction and Discharge Nozzle

The suction and discharge nozzles are part of the casings itself. They commonly have the following configurations.

1. *End suction/Top discharge*
2. *Top suction Top discharge nozzle*
3. *Side suction / Side discharge nozzles*

Rotating Components

1. Impeller

The impeller is the main rotating part that provides the centrifugal acceleration to the fluid. They are often classified in many ways.

- Based on major direction of flow in reference to the axis of rotation
    - Radial flow
    - Axial flow
    - Mixed flow
- Based on suction type
    - Single-suction: Liquid inlet on one side.
    - Double-suction: Liquid inlet to the impeller symmetrically from both sides.
- Based on mechanical construction **(Ref Figure below**)
    - Closed: Shrouds or sidewall enclosing the vanes.
    - Open: No shrouds or wall to enclose the vanes.
    - Semi-open or vortex type.

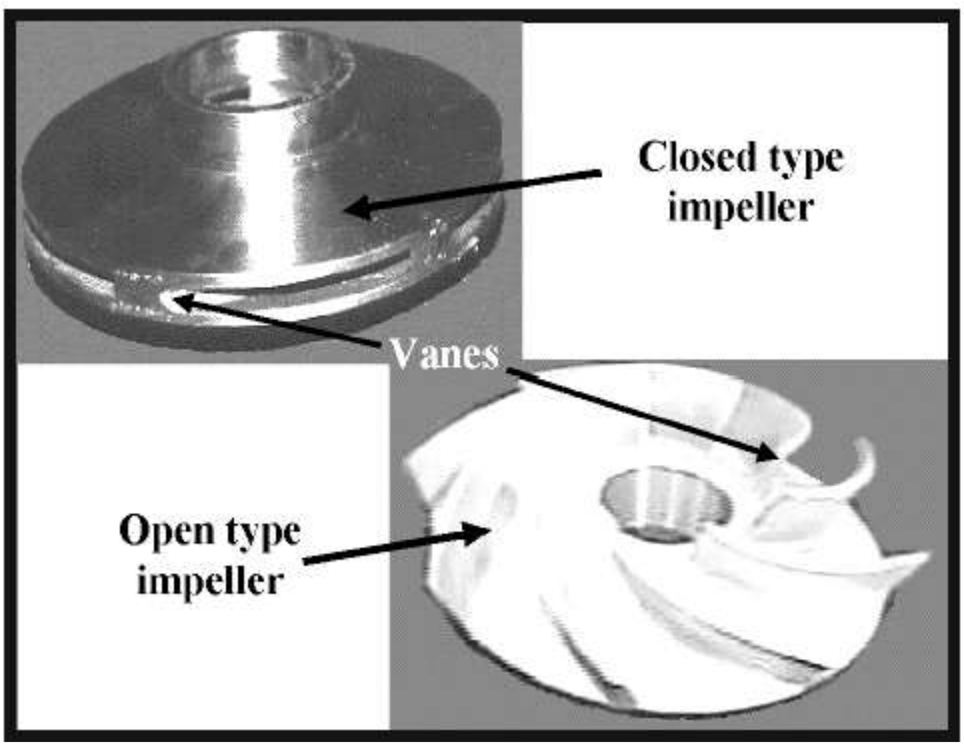


Figure: Impeller Type

2. Shaft

The basic purpose of a centrifugal pump shaft is to transmit the torques encountered when starting and during operation while supporting the impeller and other rotating parts. It must do this job with a deflection less than the minimum clearance between the rotating and stationary parts.

Definition of Important Terms

The key performance parameters of centrifugal pumps are capacity, head, BHP (Brake orse power), BEP (Best efficiency point) and specific speed. The pump curves provide the operating window within which these parameters can be varied for satisfactory pump operation. The following parameters or terms are discussed in detail in this section.

Capacity

Capacity means the flow rate with which liquid is moved or pushed by the pump to the desired point in the process. It is commonly measured in either gallons per minute (gpm) or cubic meters per hour (m 3 /hr). The capacity usually changes with the changes in operation of the process. For example, a boiler feed pump is an application that needs a constant pressure with varying capacities to meet a changing steam demand.

Head

Significance of using the ***"head"*** term instead of the ***"pressure"*** term

The pressure at any point in a liquid can be thought of as being caused by a vertical column of the liquid due to its weight. The height of this column is called the static head and is expressed in terms of feet of liquid.

Imagine a pipe shooting a jet of water straight up into the air, the height the water goes up would be the head.

Power and Efficiency

Brake Horse Power (BHP)

The work performed by a pump is a function of the total head and the weight of the liquid pumped in a given time period.

Pump input or brake horsepower (BHP) is the actual horsepower delivered to the pump shaft.

Pump output or hydraulic or water horsepower (WHP) is the liquid horsepower delivered by the pump.

Pumps can pump only liquids, not vapors
The satisfactory operation of a pump requires that vaporization of the liquid being pumped does not occur at any condition of operation. This is so desired because when a liquid vaporizes its volume increases very much. For example, 1 cubic-ft of water at room temperature becomes 1700 cubic-ft of vapor at the same temperature. This makes it clear that if we are to pump a fluid effectively, it must be kept always in the liquid form.

Two Basic Requirements for Trouble-Free Operation of Centrifugal Pumps
Centrifugal pumps are the ultimate in simplicity. In general there are two basic requirements that have to be met at all the times for a trouble free operation and longer service life of centrifugal pumps.

The **first** requirement is that no cavitation of the pump occurs throughout the broad operating range and the **second** requirement is that a certain minimum continuous flow is always maintained during operation.

There are number of unfavorable conditions, which may occur separately or simultaneously when the pump is operated at reduced flows. Some include:

- Cases of heavy leakages from the casing, seal, and stuffing box
- Deflection and shearing of shafts
- Seizure of pump internals
- Close tolerances erosion
- Separation cavitation
- Product quality degradation
- Excessive hydraulic thrust
- Premature bearing failures

Each condition may dictate a different minimum flow requirement. Both the pump user and the manufacturer take the final decision on recommended minimum flow after careful "techno-economical" analysis.

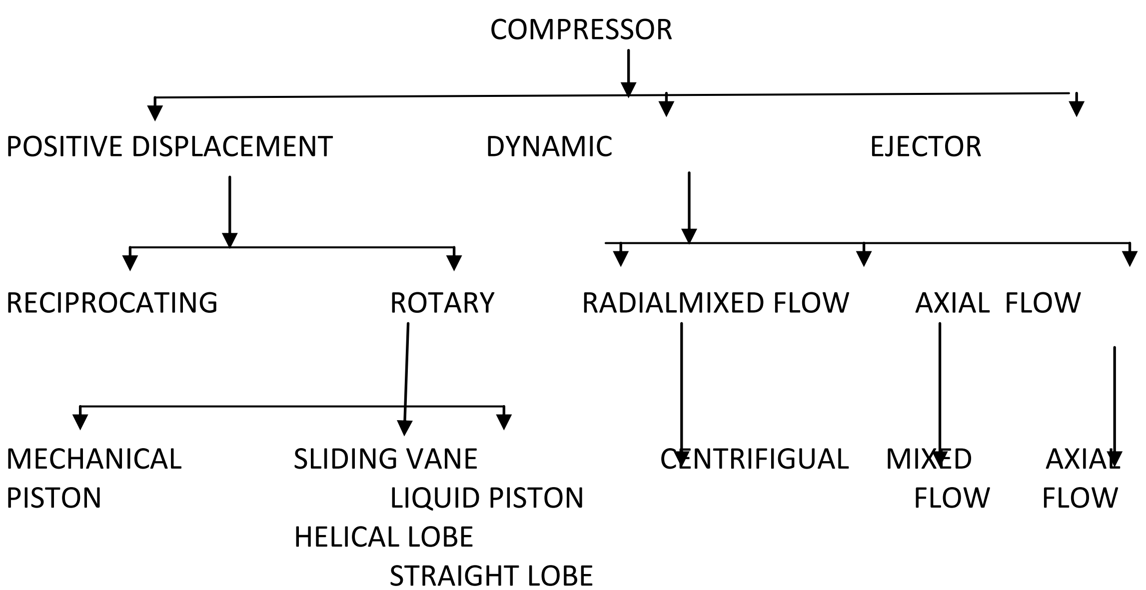
The consequences of prolonged conditions of cavitations and low flow operation can be disastrous for both the pump and the process. **Such failures in hydrocarbon services have often caused damaging fires resulting in loss of machine, production, and worst of all, human life.** Thus, such situations must be avoided at all cost whether involving modifications in the pump and its piping or altering the operating conditions. Proper selection and sizing of pump and its associated piping can not only eliminate the chances of cavitations and low flow operation but also significantly decrease their harmful effects.

As stated earlier, ***Pumps can pump only liquids, not vapours.*** *In an industry there are numerous stages where vapors is required to be handled In following chapter we will be discussing basic aspects of the equipment used in handling vapors.*

COMPRESSORS:

A compressor is a device used to increase the pressure of a compressible fluid. The inlet pressure level can be nay value from a deep vacuum to a high positive pressure. The discharge pressure can range from sub atmospheric level of high values in tens of thousands of ponds per square inch. The inlet & outlet pressure are related corresponding with the type of compressor and its configuration. Application of compressed gas varies from consumer products, such as home refrigerator to large complex petrochemical plant installation.

COMPRESSOR CLASSIFICATION:



Basically two simple methods are used to compress gas.

- The first one is: Trap a volume of gas and displace it by positive action of a piston or a rotary member. This type of compressors is termed as Positive Displacement Compressors.
- The second method uses dynamic compression. It is accomplished by the mechanical action of contoured blades, which impart velocity and hence pressure to gas. Thus in other words, The Dynamic compressors are machines in which air / gas is compressed by dynamic action of rotating vane or impellers, imparting velocity and pressure to flowing gas. The velocity head is converted in to pressure by partially in rotating element and partially in the stationary diffuser or blades. Two most popular variations are Centrifugal & Axial Flow type.

Positive Displacement Compressor:

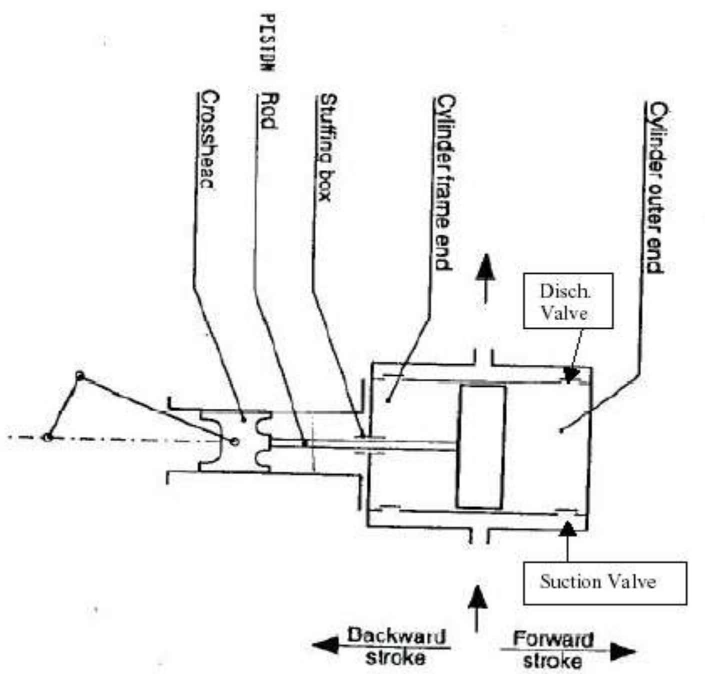
The reciprocating compressor is probably the best known and the most widely used of all compressors. It consists of a mechanical arrangement where reciprocating motion is transmitted to piston, which is free to move in a cylinder.

These are considered for applications where gas flow rate is about 30 ACFM or less i.e. they are favored for low flow and high-pressure services.

The maximum compressor ratio per stage is usually about 3:1 to 4:1. Higher compression ration can result in reduced volumetric & mechanical efficiency. Also, the outlet temperature limits the compression ratio. When multiple cylinders on a common frame are connected in series, usually through a cooler, the arrangement is referred as a multistage compressor.

Positive Displacement compressors:
Positive displacement type compressors are machines in which successive volumes of air or gas are confined within a closed space. The pressure is increased as the volume of the closed space is decreased. Four general types, broken down according to the constructional method used to carry out compression are as under:

Reciprocating compressors:
The machines in which the compressing element is a piston following a reciprocating motion in a cylinder. Figure below indicates the schematics of a reciprocating compressor.



Main Parts of a Reciprocating Machine

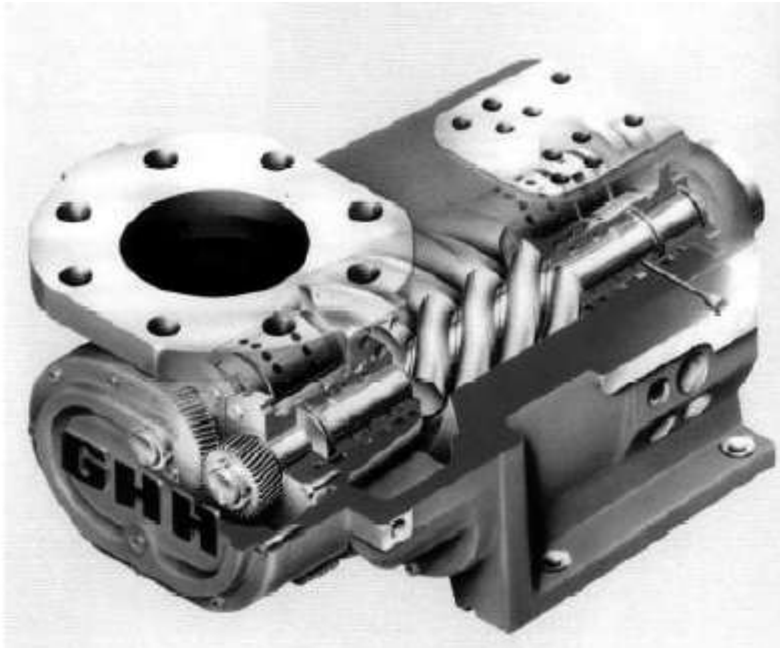
Rotary Compressor:

Rotary lobe compressors:
The machines in which two mating lobe impellers revolve within a cylinder and are prevented from making a contact with each other by timing gears mounted outside the cylinder. The gas is trapped by the lobes, which displace it from intake to discharge.

Rotary slide-vane compressors :
The machines in which longitudinal vanes slide radially in a rotor mounted eccentrically in cylinder. Gas gets trapped in the sliding vanes and is compressed and finally discharged as the rotor moves in the casing having suitable ports.

Rotary liquid piston compressors :
The machines in which water or other liquids are used usually in a single rotating element to compress and to displace the air or gas handled. Although each of the positive displacement types will vary from the other somewhat, they can be grouped together as single class of machines for the purpose of compression with dynamic type compressors.

Rotary Helical Lobe (Screw Compressor):
This compressor type is generally available up to 250 lb/in2 and for volume of 800 to 20,000 ACFM. The helical & spiral lobe compressor are generally similar and use two intermeshing helical or spiral lobes to compress gas between the lobes and the rotor chamber of casing. The gas is moved axially along the rotor to the discharge part where gas is discharged in to the discharge nozzle of casing. The volume of the trapped gas is decreased as it moves towards the outlet. Helical lobe compressor is further divided in to a dry and a flooded form. The dray form uses timing gears to hold a prescribed timing to the relative motion of the rotors, whereas the flooded form uses a liquid medium to keep the rotors from touching.



Photograph of a Screw Compressor

Sliding Vane Compressor:
It uses a single rotating element. The rotor is mounted eccentric to the center of the cylinder position of casing and is slotted and fitted with vanes. The vanes are free to move in and out within the slots as the rotor revolves. Gas is trapped between a pair of vanes as the vanes cross the inlet port. Gas is moved and compressed circumferentially as the vane pair moves towards the discharge port. The sliding vane compressor is widely used as a vacuum pump as well as a compressor, with the largest volume approximately 6000 cfm. Sliding vane compressor are available up to 150 lg/nc2 (G).

Centrifugal Compressor:
Centrifugal compressors are extensively used in modern chemical & allied industries. These are basically large volume machines. They are available for pressure of up to over 5000 lb/In^2 and handle volumes of 1000 to 15000 ACFM. Because there are no rubbing surfaces, they do not contaminate the compressed gas with lubricating oil their efficiency is in the range of 68-76. the capacity can be controlled by speed variation, reducing the suction pressure or by inlet vane control.

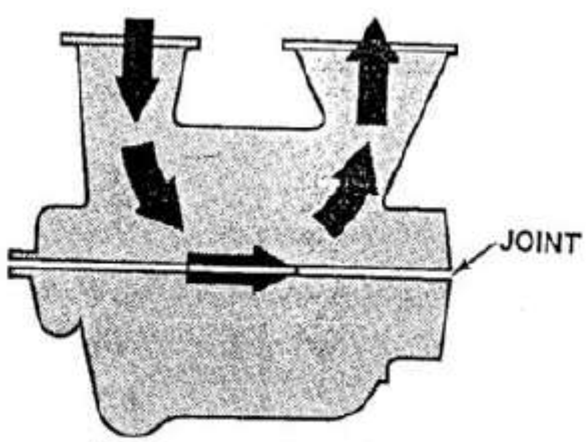
Centrifugal compressors are employed in numerous fields, chemical and petrochemical industries, refineries, fertilizer plants, nuclear reactors and air separation plants, iron and steel plants, production of liquefied natural gas (LNG) and substitute natural gas (SNG), cryogenic and refrigeration plants, mining, transportation and storage of gas, on-shore and off-shore installations. Combining these centrifugal compressors with other compressor type such as axial flow or reciprocating compressors can expand the range of application still further.

The wide range of processes in which centrifugal compressors are employed makes varying demands on these machines. Compressor demand is dependent on such factors as fluid handled, pressure ratio, the volume flow, the number of inter stage coolers, injection and extraction of the medium, and the type of shaft sealing. Taking all this factsors into consideration, the major compressor manufacturers have developed series of centrifugal compressors offering optimum engineering solution implemented by the use of standard components. These series include the two basic types, distinguished by horizontally or vertically split casing, compressors with two or three pairs of main nozzles, and compressors with additional side stream nozzles. Horizontally split casing permits simple removal of rotor and facilitates the checking of labyrinth clearances and o-rings. As pressure level rise and gas molecular becomes smaller, vertical split casings are employed.

Horizontal Split Centrifugal:

Centrifugal compressors with horizontally split casing can permit pressures of 70 bar and volume flow rates of up to 3 lac m3/hr at low pressures. Drive ratings can be as high as 30 MW.

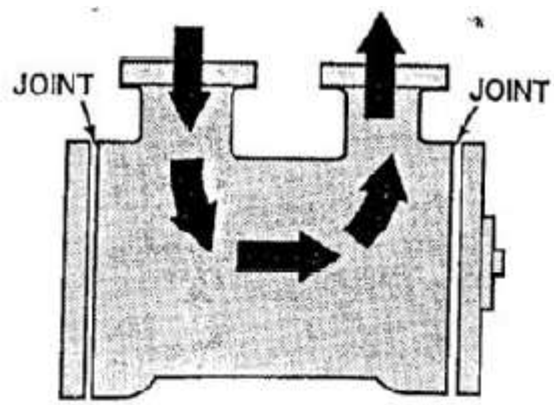
The two halves of casing are sealed and bolted together. The rigid structure is supported at the centerline, thus preventing vertical shifting of the compressor shaft as result of thermal expansion. For erection and dismantling purposes, the top half of the casing, complete with the associated stationary components, can be handled as a single unit. All types of drives, like, gas turbines, steam turbines, and electric motors. can be employed



HORIZONTALLY SPLIT

Vertically Split Compressors:
Vertically split (barrel type) centrifugal compressors are the preferred, and sometimes are mandatory design for high pressure or for compressing gases rich in hydrogen. The cylindrical casing ensures good stress distribution and extremely good gas tightness. Unlike the casing, the stationary internal components of the compressors, with the exception of the seal components, are horizontally split. During the assembly of the compressor they are mounted together with the rotor and are inserted axially into the casing. The shear ring segments retain the end covers. Some designs have bolted end covers.

VERTICALLY SPLIT



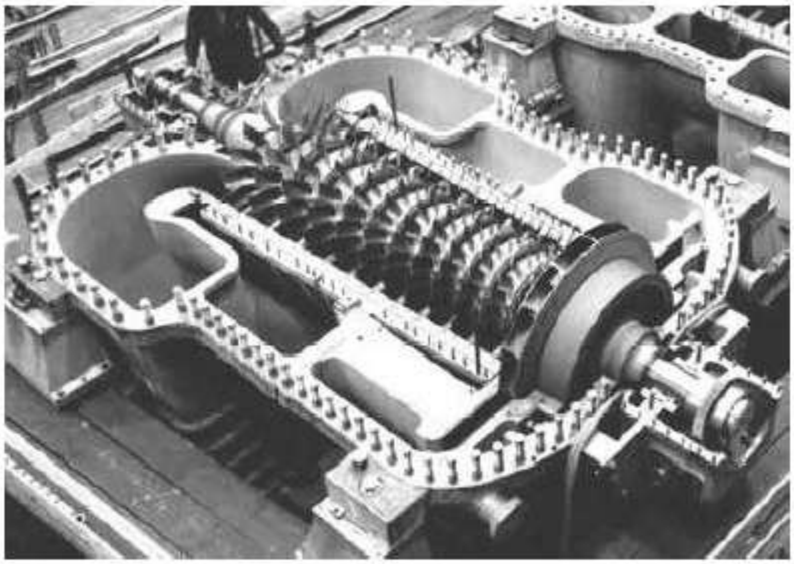
Compressor Trains:
Large pressure ratios cannot be handled by one single casing alone. Similarly it is not possible to split the compression cycle into more than two or three stages within one casing. The major compressor manufacturers therefore build compressor trains that may consist of up to four separate casings. Couplings interconnect these separate compressors, which need not be of same type,; they can be powered by a common driver. When additional timing gearing is used, the compressors casings may also be run at different speeds.

Axial Flow Compressors:
In axial flow compressor, a massive rotor with several rows of blades rotates in a casing, containing rows of stationary blades. Gas is drawn into an intake nozzle and passed in an axial direction through a series of moving and stationary rows of blades and is fully discharged through a discharge nozzle. Axial compressors are generally driven by electric motors, steam or gas turbines.

Axial compressors are large volume compressors that are characterized by the axial direction of the flow passing through the machine. The energy from the rotor is transferred to the gas by blades.

Axial compressors are most suited for higher capacity and comparatively low-pressure applications. These offer higher efficiency, smaller foundation requirements in weight and space and more efficient drive selection because of its higher speed and lower power requirements. The axial compressor is usually a single inlet, un-cooled machine consisting essentially of blades mounted on the horizontally split casing. The stationary blades can be either fixed or movable. The movable allows for better control of and increased flexibility in operations.

An open view of Axial Flow Compressor



Geared Centrifugal Compressor:

A multistage, multi-shaft integral gear compressor consists of individual scroll casings flanged to the gearbox and connected by piping. This compressor type needs fewer stages for a given pressure ratio than a multistage, single shaft turbo compressors. The reduced number of stages, i.e. the increased stage pressure ratio, results from the open-type impeller design, which can be used here as well as from the higher speeds which are achieved with this design. The resulting compact manner of construction, which involves considerable savings in terms of weight and space required, is an interesting aspect for investment planning. Not only are the investment costs reduced in comparison to single shaft compressor, the operating costs are lower as well, since all stages can be operated in their optimum efficiency range by selecting the appropriate pinion shaft speed.

CVSRTA

Further plus points of gear compressors are:

- The medium can be cooled following each stage
- Intermediate side streams and extraction are possible following each stage (Multi service operation)
- Can be easily adapted to modify operating conditions by means of a timesaving exchange of impellers.
- Each stage can easily be equipped with inlet guide vane control and adjustable diffuser vane control, thus enabling the control elements to become effective for the entire compressor.

Lubricating System:

Compressor bearings are generally lubricated by either splash lubrication or forced lubrication system. Forced lubrication system consists of main oil pump (MOP) and an auxiliary oil pump (AOP). Pressurized oil from pump passes through the inter cooler (optional) and lube oil filter (preferably duplex) and finally supplied to bearings, coupling etc.

Exercise:

1. What is a pump & what is a compressor?
2. What are different parts of pumps?
3. Describe a Centrifugal pump with construction and working details.
4. Define :
    a. Capacity of a pump.
    b. Head
    c. BHP
5. What are two basic requirements for trouble free operation of a centrifugal pump? Explain in details.
6. Write note on classifications of compressors.
7. Draw a sketch and describe Reciprocating Compressor.
8. Write notes on following :
    a. Fans & Blowers
    b. Centrifugal Compressor

PRIME MOVERS

Prime movers are the equipment which converts external power in to a energy which ultimately drives the material handling equipment like pumps, compressors etc. An economic balance between installation and operating cost always dictates the choice.

Many options are available for selection of prime movers. The prime movers can be any one of the following:

- Electric motor
- Steam Turbines
- IC Engines.

Electric Motor:

Electric motors are the versatile, economical, compact and low maintenance prime mover. It operates at a speed

N = f*50*2 / P where
N is Speed in RPM
F is frequency of the supply
P is number of poles of motor.

Thus speed of a given motor for a standard supply gets fixed and can not be varied unless either gear box or variable drive is used.

The motor drivers have following advantages:

- Low initial investment cost
- The compression train always operate at the same speed, which reduces notably, the risk of mechanical stability problems.
- Extreme reliability due to age old proven design.

The functioning of variable drive is discussed in the electrical section of the book.

Steam Turbines:

Selection of steam turbine as driver is generally dictated by steam availability and speed variation required. Many of the process plan, have exothermic chemical reactions, which can produce steam Thus due to in plant steam generation, the steam availability increases. This can be a driving force for the selection of a steam turbine.

From the point of view of compression group, steam turbine drivers have three advantages:

- Possibility of direct drive, which avoids the introduction of gearbox, which is always a critical item.
- The facility of regulating the speed of the turbine by inter locking the parameters with the governor, one can vary the turbine speed for maintaining the operating level.

- The turbine can be started with a gradual speed increase, which can avoid requirement of high inertia torque.

In addition the steam turbines are popular for variety of equipment as prime movers because:

- It can give high rotational speed.
- It's ability to utilize high pressure and high temperature steam available in the plant.
- It can give very high Break Horse Power. Thus it can run giant size machines like generators.
- Good efficiency.

Diesel Engine / Gas Engine –Internal Combustion (IC) Engines
Introduction

All engines in which the combustion of fuel occurs in the cylinders are termed as internal combustion engines.

Classification of I.C. Engine:
These engines are classed into the following important categories.

1) According to the type of fuel used
   - Petrol engine
   - Diesel engine
   - Gas engine
2) According to the method of ignition
   - Spark ignition engine
   - Compression ignition engine
3) According to the number of strokes:
   - Two stroke engine
   - Four stroke engine
4) According to the method of fuel injection:
   - Air injection
   - Airless or solid injection
5) According to the cycle of operation:
   - Otto cycle engine
   - Diesel cycle engine
   - Dual combination cycle engine

Four stroke cycle diesel engine (compression ignition engine):

The diesel engine has three valves, i.e. air inlet valve, exhaust valve and fuel injection valve. It differs from petrol engine because in this case, no spark plug is provided. The air

Injecting the fuel into the engine cylinder containing air compressed to a very high pressure ignites fuel mixture. The following are the four strokes of the piston of a diesel engine.

1) Suction stroke:
During the first out stroke of the piston, the exhaust and fuel injection valves are closed, changed of any air is drawn in the cylinders through the inlet v/v. the pressure inside the cylinder is below the atmospheric.

2) Compression stroke:
The piston moves upward from bottom dead center. The air drawn during the suction stroke is now compressed to a pressure of about 35 kg/cm^2. The air compressed is at a very high temperature, which is sufficient to ignite the fuel. Now the fuel injection v/v is opened just before the point of maximum compression.

3) Working or expansion stroke:
As soon as the fuel is injected into the cylinder, it is ignited by the heat of compression, and applies pressure on the piston to drive the engine.

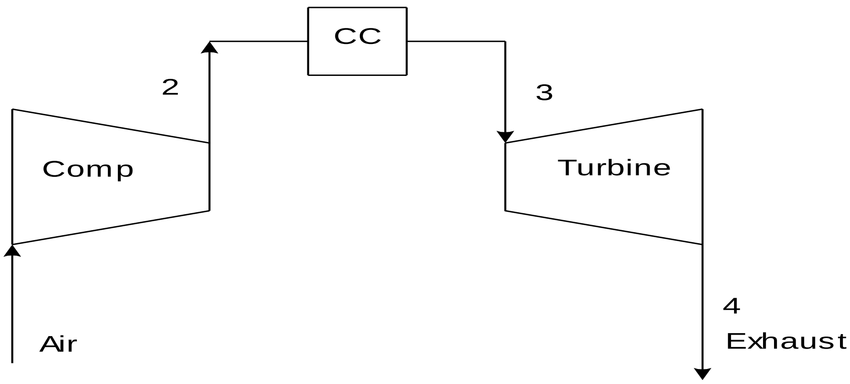
4) Exhaust stroke:
Air and fuel v/vs are closed and the exhaust v/v is open. The piston moves upward from the bottom dead center. The exhaust products leave through the exhaust v/v.
This completes the one cycle of the engine.

Gas Turbine:
In the following para we will examine the working of a gas turbine prime mover. Along with this we will also learn its association with power generation in Gas Turbine Generators.

Gas Turbine has following advantages:

- Capital cost is less.
- Fewer auxiliaries.
- Less erection time.
- Less area.
- Higher thermal efficiency when operated in combined cycle mode.
- Quick start.
- Fuel flexibility (Liquid / Gas)
- Very compact system.
- Black start facility.
- Suitable for Base load / Peak load / Part load operation.
- No/Less environmental Hazards.
- Control reliability.

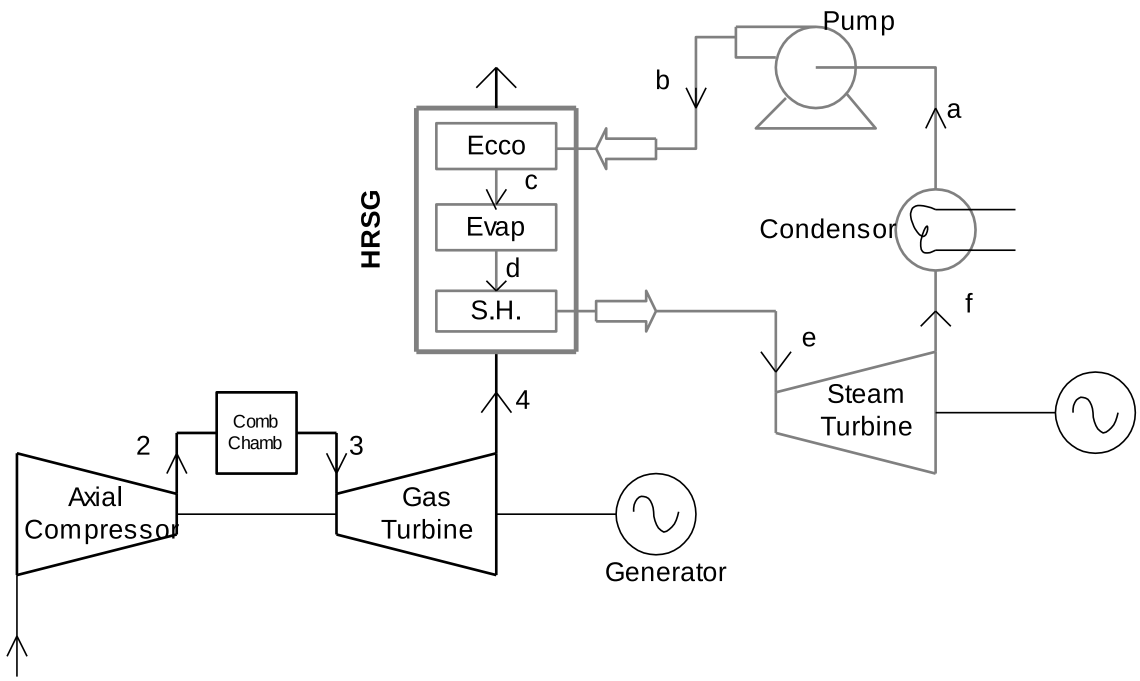
Gas Turbine is Modern Power generating equipment.



Schematic diagram of a Gas Turbine Generator

It takes the air from atmosphere, compresses it to sufficiently high pressure, same pressurized air is then utilized for combustion , which takes place in combustion chamber by addition of fuel , there by hot combustion products are generated which are expanded in the turbine where heat energy of hot combustion products is converted in to mechanical energy of shaft which in turn utilized for generating power in Generator.

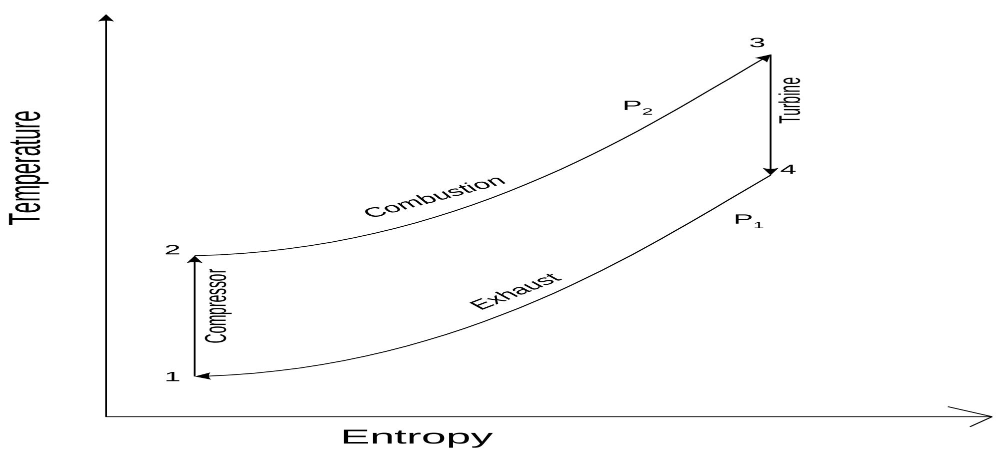
Compression is carried out by Axial Flow compressor, Heat addition is done by Fuel in combustion chambers, Expansion of hot combustible gases is carried out in Turbine and Burnt Gases are exhausted to atmosphere or utilized for steam generation in GTs. All of these four processes are carried out in Only one Factory assembled Unit which is called Gas Turbine. Drawing shows the Typical Brayton cycle and also shows the components of Gas Turbine.



Schematic Diagram of Gas Turbine with Heat Recovery Boiler

Gas Turbine operates on Brayton Cycle. Brayton cycle is having divided in four segments namely Compression , Heat addition , Expansion and Exhaust.

Process is explained in following diagram on T-S curve.



In modern days Gas Turbine Based power plants are becoming more and more popular mainly because of it's Higher efficiency, Reliability, Quick response.

In the modern Power Plants Gas Turbine Exhaust is connected to Heat Recovery Steam Generator where the steam is generated from hot gases and Steam is utilized for running the Steam Turbine such system is known as combined cycle power plants and where steam is utilized for various processes such system is called as Co-generation system .

Normally combined cycle power plant efficiency is around 48-50 % and co-generation system efficiency is around 80 % depending up on application.

Exercise:

1. What is Prime Mover? Describe them.
2. What are the advantages of Electric Motor as a prime mover?
3. What are the advantages of Steam Engine as a prime mover?
4. What is IC engine? What are it's important categories.
5. Write note on Gas Turbine.

UNIT - 03

ENERGY UTILISATION

Air Conditioning Installation

Objectives:

By the end of this chapter it is intended that the student will have fairly good idea about the working, various components used and the basic technology behind the air conditioning installations.

Most of the air-conditioning installations in common use are partial air conditioning systems. That is, the system is designed for heating, humidifying, cleaning and distribution; or it is designed for cooling, dehumidifying, cleaning and distribution.

Why air is to be conditioned?

The basic question is as to why at all the air in a specific location is to be conditioned?

The reasons are:

- To control temperature
- To control humidity
- Dust free atmosphere
- Chemical fumes free air

In any given installation, there can be need of control of one or more of the above parameters. In a complete air conditioning installation, one would expect to find the following equipment:

(i) Basic air conditioning systems (both heating and cooling units)
(ii) Humidifiers
(iii) Dehumidifiers
(iv) Circulating/distributing equipment
(v) Air cleaning equipment

Basic Air Conditioning Systems

Raising the ambient temperature:

In cold regions where ambient may drop to sub zero temperature, it is essential to raise the temperature. Very low temperature can cause problem in lubricating system, circulation system and also the human working. The temperature is raised to a level so that above factors can be eliminated.

Gravity Warm Air Furnace – Fuel Gas Atmospheric Burner

Fuel gas controlled by a pressure regulator, is fed to the burner in this heating system, Fuel is under constant low pressure. An atmospheric – type burner is used. Fuel may be natural gas, propane, LP gas or artificial gas.

The thermostat controls the operation of the burner by means of the gas burner control. Products of burning, carbon dioxide and water vapour, flow through the stack into the chimney. An air break helps keep constant pressure in the combustion chamber.

The heat generated in the combustion chamber is conducted through the chamber wall and is carried or radiated into the air surrounding the chamber. This air is heated up and naturally rises and flows through the warm air ducts into the rooms through warm air registers. As air cools, it becomes heavier and flow down through the cost air duct and back into the bottom of the furnace.

A high-limit control (for safety) is located in the bonnet of the furnace. (The bonnet is a sheet-metal chamber where heat collects before being distributed). The high-limit control will automatically shut off the gas if the bonnet temperature goes higher than the high-limit control temperature setting.

A room thermostat checks the room temperature and responds as needed. The thermostat operation keeps the temperature of the room within about 2°F (1.1°C) of the desired temperature.

Forced Warm Air – Fuel Gas Power Burner

This heating system is essentially similar to that of the gravity warm air furnace except that the fuel gas is burned in a power-type burner in this case. The other difference is that as soon as the bonnet temperature is high enough, the fan in the cold air duct return starts and moves air through the heating system. This air is drawn from the cold air register in the floor, above, through the air filter, and then through the furnace. Warm air is then distributed through the various warm air ducts and warm air registers or diffusers into the space to be heated.

Fuel Gas atmospheric Burner – Hydraulic Systems

The ignition system of this heating system is similar to that of gravity warm air furnace. In this heating system the room thermostat controls the operation of the water pump. The pump circulates the warm water through the room radiators and returns it to the boiler.

The water temperature is controlled by temperature and pressure – sensing element in the top of the boiler. An expansion tank is used to take care of expanding (warm) or contracting (cool) water. Air in the tank acts as a cushion.

Oil Burner – Forced Warm Air

Where fuel oil is the heat source, a gun-type oil burner throws a flame into a firepot lined with refractor (fire resistant) material. Fuel oil is stored in a tank, either inside or outside the building. Fuel oil is stored in a tank, either inside or outside the building. It is pumped into the burner under pressure. When heat is required, the thermostat sets the burner into operation. A high voltage transformer then sets sparks to ignite the atomized fuel vapour at the burner nozzle.

The blower or fan in the cold-air duct will start as soon as the bonnet temperature reaches its desired setting to distribute warm air through the ducts.

Oil burner – Hydraulics

The ignition system of this heating system is similar to that of forced warm air oil burner type. Where a high voltage transformer set sparks to burn atomized oil vapour at the burner nozzle. Heat from the combustion chamber is conducted through the boiler wall into the water. The room thermostat sets the circulating pump running to distribute the warm water once desired water temperature is reached.

Forced Warm Air – Electric Resistance Heat

In this heating system Fig 3.6, the room thermostat turns on the electric resistance heating elements when heat is needed. When desired temperature is reached, the same thermostat turns off the power to the heating units.

Warm air distributed by a blower which forces through the resistance unit where it picks heat. Heated air then distributed to the registers.

A filter is placed between the cold-air duct and blower. A humidifying device is usually placed in the warm air duct and operates whenever the blower is running.

There is an advantage of heating forced air with an electric resistance element. This furnace does not require a stack or chimney.

Hydraulics – Electric Resistance Heat

In hydraulic systems, the electrical resistance-heating units are inside the boiler. A high limit and safety control attached to the boiler chamber automatically turns on one or all three stages or resistance heating units when temperature of the water at the top of the boiler drops below a minimum setting. It also turns off electric heating units when the temperature of the water reaches the upper setting. The same control becomes a safety device, shutting off heating elements if no water is circulating through the radiators.

The room thermostats control the operation of the pump or pumps, which force the warm water through the room radiators. More than one pump can be used in this system and separate thermostat controls the temperature at the space served by each pump.

Room Heating Units – Electrical Resistance

Individual electric resistance units are installed in each room in this system. Electrical power is connected to the units from a electric power panel. One advantage of this system is that its own thermostat regulates the temperature of each room.

Air Conditioner, Cooling – Window or through The Wall

Window or through-the wall air conditioners consist of three basic parts:

1. A hermetic compressor
2. Condenser
3. Evaporator using a capillary tube refrigerant control.

When the system operates, liquid refrigerant at the bottom of the condenser is drawn through the capillary tube into low-pressure evaporator. Here the refrigerant vapourises thus absorbing heat from the evaporator surface. Air from the room is drawn into air conditioner through a filter. The air is then forced over the evaporator and cooled before going back into the room. The low-pressure vapour in the evaporator is then drawn through the suction line into the compressor, where it is then compressed to the high-side pressure and sent into the condenser to be cooled and condensed to a liquid. The cycle then repeats.

The condenser and compressor are in the part of the unit, which is outside the building. The condenser fan draws outdoor air in to cool the condenser and discharges it outside.

Air flowing through the evaporator is cooled and dehumidified. Moisture that collects on the evaporator surface is drained to drip pan under the evaporator. In some machine, it flows into a pan in the compressor compartment, which in evaporating, helps to cool the compressor and condenser.

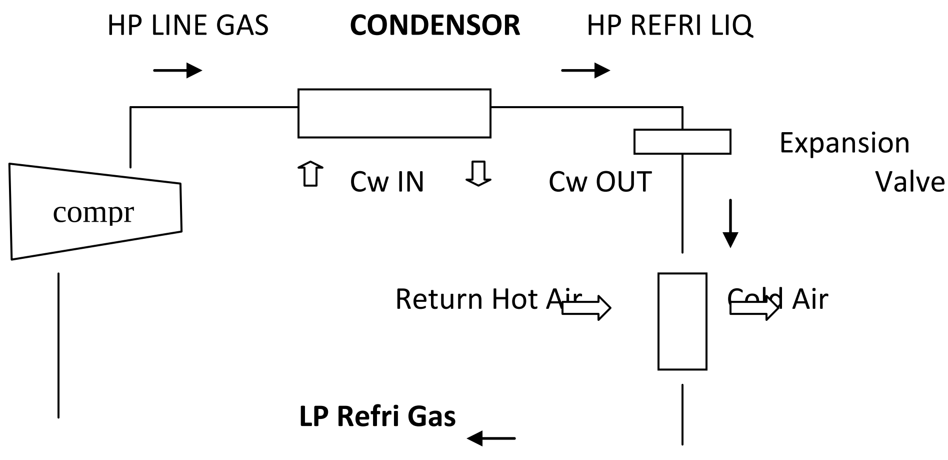
LOWERING THE AMBIENT TEMPERATURE: (COOLING THE AIR)

In most of the Indian states where ambient temperature during most part of the year is on higher side of the comfort zone, it is essential to lower down the temperature. Refrigeration and air handling do this. There are two basic type of the system of refrigeration or air conditioning. This is differentiated by the means of transfer of heat.

Types of Central A/C system

- Vapour compression system OR DX type
- Chilled water type

In the A/C system, the refrigerant is compressed and then suddenly expanded. This will result in drop of temperature of the refrigerant. This chilled refrigerant is then passed through a coil, through which the heat is transferred to the other media. When the heat transfer is directly taken place between refrigerant & air, it is termed as DX (Direct Expansion) type. In some of the case where the distance between the a/c plant and the volume to be cooled is more or divergent, a intermediate media is cooled first. This media is normally water. This chilled water is then circulated through the coil and a blower passes the air over this coil. This in direct method of cooling is known as Chilled water system. The system of cooling and the flow chart is indicated in the given figure.



A/C Refrigeration Cycle Flow Chart

Cooling Through–Window or Wall (Window Air Conditioning)

The window air conditioner is some times fitted with electric resistance heating units for cold weather use. The units are available up to 3 TR capacity.

During cold weather:

1. The refrigerating mechanism is turned off
2. The electric resistance heating units are turned on
3. The room air fan is turned on. The same circulates warm air in cold weather and cooled air in warm weather.

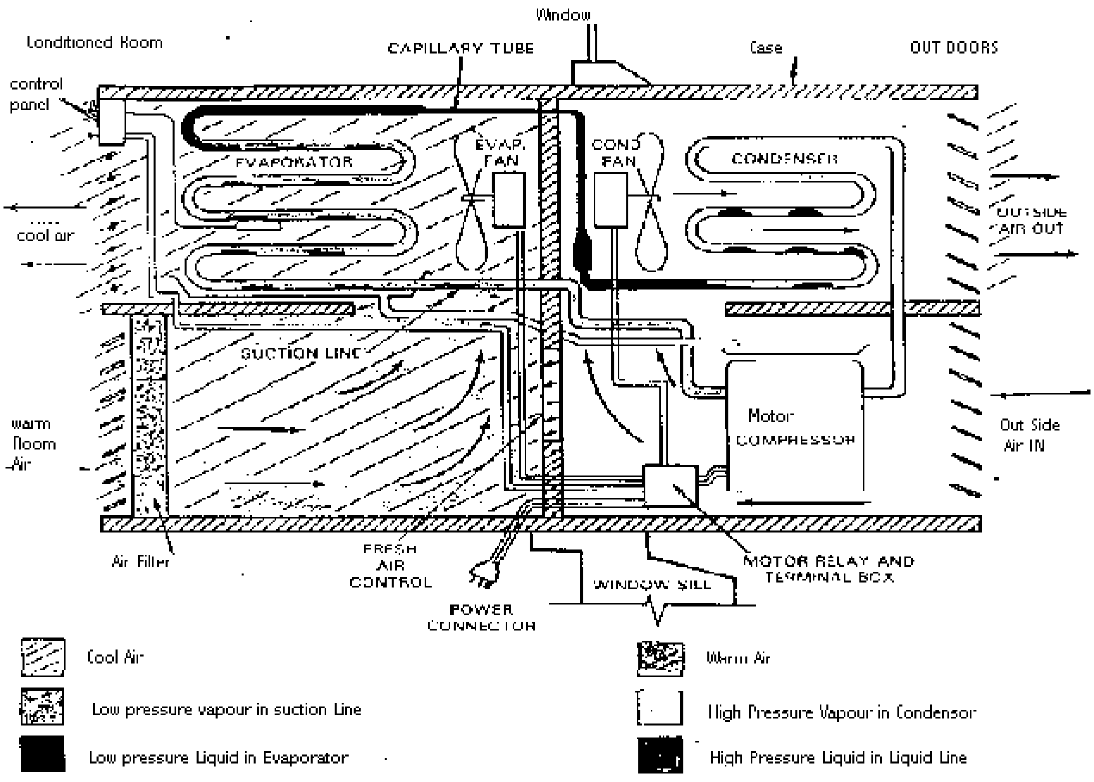


Fig : Window A/C System

Central Air Conditioner, Complete System –
Gas Heating, Compression System and Cooling with Humidity Control
This is an industrial type of system to condition the air. The heating is accomplished with gas. This is to increase the air temperature in winter season.

The cooling in summer season is accomplished by compressor system; this brings down the air temperature to a required level.

Fuel gas, burned in an atmospheric burner, is used for heating in this air conditioning system. A compression system using a A-frame evaporator in the furnace plenum chamber provides cooling.

The condensing unit is located outside the building. A single combination heating and cooling thermostat is often used. A humidistat controls the relative humidity in the conditioned space.

In winter, a humidifier in the plenum chamber adds moisture to the heated spaces. Summer humidity is controlled by condensation of moisture on the evaporator. A drain removes this moisture.

A blower forces warm air from the furnace into the rooms. This is located beneath the filter in the cold air return. The electrical power is turned on or off depending on the predetermined setting.

In summer, when cooling is required; the same airflow is used for cooling. However, instead of forced air passing through a heated chamber, passes across the cooled evaporator. This lowers the temperature of the air and also removes source moisture to reduce the humidity. The filter in the incoming air duct does air cleaning before air reaches the blower.

Absorption Cycle

Most large absorption air conditioning systems use water as the refrigerant and a Li Br (lithium bromide) water solution as the absorber.

Steam or hot water heats the water and lithium bromide solution. The water turns into water vapour, which is then condensed by a water-cooled condenser, the water then flows into the evaporator where it evaporates (under near vacuum pressure) and is absorbed by the lithium bromide at the absorber.

Three pumps maintain the pressure difference. First moves the solution, which is strong in Li Br back to the absorber and removes more strong Li Br solution from the concentrator. Second recycles water not evaporated in the evaporator back to the spray heads in the evaporator. Third moves the solution which is weak in Li Br up to the concentrator. Cooling water leaves the evaporator at 7°C and travels through the cooling coils located in the rooms to be air-conditioned. The water then returns to the evaporator at 12°C. The LiBr solution always stays in liquid form; the condenser cooling water also cools the absorber.

Evaporative Condenser

Many air conditioning systems use water-cooled condensers. An evaporative condenser may be used to cool the condenser vapour. The system comprises a conventional motor compressor, evaporator, thermostatic expansion valve, liquid receiver and evaporative condenser. The hot compressed refrigerant vapour is piped to the evaporative condenser (normally outside the building). Water supply is connected to a float controlled holding tank and pump circulates the water to spray over the condenser. A fan draws in air from the side of the condenser housing and forces it upwards through the top. This cools the water droplets by evaporation which then flows over the condenser to cool the refrigerant vapour into liquid. Some water is used up in evaporation and it is replaced (make up water) automatically using a holding tank and float mechanism.

CVSRTA

Cooling Tower

As mentioned earlier, water-cooled condensers are common in many refrigeration and air conditioning systems as they are efficient and do not occupy much space. Often tap water are used to circulate over condensers and then discharged into sewers. This can use up large amounts of water (in some places, may be prohibited) and may be expensive. Economics apart, it is a national waste also.

In such cases, a cooling tower can be used to cool the water. Water is re-circulated through the condenser and sometimes the outer shell compressor. Some water has to be replaced due to loss in evaporation.

The cooling tower is a housing or shed in which air is drawn. It has a water spray arrangement and baffles. The fan forces air to cool the sprayed water, which is then collected in the holding tank. In the process, the heat from the water is transferred to air and the temperature of the water is lowered. The water is then circulated through the water-cooled refrigerant condenser. A float mechanism connected to the water spray maintains constant water level in the tank.

Room Humidifiers:

The function of a humidifier is to add and control moisture (relative humidity) in heated air for environmental comfort and reduce static electricity conditions. Most humidifiers in warm air systems are part of the furnace or the ductwork.

Humidifiers can easily the added to warm air-heating systems. Hot water, steam and most electric heating systems, however, require a separate cabinet type humidifier.

Various cabinet type humidifiers are used in the industry viz:

1. Plate type humidifier (low capacity)
2. Rotating drum type (for restricted space)
3. Rotating disk type
4. Fixed filter type
5. Fan type
6. Plenum/warm air duct humidifier (slings the water)
7. Plenum/duct electric type
8. Ultrasonic (piezoelectric) type

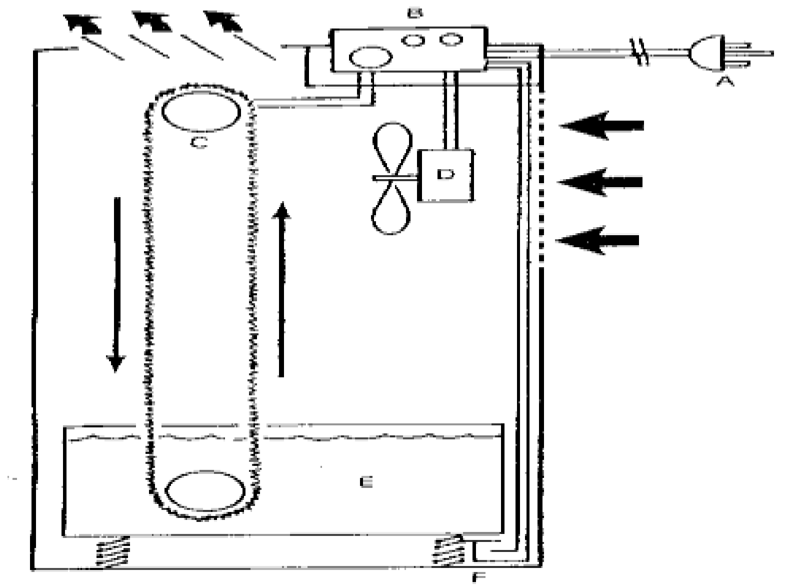
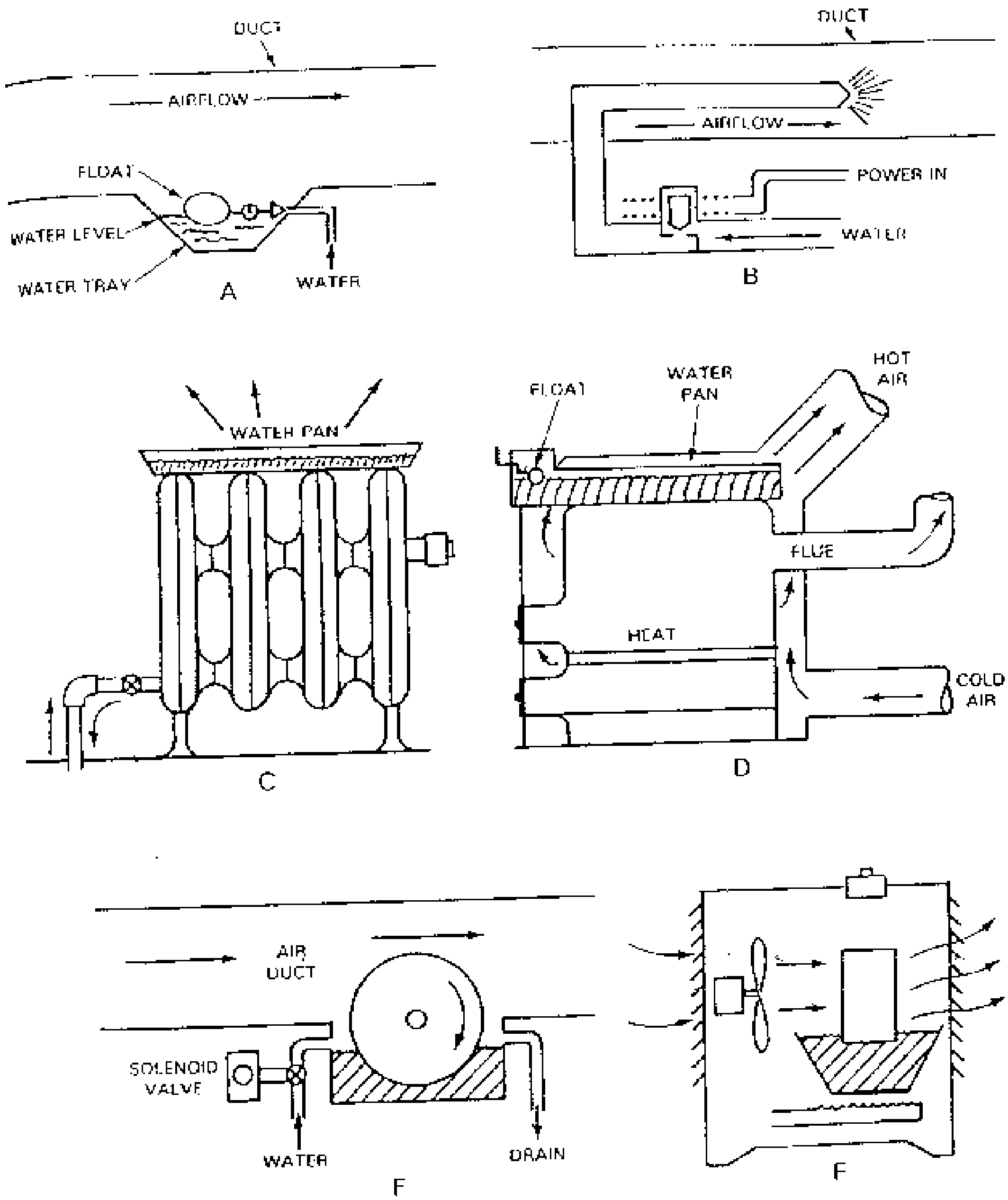


Fig. Cabinet Type Humidifier



Types of Humidifiers

A – Open water tray in warm air duct
B – Spray nozzle in warm air duct
C – Water pan on radiator
D – Water pan in top of warm air furnace
E – Wetted revolving screen in warm air duct
F – Space humidifier (by electric heat)

Dehumidifiers:

A dehumidifier is equipment, which removes moisture from the air by drawing air over a cold coil to condense the moisture in the air. It is usually a small hermetic refrigerating system that has both a condenser and evaporator in a cabinet. Air is drawn over the evaporator. Air moisture is condensed in the evaporator surface and collected in a pan and drained. The cooled air then moves over the condenser to reheat the air to a reasonable relative humidity. The device is used to 'dry' the air in damp places like basements etc.

In some installations, chemicals are used to absorb moisture from the air and then it is heated to remove absorbed moisture. The moisture is then exhausted out side and the chemicals are re-used.

Circulating / Distributing Equipment:

Air Ducts

Air ducts act as air carriers to deliver air to the conditioned space.
Ducts work on the principle of air pressure difference. If a pressure different exists, air will move from the higher-pressure area to the lower pressure places. The greater the pressure difference, the faster air will flow.

There are three common classifications of ducts:

1. Conditioned air ducts
2. Recirculating air ducts
3. Fresh air ducts

Ducts commonly used for carrying air are round, square or rectangular. Round ducts are more efficient based on volume of air handled per perimeter distance. That is, less material is needed for the same capacity as a square or rectangular duct. Resistance to airflow is also less. In addition, the round duct has a less outside area than a rectangular duct of equivalent capacity; it will have a much lower heat loss or gain.

The square or rectangular ducts conforms better to building construction. It fits into walls and ceilings better than round ducts. It is easier to install rectangular ducts between joists and studs.

Types of Duct Systems

There are several types of supply duct systems:

1. Individual round pipe system
2. Extended plenum system
3. Reducing trunk system

Return air systems are usually of two types:

1. Single return system
2. Multiple return system

The return systems can also be combinations of the two systems.
Duct systems may be installed in basements, in crawl spaces and just below ceiling level. Ducts may be made of galvanized sheet steel, aluminium sheet, glass fibre and plastic. Sheet lead is used when the duct must carry corrosive gases. Insulated ducts made from fiberboard have also been developed.

Diffusers, Grilles and Registers

Room openings to ducts have several different devices. They are used to control the airflow and to keep large objects out of the duct
There are many devices like Diffusers , Grilles or Registers
Diffusers deliver widespread fan-shaped flows of air into a room. Some diffusers cause the duct air to mix with some room air in the diffuser.
Registers are used to deliver concentrated air streams into a room. It may be one way or two-way adjustable air stream deflectors.

Grilles have an aesthetic purpose also in addition it control the distance, height and spread of air throw as well as the amount of air. Grilles have many different designs. Some are fixed and can direct the air only in one direction. Others are adjustable and can be set to send air in different directions. Fixed type grilles and usually used as covers for the return air duct.

Dampers

To ensure even air distribution in forced air systems, dampers are used to balance airflows or they can shut off or open certain ducts for zone control.

There are three types of dampers, some located in the diffuser or grille, some are in the duct itself. They are Butterfly , Multiple blade and Split damper

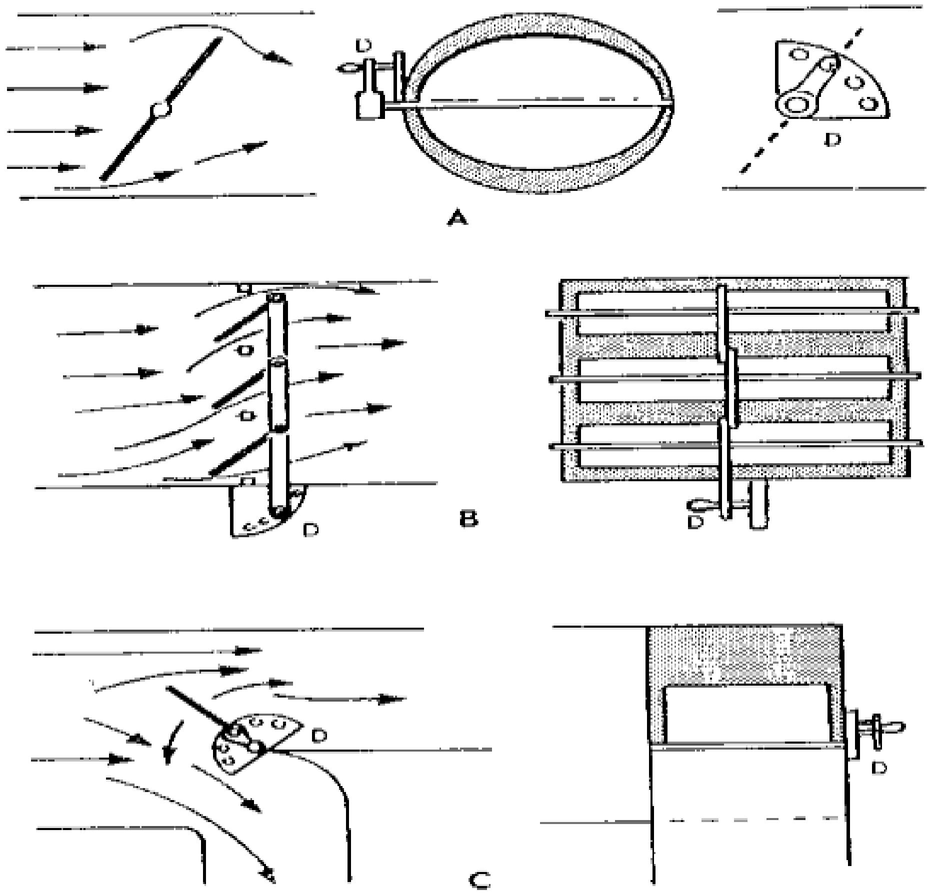


Fig. Types of Duct Air Flow Controls

(Types of Dampers)

Air Circulation

In air heating, three basic systems are used to circulate the air: They are Gravity, Intermittent forced air or Continuous forced air

The first type i.e. gravity system is no longer popular. Due to heavy energy lost before the air gets to the room being heated. The second type is widely used i.e. intermittent forced air system. A thermostat in the furnace plenum chamber is used to control the fan. Now a days the third type is becoming more popular i.e. continuous blower system. It provides a more constant temperature in rooms.

Systems designed to provide cooling as well as heating need additional capacity to move air. This is because a cubic foot of cooled air will not change the room temperature as much as the same amount of warmed air. In average conditions, a 30 to 50 per cent air flow increase is required.

FANS AND BLOWERS:

While discussing circulation, it would only be appropriate to briefly cover fans and blowers. Though essentially belonging to the compressor family of machines, they generally differentiate from compressors in their nomenclature. This is most likely due to the fact that the pressure development is marginal and does not affect much of volume reduction.

Fans:

Fans are used for low pressure , generally the delivery pressure is less than 0.5 lbs/m2. Fans can also be either centrifugal, axial or mixed flow types. Fans are generally used to handle very large flow rates and low pressure. Main applications consist of Combustion Air, Draft, Cooling Towers and Fin Coolers, Drying Units, Ventilation System etc. While centrifugal fans would have axial entry and radial exit, the axial fans are of propeller design having axial entry as well as discharge. Unlike centrifugal fans, axial flow fans would not have ducts.

Fans in Air Conditioner

Air movement is usually produced by some type of fan. Usually fans are located in the inlet of the air conditioner. There are several types of fans, but the two most popular types are: Axial flow (propeller) & Radial flow (squirrel cage)

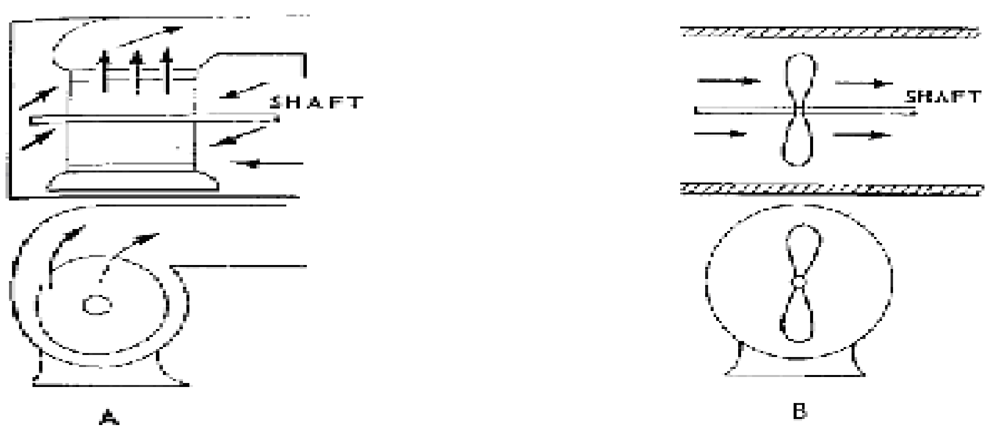


Fig. Principal Types of Fans

A – Radial flow & B – Axial flow

The fan construction tells which type it is. If air flows along the direction the axle is pointing, it is called axial flow. If the flow is at right angles to the axle (radius), it is called the radial flow.

The axial flow fan is usually direct driven by mounting the fan blades on the motor shaft. The radial flow fan is most often used on large installations. It is either directly driven or belt-driven.

Blowers:

Blowers develop little higher pressure in comparison to fans. They are used for pressure below 1.65 Psi. The centrifugal blower produces energy in the air stream by the centrifugal force and a velocity to the gas by the blades. The scroll shaped volute diffuses the air and creates an increase in the static pressure by reducing the gas velocity.

The performance of a centrifugal fan varies with change in conditions like temperature, speed and density of the gas being handled. Corrections must be applied to manufacturing standards with respect to operating conditions.

Air cleaning Equipment:

With air pollution as a growing problem, increasingly cleaning the air has become an important part of air conditioning.

Air may be cleaned in many ways, depending on the foreign matter contaminating it. The means of doing this is as under :

1. To remove solids such as dust, soot and smoke, one may use:
   - (a) Centrifugal force (for large particles)
   - (b) Washing the air (for particles that are wettable)
   - (c) Screens (to block the larger particles)
   - (d) Adhesives. The air impinges on a sticky surface and the dirt particles in the air stick to the adhesive.
   - (e) Electrostatic (electrically charging the particles and adhering these particles to an opposite charge surface). Most of these cleaners have a screen to trap large particles, an electronic unit to remove particles as small as 0.001 micron, and a mat to trap the electron-treated particles. This uses hot water to wash the unit through a spray manifold. Water is released into the manifold and forced through a series of spray jets. The dirt is flushed off and drains to the bottom of the unit.

2. To remove liquids:
   - (a) Liquid absorbents (chemicals to absorb or react with liquid)
   - (b) Deflector plates
   - (c) Settlement chambers

3. To remove gases and vapours (these are molecular size particles)
   - (a) Condensation (cool the contaminant gas to its dew point and remove as a liquid).
   - (b) Chemical reaction (to react with the gas)

(c) Some odors are removed by oxidation and by ultraviolet ray treatment. Ultraviolet lamp fixtures can be installed across the full cross section of the duct to do so.

4. Dilution: Activated carbon filters made from various substances including carbon from refining petroleum and coconut shells are used to adsorb odors. This carbon will adsorb (hold on the surface) as much as 50 per cent of its weight in foreign gases. It is possible to remove almost 100 per cent of the contaminants in the air, but to do so is expensive. Removal of 90 to 95 per cent is much more common and practical.

Exersise :

1. What is air conditioning? What one would expect to find in an a/c installation?
2. Where a/c system for raising ambient temperature is used? Name the systems for raising ambient temperature. Describe one of them.
3. What are the basic parts of a/c cooling system? Describe the cooling cycle
4. Draw and describe refrigeration cycle.
5. Describe an absorption cycle.
6. Write short note on:
    a) Window a/c
    b) Cooling Tower
    c) Room Humidifiers
    d) Air Ducts
    e) Dampers
    f) Types of fans
    g) Air Cleaning System

UNIT - 04
ELECTRICAL INSTALLATIONS

ELECTRICITY & ELECTRIC CURRENT

It is comparatively easy to describe what electricity can do than to give a simple and direct answer to the question: - " What exactly is meant by electricity? " Electricity has become such a universal medium for transmission and utilization of energy that almost every one is familiar with its innumerable uses right from the earlier childhood. Electric energy is utilized for lighting, transportation, communication, heating, refrigeration, and various types of machine tools.

Turning back to the question regarding the nature of electricity, it may be noted that ancient Greeks were the first to observe that when amber is rubbed against a piece of silk cloth, it attracts light objects like pieces of paper etc. The Greek name of amber is "Electron" and thus the name "Electricity" was derived.

The field of electrical engineering is vast and diverse one. Often included under the general title of electrical engineering are the fields of electronics, semiconductors, computer science, power, lighting and electro-magnetic. The focus of this class and the notes is on professionals whose responsibility includes judging and evaluating an electrical machine in the right perspective of engineering.

The following chapter provides a brief review of basic concepts, which serves as background for the professionals in the field of valuation. A thorough understanding of these concepts, while helpful, is not essential to understanding the remaining part.

ELECTRICAL UNITS :

Table 1.1 and the following texts provide definitions of the basic electrical quantities.

Table 1.1 Electrical Quantities in MKS units.

Quantity	Symbol	Definition	Unit
Force	f	Push or pull	Newton
Energy	wh	Ability to do work	Wh or KWH
Power	p	Energy/unit time	Watt
Charge	q	Integral of current	Coulomb
Current	I	Rate of flow of charge	Ampere
Voltage	v	Energy/unit charge	Volt
Magnetic Flux Density	H	Force /unit charge momentum	Tesla
Magnetic flux	∅	Integral of magnetic flux density	Weber

"Force": A force of 1 newton is required to cause a mass of 1 kilogram to change it's velocity at a rate of 1 meter per second per second.

"Energy": Energy in a system is measured by the amount of work, which the system is capable of doing. The joule or watt-second is the energy associated with an electromotive force of 1 volt and the passage of one coulomb of electricity.

"Power": Power measures the rate at which energy is transferred or transformed. The transformation of 1 joule of energy in 1 second represents an average power of 1 watt.

"Charge": Charge is a "Quantity" of electricity .The coulomb is defined as the charge on 6.24 x 10^{18} electrons or as the charge experiencing a force of 1 newton in an electric field of 1 volt per meter or as the charge transferred in 1 second by a current of 1 ampere.

"Current": The current through an area is defined by the eloctric charge passing through per unit of time. The current is the net rate of flow of positive charges. In a current of 1 ampere, charge is being transferred at the rate of 1 coulomb per second.

"Voltage": The energy transfer capability of a flow of electric charge is determined by the potential difference or voltage through which the charge moves. A charge of 1 coulomb receives or delivers an energy of 1 joule in moving through a voltage of 1 volt.

"Magnetic Flux Density": around a moving charge or current exists a region of influence called a "Magnetic Field"." The intensity of the magnetic effect is determined by the magnetic flux density which is defined by the magnitude and direction of a force exerted on a charge moving in the field with a certain velocity. A force of 1 newton is experienced by a charge of 1 coulomb moving with a velocity of 1 meter per second normal to a magnetic flux density of 1 tesla.

"Magnetic Flux": Magnetic flux quantity I, in Weber, am obtained by integrating magnetic flux density over an area.

The idea of electric potential & current: -

The Voltic Cell

The figure here indicates a simple voltic cell. One copper plate and one zinc rod are immersed in dilute H_2SO_4.

Flow of electrons

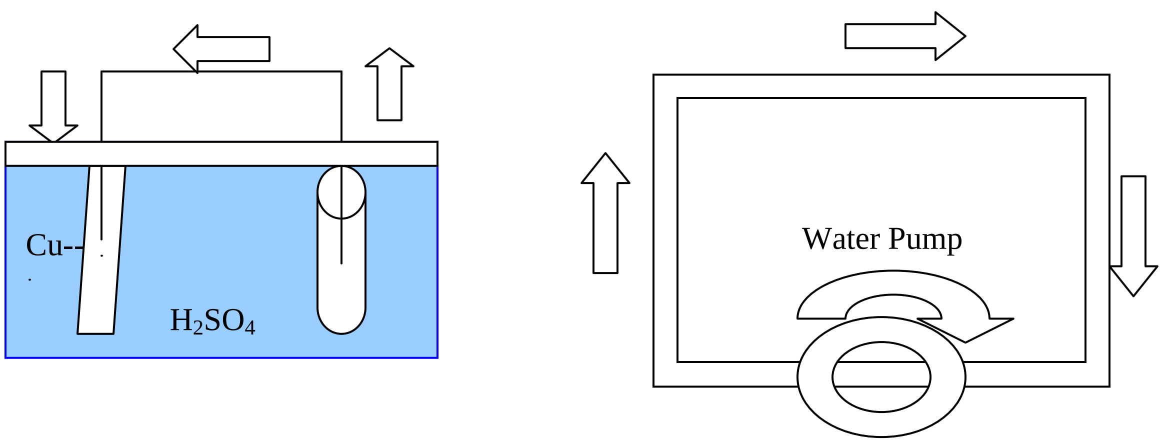


Figure 1.1 Voltic cell & it's analogy

Due to chemical reaction the electrons are removed from copper plate and deposited on zinc rod. Thus Cu becomes positive and Zn becomes negative charged. As large number of electrons gets deposited on zinc, they are being attracted by anode but due to the force setup by chemical reaction, they cannot take internal route. Now if a conductor connects the two electrodes, then the electrons will travel from Zn to Cu via this route. This flow is continuous due to continuous chemical reaction and the balance is maintained between the levels of electrons. The direction of current is the direction of positive charge i.e. from Cu to Zn.

This phenomena is similar to that of water pump, which while working maintain continuous flow(current) through pipe.

This principle of electric current production is used in storage battery.

Let us understand some basic rules of electricity :
RESISTANCE: -
If a battery is connected with a wire to make a complete circuit, a current will flow.(Refer figure 1.2) The current that flows is observed to be proportional to the applied voltage .The constant that relates the voltage and the current is called "resistance". The relation can be expressed by an equation :

V=R I where

v – volts, **I** – current in amperes and & **R** – resistance in Ω (Ohms)

This expression is called **Ohm's Law.**

Since voltage is the energy per unit charge and current is the charge per unit time, the basic expression for electrical energy per unit time or power is:

$$P = VI = I^2R$$

The resistance is also defined as a measure of the ability of a device to dissipate (in the form of heat) power.

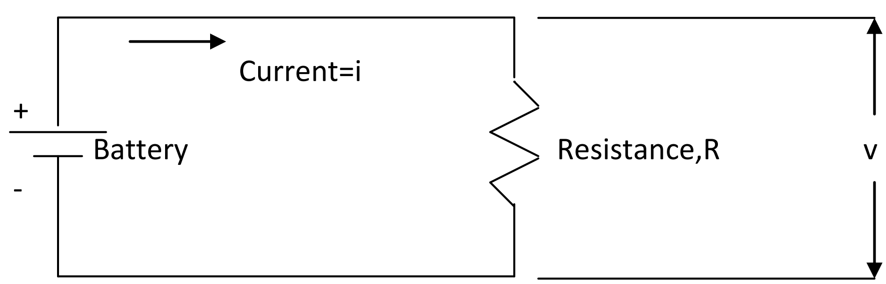


Figure 1.2 OHM'S LAW

CAPACITANCE :-

Now let's connect the battery to two flat plate separated by a small air space between them. (Refer figure 1.3) When a voltage is applied, it is observed that positive charge appears on the plate connected to positive terminal of the battery and negative charge appears on the plate connected to the negative terminal of the battery. If the battery is disconnected the charge persists. Such a device, which stores charge, is called a capacitor.

If a device called signal generator, which generates an alternating voltage, is connected in place of the battery, the current is observed to be proportional to the rate of change of voltage. This relationship can be expressed in the form of a equation as: **I = c.dv/dt**

Where "c " is a constant called "capacitance" (Measured in farads) and dv/dt represents the rate of change of volts.

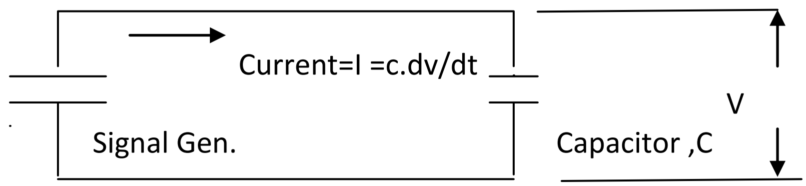


Figure 1.3 CAPACITANCE LAW

INDUCTANCE :-

If the signal generator is placed in a circuit in which a coil of wire is present, it is observed that only a small voltage is required to maintain a steady current. (refer figure 1.4) However to produce a rapidly changing current, a relatively large voltage is required. The voltage is observed to be proportional to the rate of change of the current and can be expressed as:

V = L . di/dt

Where "L" is the constant called " inductance " (measured in henrys-H) and di/dt is the rate of change of current.

Additionally it is observed that, when a direct current is removed from an inductor the resulting magnetic field collapses thereby " inducing " a current in an attempt to maintain the current flow. Inductance is the measure of the ability of a device to store energy in the form of a magnetic field.

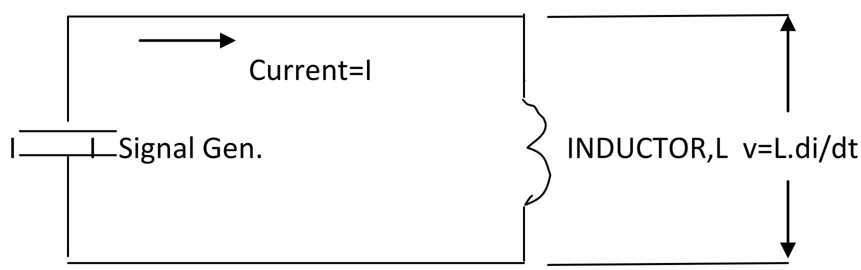


Figure 1.4 INDUCTANCE LAW

EXERCISE :

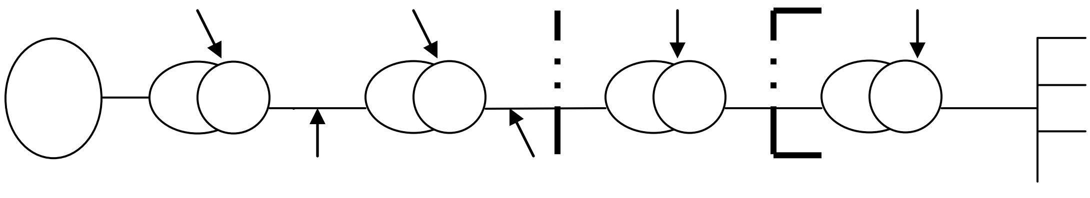
1. Define the terms
   Force, Energy, Power, Voltage & Current
2. Describe Voltic cell and it's analogy with water pump.
3. What is Ohm's Law. Explain in brief the relation between Voltage applied, Current passing through and the resistance.

Transmission & Distribution

General layout of the system

The conductor system by means of which electric power is conveyed from a generating station to the consumer's premises may, in general, be divided in to two distinct parts namely transmission & distribution network. This would be made-up of elements shown in the single line diagram below:

11/132KV step up transformer 132/33KV step down transformer Receiving Station (RS) 6.6KV/415V 33/11 KV (or 6.6KV) Distribution Transformer transformer **Consume**r



Generator Primary Transmission Secondary Transmission Primary Distribution

Fig 1 : Typical Power System Diagram

The power generated at a generating station is usually at 11 KV level. For economics of transmission it is stepped up to 66KV or 132 KV.at generating station itself. From here it is transmitted over a long distance through overhead lines. This is called a primary transmission. The electricity company set up a receiving station near the utility point, where this Extra High voltage is stepped down to High Voltage (the diagram above show this stepping down in two phases but it may be in one phase also) This high voltage is carried to the users door step. This is secondary transmission. The user industry (for small industries the electricity company in the vicinity) steps down this voltage to Low Tension (415V) This distribution is called primary distribution. Large industries may use both the levels of voltage i.e. 6.6 KV (6600V) & 415 V. Small scale units use only LT supply i.e.415V.

It has to be realized that one or more of these elements may be missing in any particular system.

The transmission voltage to a large extent is determined by economic considerations. High voltage transmission requires conductor of smaller cross section resulting in saving of copper or aluminum. But the cost of insulation, transmission structures & substation equipment increases. Hence the economical voltage of transmission is one, which balances these two aspects. As a rough thumb rule 1000volts per mile of line length is considered.

Power Flow Concept:

Power flowing is analogous to water flowing in a pipe. To supply several small water users, a large pipe serves the plant at a high pressure. Several branches from the main pipe service various loads. Pressure reducing stations lower the main pressure to meet the requirement of each user. Similarly, a large feeder at a high voltage serves a plant. Through switchgear breaker, the main feeder is distributed into smaller feeders. The switchgear breakers serves as a protector for each of the smaller feeders. Transformers are used to lower the voltage to the nominal value needed by the user.

How to design a single line diagram:

An overall one-line diagram indicates where loads are located and how they are fed.

- The first step is to establish loads and their locations by communicating with the various engineers.
- The next step is to determine the incoming voltage level based on available voltages from the utility company and the distribution voltage within the plant.

(a) For single buildings and small complexes without heavy equipment loads, incoming voltage levels may be 230 or 415 volts. For small industrial plants to 10,000 KVA, voltage levels may be1100, 3300, 6600 or 11.0KV.

(b) For medium plants 10,000 KVA to 20,000 KVA voltage levels may be 11.0 KV.

(c) For large plants above 20,000 KVA, 11.KV or 33 KV are typical values.

(d) For mega size plants, 132 KV voltage level is becoming popular

The advantages with the higher voltage levels are:

(a) Feeders and feeder breakers can handle greater loads , since for a given power, as the voltage goes up the current reduces. The capacity of a conductor is to carry current. Hence as the voltage goes up the system can carry higher load power. Of course the higher voltage means higher insulation level, which also costs. (More economical at certain loads.)

(b) For feeders which serve distant loads, voltage drops are not as noticeable on the higher voltage system.

- The third step is to establish equipment types, sizes and ratings.
- The last step is to determine the system reliability required. The type of process and plant requirements is the deciding factors. The number of feeds and the number of transformers determine the degree of reliability of a system.

Types of Primary Distribution System

The three commonly used primary distribution systems for industrial plants are the simple radial, primary selective, and secondary selective systems.

- The Simple Radial System is the most economical. As Figure 2 indicates, it is comprised of one feed and one transformer.

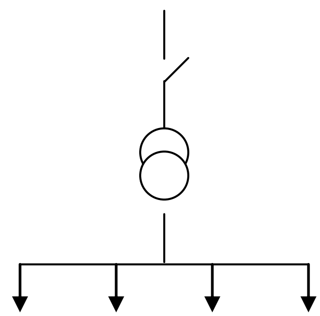


Figure 2: Simple Radial System

- The Primary Selective System is comprised of two feeds and two disconnect switches. for primary transformer See Figure.3.

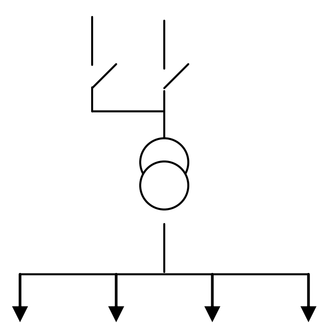


Figure 3: Primary Selective System

- The Secondary Selective System is the most reliable and the most expensive. As Figure 4 indicates, it is comprised of two complete substations joined by a tie breaker.

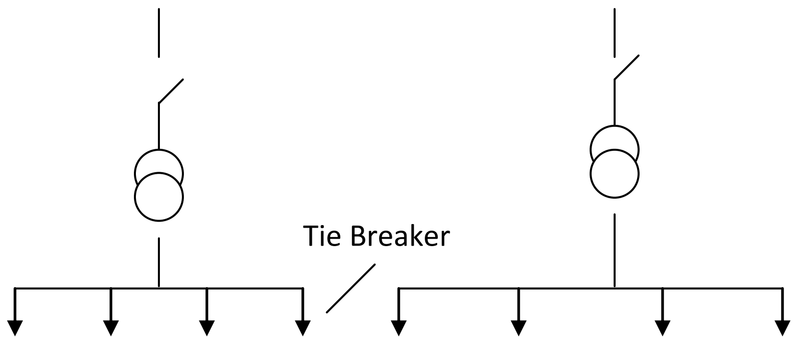


Figure 4: Secondary Selective System

General Tips for Distribution System:

- Always size unit substations with growth capacity (25% growth Capacity for transformers is common practice).
- A transformer with fans increases its rating. A 1000 KVA dry-type transformer with fans is good for 1333 KVA (33% increase). For an oil-type transformer a factor of 25% is used. Fans should only be considered for emergency conditions or for expanding existing plants.
- The question comes up as to where to locate equipment. Incoming Switchgear is usually located near the property line so that the utility company can gain easy access to the equipment. Substations and motor control centers are usually located indoor in electrical rooms.

Electrical Rooms:

The electrical engineer should keep in mind the following when specifying electrical room requirements.

- Do not allow roof penetrations. Any roof opening increases the risk of fluid entering the electrical equipment.
- Do not allow other trades to use electrical room space.
- General ambient temperature should be 40°C. (Special equipment, such as computers, may require air conditioning.)
- Lay out electrical rooms with the following in mind.
  - (a) Sufficient aisle space and door clearances should be provided to allow for maintenance and replacing of damaged transformers and breakers. Use the recommended clearances established by the vendor.
  - (b) Double doors of adequate height (usually 8 feet) should be provided at exists in order to remove equipment.

While designing the electrical lay out, one must keep certain statutory requirement in mind. The Indian Electricity Act specifies the safety aspects for all electrical equipment. In the following Chapter The basic scope and some of the important provisions are indicated in brief. These provisions are important for loss assessors to decide the non-compliance of the statutes.

EXERCISE :

1. Draw and describe the general electrical distribution diagram.
2. Explain the power flow concept in electrical engineering. Explain the same giving analogy.
3. What atr the advantages of higher transmission voltage ?
4. Describe the types of primary distribution system.
5. What are the requirement of electrical sub station room ?
6. Write short notes on :
   a. Design a single line diagram of an electrical system
   b. Secondary selective distribution system
   c. Tips for distribution system

Main Switchgear for Industrial Installation

The power received at the doorstep of the unit is required to be distributed throughout the facility for utilization. Here we will be discussing some of the equipment used for the purpose and the safe ways of doing so. We shall also see selection & lay out of equipment for distribution like Circuit Breaker, Motor Control Centre etc.

Electrical Equipment

Electrical equipment commonly specified is as under:

- **Switchgear Breaker –** used to distribute power and provide over current protection for high voltage applications.
- **Unit Sub Station -** The high voltage received is stepped down to a usable voltage level at unit s/s. It consists of high voltage dis-connect switch, transformer & low voltage breakers.
- **Motor Control Centre -** is a sheet steel structure which houses starters, circuit breakers or fuses for motor control. It consists of following:
  - ✓ Thermal over load relays which guards against motor over load.
  - ✓ Fuse Disconnect Switch OR breaker, which protects cable or / and motor from over load / short circuit and also can be used as dis connecting device.
  - ✓ Contactors whose contacts are capable of opening or closing the power to motor.
- **Panel board / Switchboard –** breakers used to distribute power & provide over current protection to motor control centers, lighting receptacles and miscellaneous power circuits within the building.

High Voltage Breakers:

In a typical medium-duty installation, the incoming supply of 11KV rating can go through an oil or gas filled ring main unit before the step-down transformer.

Oil immersed circuit breakers are located in oil-filled ring main units. These breakers can be further classified by its operating mechanism:

- Manual operation,
- Solenoid operation,
- Motor spring operation and
- Handspring operation.

The capacity rating of these units is three phase 11KV, 650 to 1250 amps normal current capacities and 20 to 25KA fault current levels. The circuit breakers are housed in cubicles.

In a gas filled ring main unit, SF6 (sulphur hexafluoride) gas circuit breakers are used and they are housed in cubicles. Their operating mechanism is of either handspring or motor spring types. Their fault current levels 20 to 40KA.

Other high voltage circuit breakers are the air blast and vacuum types. These circuit breakers can be fitted in main switchboards. Air blast circuit breakers come in either 'plug in' or withdraw able cassette units in three or four pole configuration. Their operating mechanisms are like that of oil-immersed circuit breakers. Normal current capacities range from 800 to 4000amps and fault current level up to 50KA.

Vacuum type circuit breakers are housed in cubicles and their operating mechanisms are either of manual solenoid, motor spring or handspring. Normal current capacities of VCBs are up to 2500 amps and fault current level up to 40KA.

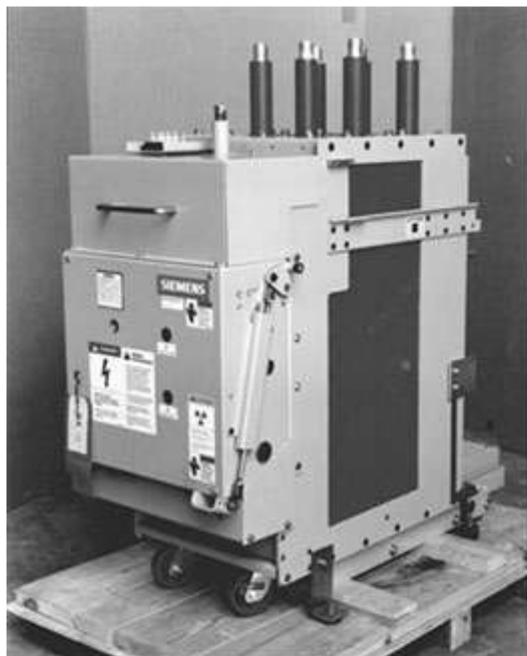


Fig : Vacuum Circuit Breaker

All four types of circuit breakers can also be located in main switchboards, Air-blast, oil immersed and vacuum breakers are commonly found in older installations. Although SF6 circuit breakers have been in use in primary distribution (i.e. from electric generating plants to various transformers in the National Grid) for a long time, its use in secondary distribution, i.e. within industrial installation, is relatively new. Increasingly, the use of air-blast and oil-immersed types is being phased out as air types are relatively expensive and due to its flammability, oil-immersed types pose fire risks. Both the vacuum and SF6 circuit breakers, considered as dry-type, are favored due to its safety in use. Once the supply has passed through the circuit breakers without triggering any faults, it goes into the step-down transformer.

Transformers:

The transformers used in industrial plants are either of liquid filled or dry types. The liquid-filled types are suitable for use outdoors in hostile environments and for arduous duty cycles. They can come into different forms such as ground / floor mounting, pole mounting and unit substation (known as packaged substations) transformers in a typical range from 500KVA to 5MVA and voltage levels up to 33KV. Liquid cooled transformers are used for a wide variety of applications for both AC and DC supply, typical examples of which are: furnace heating, mining, electro-plating, cathodic protection, thruster drives and converters. Cooling for these transformers is normally with both oil and air circulating by natural convection (ONAN). Improved cooling can be obtained by the use of fans (ONAF), oil pumps (OFAN) or both (OFAF). In locations where fire risks must be greatly reduced, oil is replaced by silicone liquid or other synthetic fluids (LNAN).

Dry-type transformers are available as resin cast transformers and aramid insulated transformers. Resin cast transformers covers voltages from 11 to 35KV and a ratings from 500KVA to 15MVA. Forced air-cooling systems can be fitted to increase continuous ratings by 40 to 50%. These transformers are also suitable for rectifier applications and other special purposes, such as, rapid transit systems and air and iron core reactors. The aramid-insulated transformers operate at 11KV primary voltage with rated power output of 500KVA to 2.5MVA. This type of transformer is suitable for medium voltage distribution needs. Dry-type transformers have a major advantage for installation in hazardous areas, as they do not contain any materials that might add to a fire or pollute the environment.

Fig: Power Transformer

The function of the transformers at this stage is to step down the incoming supply of 11KV to the required voltage level commonly to 415V into the main switchboards. In some cases such as electric are furnaces; the supply is stepped down to 3300V.

One of the important accessories of transformer is a Tap Changer. Tap changer is a switch, which either adds or cuts off a section of the winding. This is achieved by taking out different leads of winding and connecting only the required section By doing this, the voltage at secondary side can be increased or decreased.

The cost of the transformer is mainly contributed to copper, as it is active part in the winding. The other parts are insulation, oil and the tap changer. The life of a transformer is very long since there is no wear and tear of any of the components. (Except tap changer). Also due to heavy copper content, the scrape value of the transformer is high.

Open-Type Switchboards

An open-type switchboard is one, which has exposed current-carrying parts on the front of the switchboard. It is rarely used in low voltage installations due to safety hazards. It is normally confined to extra low-voltage installations.

Protected Type Switchboards

A protected switchboard is one where all of the conductors are protected by metal or other enclosures. They may consist of metal cubicle panel, or an iron frame upon which is mounted metal-clad switchgear, They usually consist of a main isolator, bus bars, circuit breakers or fuses controlling outgoing circuits, power transformers, power correction factor correction panels, motor control and metering equipment. Depending on the equipment they control they can be called as Motor Control Centre (MCC) or Power Control Centre (PCC)

Power Factor Correction
The power factor is the ratio of the True power, i.e. the power consumed by a circuit, to the apparent power, i.e. the power supplied to the circuit. When the current and voltage in a circuit are in phase, the true power equals the apparent power and the power factor is 100%.

If the current and voltage go out of phase, electrical energy is fed back to the source and is not consumed by the motor. Power supplied at a low lagging power factor requires a larger current than is necessary for the same power at a higher power factor. A large cable (and therefore larger and more expensive switchgear and transformers) is needed to carry the current, and therefore the capital required by the utility to supply power is higher and charges to the consumer increase accordingly. Therefore consumers install equipment to correct the power factor, viz:

(a) Static capacitors
(b) Phase advancer
(c) Synchronous motors

The metering equipment involved in measuring the power factor variation would include kilovolt-ampere and kilowatt-hour meters.

Rising Mains Busbar System:
Rising mains bus bar systems are frequently used for vertical rising mains power distribution. They are rarely encountered in industrial plants except for flatted factory units and multi-storey buildings. The system comprises copper or aluminium bus bars of capacities of 100A to 800A with two, three or four conductors. These are usually metal clad and are made in various lengths up to 4 meter sections. All insulated rising bus bar systems are also available.

Tap-off boxes with fuse links or fuse switches are provided for distribution to various distribution boards. The fuse switches can be of various maximum current ratings from 20A to 800A in SPN, DP, TP and TPN configurations, the fuses used are generally of HBC or circuit breaker types.

Distribution Boards
Definition: A unit comprising one or more protective devices against over current and ensuring the distribution of electrical energy to the circuits.

Distribution boards are normally selected to provide plenty of wiring space and with terminals of adequate size to accommodate the cables, which will be connected to them. This is to ensure that when larger than would normally by required cables are installed, in order to limit voltage drop, they would be adequately accommodated.

Types of Distribution Boards

There are three types of distribution boards, segregated by the way it is clearing the short circuit, namely:

(i) Those fitted with rewire-able fuse links
(ii) Those fitted with HBC (high breaking capacity) or HRC fuse links
(iii) Those fitted with miniature circuit breakers

i) The rewire-able fuse is now rarely used for main distribution boards as the most common case of overheating and breakdown of switchgear is due to the fittings of incorrect sizes of fuse wire. It is unreliable as it deteriorates, due to oxidation and scaling, resulting in a reduction of its carrying capacity. Other disadvantages include a low rupturing capacity and cannot be relied upon to clear heavy faults. The only advantage it has is its relative cheapness. It costs practically nothing to renew.

ii) Distribution boards fitted with HRC fuse links are popular as they give discriminate protection against over current and will also clear short-circuit currents rapidly and safely up to their rated capacity. This means that the fuse will blow off if the current (or load) increases the rating. The time of blowing (or the time it can sustain the over load) is inversely proportional to the extent of over load. Higher the current, faster it clears the fault. In case of short circuit, the current is very high and hence the time required to clear this short circuit fault is very less. (It is almost instantaneous)

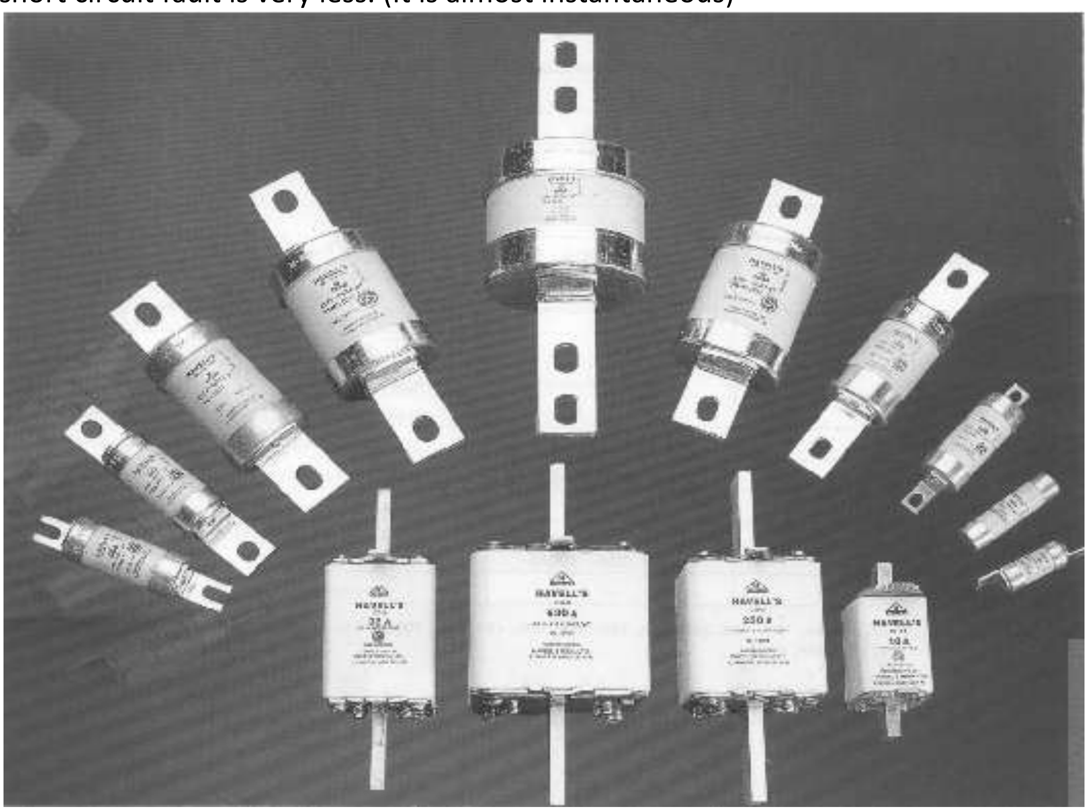


Fig: Various Types of HRC Fuse Links

HRC fuse links, are designed so that they will withstand as much as 10 times full load current for a few seconds, by which time the fault will probably be cleared by a final circuit protective device or a local control gear. When main HRC fuses are carefully selected and graded so as to function with discrimination, the final circuit protective device will take care of all normal overloads and main HRC fuse will operate only when the short circuit is of such magnitude that there is possibility of a dangerous build up of a heavy short circuit current, or in the event of cumulative load of the final circuits exceeding the rating of the main fuses.

iii) Distribution boards fitted with miniature circuit breakers are more expensive in their initial cost, but, they have much to commend them, especially as they can incorporate an earth leakage trip.

Modern circuit breakers are designed to handle safely, heavy short circuit currents in the same manner as HRC fuses. The circuit breaker has several advantages over any type of fuse. Briefly these are:

1. In the event of an overload or fault, all poles are simultaneously disconnected from the supply.
2. Some types are capable of remote control by means of emergency stop buttons
3. Some types have overloads capable of adjustment within proper limits
4. Circuits can be closed again quickly
5. They can be used in place of switches to control lights

Miniature circuit breakers are obtainable in ratings from 0.5A to 60A, all of which are of the same physical size, and are therefore, easily interchangeable (not to be interchanged without ensuring that the cables they protect are of the correct rating).

Distribution boards can be classified into four configurations, namely:

(i) single pole and neutral (SPN)
(ii) double pole (DP)
(iii) triple pole (TP)
(iv) triple pole and neutral (TPN)

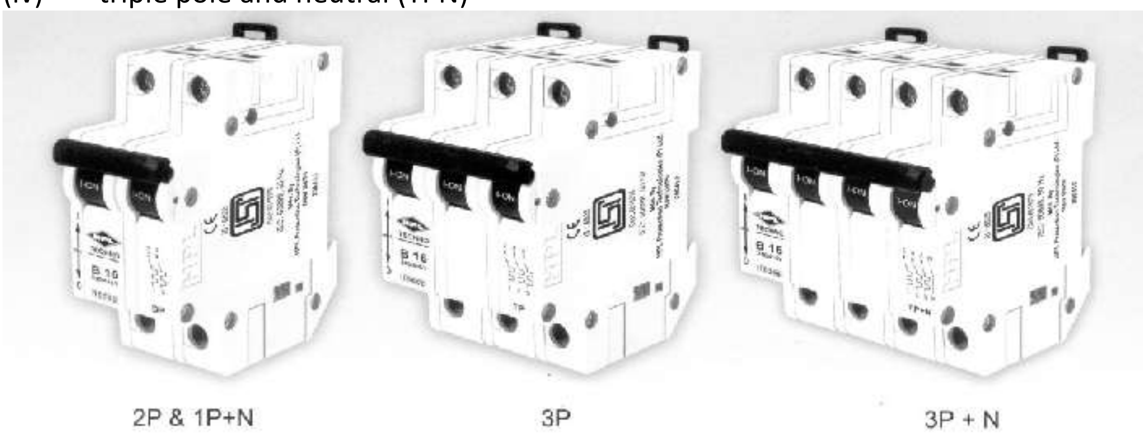


Fig: Miniature Circuit Breakers

Within each of these configurations, the number of ways available in it can further describe by the number of ways available in it and the maximum rated current per way. The distribution boards can be described, for instance in "___ way x ___ Amp triple pole and neutral distribution board".

The fuse boards cover a range from 20A to 200A: The 20A and 32A up to 12 ways in SPN, DP and TPN configurations; 63A up to 10 way, 100A up to 8 way in SPN and TPN configurations; and 200A up to 6 ways in TPN only.

From the distribution boards, cables are drawn to feed various motors that drive various machines and the means of isolation could be either the switch fuses in the distribution boards or isolator boxes or switches at the motors. Isolators are important for the purpose of mechanical maintenance, as it ensures that all voltage is cut off from the machine, which is being worked on.

EXERCISE:

1. Explain the working principle and application of the following :
   a. Switchgear Breaker
   b. Unit s/s
   c. Motor Control Centre (MCC)
   d. Transformer
   e. Types of switch boards
2. What is Power factor Correction ? Why it is done ?
3. Describe all three types of Distribution boards.
4. Explain the advantages of circuit breaker over fuse.
5. What is MCB?

BATTERY & BATTERY CHARGER:

In an electrical s/s, DC supply is used as a control supply for switchgear. The main idea of having separate ind independent supply is to cope an eventuality of total power failure. If control supply is taken from normal supply then at the time of emergency we may not get any power to restore back the supply.

Introduction:

Station battery charger is used to supply the control power to the electrical switch gear like breakers, etc. which need the DC supply for its operation and in case of failure of electrical power the control power continue to be fed by the battery. Generally when the electrical power is available, the charger develops DC power through rectifier and feeds the load and at the same time it also keeps battery in charging, thus maintaining the battery healthy.

Charging Equipment:

Battery charging equipment consists of
1) Float Charger & 2) Boost charger

Battery charging equipment comprises of float charger and float cum boost charger. Float charger is one which keeps the charged battery in healthy condition by supplying small amount of charge to the battery. It also feed to the DC load (or station load)

Float cum boost charger has two modes of operation, constant voltage mode and constant current mode. In constant voltage mode it works as float charger and in constant current mode it works as boost charger. After getting battery discharged during input power failure, when AC power is restored, the battery needs to be charged. Boost charging is being done off line. For charging the battery or when giving equalizing charge to the battery, float cum boost charger is used in its constant current mode. During boost charging the battery tap which is connected the load through a blocking diode maintains DC continuity on load, in case of failure of input power while batteries are on boost charging, float charger is also kept `ON'. Float charger supplies the station load.

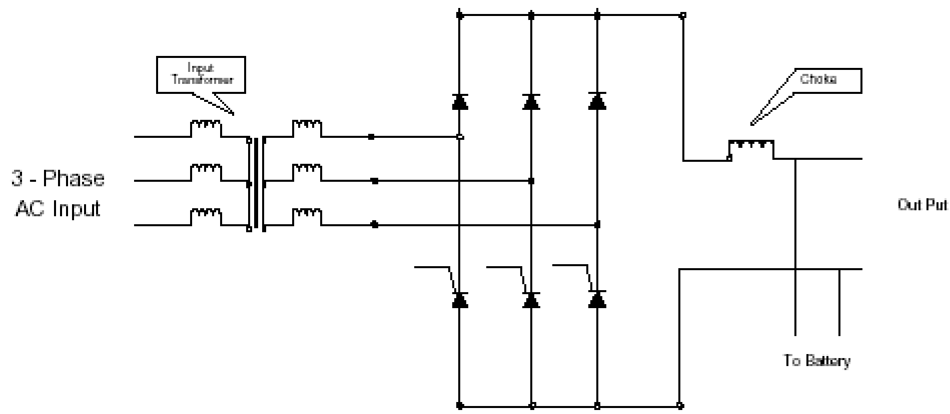
Basically there are two types of rectifiers used in the battery charger. Namely:
□□Full-wave half controlled rectifier. & □□Full-wave fully controlled rectifier.

We will try to understand some basic working of the charger. Though an effort is made to explain in as simple a way as possible, due to basic electronics involved, it may be difficult for a student who do not have a science background, to understand it. As a valuer, the in side working knowledge is surely helpful in analysys, however, lack of it will not be a hindrance.

Full Wave Half Controlled Rectifier:

In half controlled rectifier 3 nos. SCRs and 3 nos. Diodes are used for 3 phase rectifier bridge. Similarly in 1 phase rectifier bridge 2 nos. SCRs and 2 nos. Diodes are used. In half controlled rectifier bridge one half cycle cannot be controlled and thus control is limited to some extent.

3 - Phase Full wave Half Controlled Rectifier



3.1 Operation of three phase Full-Wave Half controlled rectifier Bridge

When the charger is connected to the an appropriate AC voltage source, the voltage is connected to the primary of the main transformer through a 3 pole contactor and fuses or 3 pole circuit breaker. The transformer steps the voltage up or down as required for the specific DC output voltage and provides galvanic isolation between battery and input supply. The transformer's secondary is connected to the full wave bridge rectifier assembly.

The bridge is the heart of the power circuit. This assembly is a standard three phase full-wave half controlled silicon bridge. The voltage control is accomplished by the application of a positive pulse to the gate terminals of the SCR at the desired time. Before the "pulse" is applied, the SCR is "open", and no current flows in the circuit. However, as soon as the SCR is fired, it operates as a standard silicon diode until the forward current is reduced to almost zero. Charger output control can therefore be accomplished by changing the firing angle.

The bridge rectifier provides a variable DC voltage at its output.

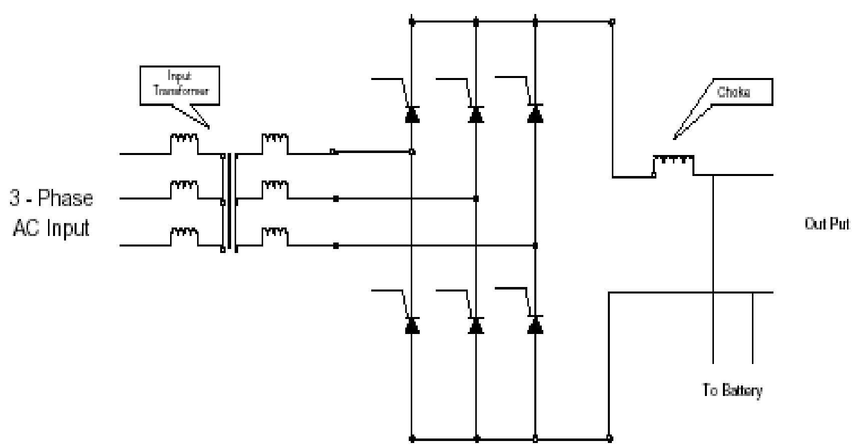
The quick acting fuse protects the bridge in case of accidental short circuits at the output.

The different function, protection and sensing is done by various electronics circuits for the proper functioning of the charger. The general description and constructional detail are given below.

Protection:
The charger is protected by the following:
* AC input fuses. * AC input overload relay. * DC output fuse (or Breaker)
* AC surge suppresser. * Snubber.(RC circuit) * Automatic current limiting.
* Reverse battery protection.

Fully Controlled Rectifiers:
In full controlled rectifier 6 nos. SCRs are used for 3-phase rectifier bridge. Similarly in 1 phase rectifier bridge 4 nos. SCRs are used. In full controlled rectifier bridge both the cycles can be controlled and hence better regulation is possible. So normally full controlled rectifiers are used for the applications where the accuracy is main criteria. Also better ripple reduction is possible in fully controlled rectifier than the half controlled rectifier.

3 - Phase Full wave Full Controlled Rectifier



SCR Controllers for 3 phase Fully Controlled Bridge:
This controller is designed for complete control of the fully controlled SCR bridge rectifier consisting of six SCRs (Thyristors)

The controller senses both the voltage and current of the bridge rectifier, processes both these signals and provides appropriately phase shifted trigger pulses for the six thyristors, so that the required control is achieved.

Float Charger:
The charger is fed from three phase, AC supply and gives a DC stabilized output at rated full load current. The float charger is used to maintained the battery in charged condition. The out put voltage of the float charger is slightly higher then the battery, so very small current will continuously flow through the battery and keep the battery charged.

Boost Charger:

During power failure, the load is fed from battery and as a result the same gets drained. To bring the battery to its normal "ready to meet next emergency " mode we have to give additional charge to battery. Boost Charger does this boosting of the charge. Here the out put voltage of the charger is considerably higher and hence the battery gets back to normal in a short time.

In the event of the float charger going defective, the boost charger will take over the load in constant voltage mode. During transition period battery will supply the load.

Battery:

There are two types of battery cells:

- Primary Battery &
- Secondary battery

Primary Battery:

Primary battery is basically zinc-anode base system. Recently significant advances in energy density have been achieved, together with improvement in other areas like as low temperature performance and storage capability, through the development of lithium - anode-based systems and Specialist couples using anodes materials such as cadmium, magnesium and indium-bismuth.

There is no battery system that has every advantage over all the other system, and therefore a procedure for selecting the most suitable system is necessary. The factors involved in selection of primary batteries suitable to meet a particular requirement are extremely complex. So it is essential to consult manufacturer to ensure that the characteristics of the battery and equipment are matched so that the user of the equipment obtains the best possible performance from both.

There are three basic applications for which primary batteries are used:

- Miniature equipment.
- Equipment that is portable in use.
- transportable equipment and standby systems.

Secondary Battery:

In order to increase gravimetric density, the gravimetric and volumetric densities, the open circuit and on load cell E.M.F values and the minimum and maximum operating temperature secondary batteries are used. Following are the various batteries used.

- Sealed lead acid.
- Unsealed lead acid.
- Silver cadmium.
- Sealed nickel cadmium.
- Vented nickel cadmium.
- Nickel zinc.
- Alk mg rechargeable.
- Silver zinc.
- Nickel hydrogen.
- Silver hydrogen.
- Zinc chlorine.
- Zinc air.
- Sodium sulfur.
- Lithium-chlorine.
- Lithium-sulfur.

Out of these, two types of secondary rechargeable batteries, which are lead -acid and nickel-cadmium, are generally used in the industries.

The lead acid battery is a primary cell. The rubber or SAN container is filled with sulphuric acid. The active material in negative electrod is metallic lead in spongey form and the in positive electrod is lead dioxide. These electrodes are placed alternatively in the container. Due to the chemical reaction between the acid and the lead, the flow of electron is established.

Characteristic Voltage:
The nominal voltage of the lead acid cell is 2.0volts, which remains unaltered by the number of plates or their capacity. In practice, the voltage of a cell does vary slightly according to the state of the charge, the cell temperature, the charge or discharge current, and the age of the cell.

Capacity:
The capacity of the battery will vary according to current at which it is discharged. The higher the current being taken out of the battery, the lower the available capacity. For example, if a battery of 500AH capacity ids discharged at the 5hour rate, it will give 100 amperes for 5 hours. The same battery discharged at 200 amperes, however, will give current for only 2 hours, thereby providing capacity of 400 AH at the 2hour rate of discharge. This is because, at higher rate, the voltage drop is more rapid and the final voltage is reached more quickly.

Maintenance Free Lead Acid Battery:
Any battery, when overcharged, will liberate hydrogen and oxygen gases as water is decomposed. For a battery to be maintenance free, it is necessary to retard gas liberation, otherwise the electrolyte would be depleted prematurely and catastrophic failure would result. There are two principles types of maintenance free Lead Acid battery.

1) The type featuring calcium lead alloys and immobilized Sulphuric acid electrolyte, which reduces but does not completely eliminate gassing, i. e. there is electrolyte volume reduction. Such cells are usually manufactured containing a reserve of electrolyte so that topping up is not required during battery life.

2) The type in which complete recombination of electrolysis gases occurs,i.e. virtually no electrolyte loss occurs.

Nickel Cadmium (NiCd) Battery:
Normally now a days using Nickel Cadmium pocket plate battery for AC and DC UPS and Vented type Lead Acid type battery for station battery charger has become a practice.

The storage battery consists of a number of individual cells connected in series to produce the required voltage. Each cell contains positive plates (containing nickel hydroxide as the active constituent) and negative plates (containing cadmium hydroxide) immersed in a solution of potassium hydroxide in deionised water with lithium hydroxide as an additive. The voltage produced is dependent upon the chemical composition of the active materials contained in the plates. In the nickel cadmium cell the active constituents are cadmium in the negative plates and nickel in the positive plates. The electrolyte is a solution of potassium hydroxide in deionized water with lithium hydroxide as an additive. Low impurity content is specified to minimize losses and the constituent parts of the positive and negative electrodes are insoluble in the electrolyte. The resulting electrochemical reaction produces a nominal discharge voltage of 1.2 volts per cell.

Advantages:

The major advantages of pocket plate nickel cadmium batteries are total reliability combined with extremely long life. This superiority is due to chemical and mechanical characteristics unique to pocket plate nickel cadmium batteries. Nickel cadmium batteries can withstand electrical abuse to a very high degree. They can be deep discharge,

- Over charging even for a pro-longed period, is tolerated by nickel cadmium batteries.
- The high rate performance of nickel cadmium batteries is excellent, and the voltage recovery after high power discharge is almost instantaneous.

The mechanical strength of nickel cadmium batteries is unsurpassed. The reason is the all steel internal construction and the high impact plastic or steel used in the container.

- The support material in nickel cadmium batteries is corrosion free. Thus these batteries do not suffers from the problem of sudden death, which is the usual end of life for most other types of industrial batteries.
- The end of the life cycle of nickel cadmium batteries is predictable. The aging process is very slow and is determined by slightly decreasing performance that allows the user to plan battery replacement years ahead.

Applications:

The nickel cadmium pocket plate battery is available in different designs optimized with regard to the required discharge time. Though these batteries are much costlier then Lead acid battery, due to its reliability it is widely used in critical applications like control supply for switch gear system, emergency lighting, telecommunication & fire alarm systems.

EXERCISE:

1. Explain Trickle (or Float) and Boost charging in a battery.
2. What is meant by Primary battery? List the basic application of primary battery.
3. Describe the construction and electro chemistry of lead acid battery.
4. What is MF (Maintenance Free) battery? List the types of MF battery.
5. What is meant by characteristics voltage of a lead acid battery?
6. Explain NiCd battery giving advantages.

THE PHILOSOPHY OF PROTECTIVE RELAYING

What is Protective Relaying?

We usually think of an electric power system in terms of its more impressive parts–the big generating stations, transformers, motors, high-voltage lines, etc. While these are some of the basic elements, there are many other necessary and fascinating components. Protective relaying is one of these.

It is evident that in spite of all the precautions taken during design and installation of the system, there is every possibility of arising of an abnormal conditions or faults, some of which like short circuit may prove extremely damaging to not only the faulty component but to the neighboring components and to the power system as a whole. It is of vital importance to limit the damage to a minimum by speedy isolation of the faulty section, without disturbing the working of the rest of the system.

The role of protective relaying in electric-power-system design and operation is explained by a brief examination of the over-all background. There are three aspects of a power system that will serve the purposes of this examination. They are

A. Normal operation
B. Prevention of electrical failure.
C. Mitigation of the effects of electrical failure.

The term "normal operation" assumes no failures of equipment, no mistakes of personnel, nor "acts of God." It involves the minimum requirements for supplying the existing load & a certain amount of future load. Some of the considerations are:

The provisions for normal operation involve the major expense for equipment and operation, but a system designed according to this aspect alone could not possibly meet present-day requirements. Electrical equipment failures would cause intolerable outages.

Faults:

The flow of current towards an undesirable path or abnormal stoppage of current are termed as fault. As mentioned earlier these faults may prove extremely damaging for the faulty components and also to the neighboring components. Faults can also cause interruption in power supply to other equipment.

There must be additional provisions to minimize damage to equipment and interruptions to the service when failures occur. Two recourses are open:

(1) to incorporate features of design aimed at preventing failures, and
(2) to include provisions for mitigating the effects of failure when it occurs.

Modern power-system design employs varying degrees of both recourses, as dictated by the economics of any particular situation. Notable advances continue to be made toward greater reliability. But also, increasingly greater reliance is being placed on electric power. Consequently, even though the probability of failure is decreased, the tolerance of the possible harm to the service is also decreased. But it is futile-or at least not economically justifiable-to try to prevent failures completely. Sooner or later the law of diminishing returns makes itself felt. Where this occurs will vary between systems and between parts of a system, but, when this point is reached, further expenditure for failure prevention is discouraged. It is much more profitable, then, to let some failures occur and to provide for mitigating their effects.

The type of electrical failure that causes greatest concern is the short circuit, or "fault" as it is usually called, but there are other abnormal operating conditions peculiar to certain elements of the system that also require attention. If we disconnect or isolate the faulty system in a fast manner, the damage can be limited.

Features for promptly disconnecting the faulty element.

1. Protective relaying.
2. Circuit breakers with sufficient interrupting capacity.
3. Fuses.

Thus, protective relaying is one of several features of system design concerned with minimizing damage to equipment and interruptions to service when electrical failures occur.

The Functions Of Protective Relaying:

The function of protective relaying is to cause the prompt removal from service of any element of a power system when it suffers a short circuit, or starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. The relaying equipment is aided in this task by circuit breakers that are capable of disconnecting the faulty element when they are called upon to do so by the relaying equipment. Circuit breakers are generally located so that each generator, transformer, bus, transmission line, etc., can be completely disconnected from the rest of the system. These circuit breakers must have sufficient capacity so that they can carry momentarily the maximum short-circuit current that can flow through them, and then interrupt this current; they must also withstand closing in on such a short circuit and then interrupting it according to certain prescribed standards.

Fusing is employed where protective relays/circuit breakers are not economical. Although the principal function of protective relaying is to mitigate the effects of short circuits, other abnormal operating conditions arise that also require the services of protective relaying. This is particularly true of generators and motors.

To sum up the above, we can say that the protective relaying system should sense the fault and perform following four functions:

1. To operate the correct circuit breakers so as to disconnect only the faulty equipment from the system as quickly as possible thus minimizing the trouble and the damage caused by faults when they do occur.
2. To operate the correct circuit breakers to isolate the faulty section from the healthy system
3. To clear the fault before the system become unstable.
4. To give indication as to where the fault has occurred.

Let us consider for the moment only the relaying equipment for the protection against short circuits.

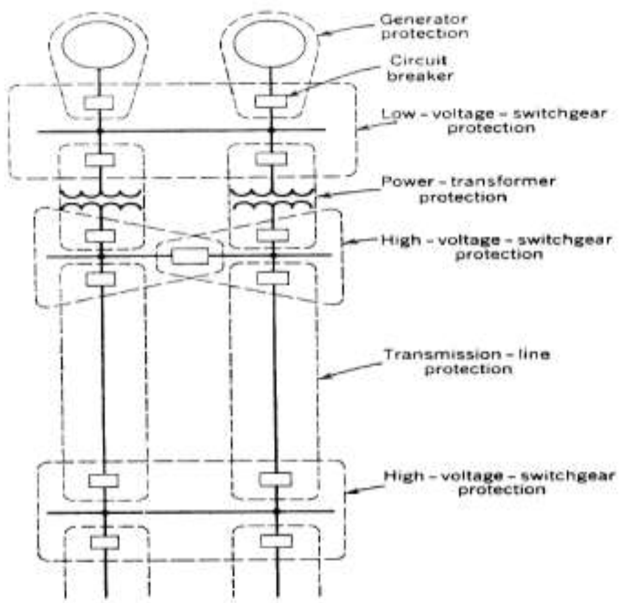


Fig. 1. One-line diagram of a portion of an electric power system illustrating primary relaying.

Figure 1 illustrates relaying. The first observation is that circuit breakers are located in the connections to each power element. This provision makes it possible to disconnect only a faulty element. Occasionally, a breaker between two adjacent elements may be omitted, in which event both elements must be disconnected for a failure in either one.

Finally, it will be observed that adjacent protective zones of Fig. 1 overlap around a circuit breaker. This is the preferred practice because, for failures anywhere except in the overlap region, the minimum number of circuit breakers needs to be tripped. When it becomes desirable for economic or space-saving reasons to overlap on one side of a breaker, as is frequently true in metal-clad switchgear the relaying equipment of the zone that overlaps the breaker must be arranged to trip not only the breakers within its zone but also one or more breakers of the adjacent zone, in order to completely disconnect certain faults.

Primary & Back up Relaying:
Main or primary protective schemes are used as the first line of defense. There must be a second line of defense, which will clear the fault in the eventuality of failure of primary system to do it due to any reason.

Though technically possible, normall back-up relaying is employed only for protection against short circuits. Because short circuits are the preponderant type of power failure, there are more opportunities for failure in short primary relaying. Experience has shown that back-up relaying for other than short circuits is not economically justifiable. It is highly desirable that back-up relaying be arranged so that anything that might cause primary relaying to fail will not also cause failure of back-up relaying. It will be evident that this requirement is completely satisfied only if the back-up relays are located so that they do not employ or control anything in common with the primary relays that are to be backed up. So far as possible, the practice is to locate the back-up relays at a different station.

Requirements of Protective System:

1. **Reliability:** That protective-relaying equipment must be reliable is a basic requirement. When protective relaying fails to function properly, the allied mitigation features are largely ineffective. Therefore, it is essential that protective-relaying equipment be inherently reliable, and that its application, installation, and maintenance be such as to assure that its maximum capabilities will be realized. Inherent reliability is a matter of design based on long experience, and is much too extensive and detailed a subject to do justice to here.

2. **Selectivity:** This is the property by which only the faulty element of the system is isolated and remaining healthy system are left intact.

3. **Speed:** It is obvious that faster the speed of operation of elements of the protective system (relay and breakers) less is the damage to the equipment. As such the equipment are short time rated for high fault currents and therefore there will be practically no damage to the equipment if the relay and breakers operate fast enough. The time setting of the relay has to be decided on the basis of this short time ratin of the equipment to be protected.

4. **Discrimination:** Protective system should be able to discriminate between fault and load conditions even when the minimum fault current is less then the maximum load current. A relay must be able to distinguish between a fault and an overload.

5. **Stability:** It is the quality of protective system by virtue of which it remains inoperative under specified conditions associated with high value fault current. i.e. it has to remain inoperative under what ever condition of fault current, if the fault is out side their own zone.

6. **Sensitivity:** Sensitivity refers to the minimum level of fault current at which the operation occurs.

Fundamental Relay – Operating Principles:

Protective relays are the "tools" of the protection engineer. As in any craft, an intimate knowledge of the characteristics and capabilities of the available tools is essential to heir most effective use. Therefore, we shall spend some time learning about these tools

General Considerations:

All the relays that we shall consider operate in response to one or more electrical quantities either to close or to open contacts. We shall not bother with the details of actual mechanical construction except where it may be necessary for a clear understanding of the operation. One of the things that tend to dismay the novice is the great variation in appearance and types of relays, but actually there are surprisingly few fundamental differences. Our attention will be directed to the response of the few basic types to the electrical quantities that actuate them.

Operating Principles:

There are really only two fundamentally different operating principles: (1) electro- magnetic attraction, and (2) electromagnetic induction. Electromagnetic attraction relays operate by virtue of a plunger being drawn into a solenoid, or an armature being attracted to the poles of an electromagnet. Such relays may be actuated by d-c or by a-c quantities. Electromagnetic-induction relays use the principle of the induction motor whereby torque is developed by induction in a rotor; this operating principle applies only to relays actuated by alternating current.

Definitions Of Operation:

Mechanical movement of the operating mechanism is imparted to a contact structure to close or to open contacts. When we say that a relay "operates," we mean that it either closes or opens its contacts-whichever is the required action under the circumstances. Most relays have a "control spring," or are restrained by gravity, so that they assume a given position when completely de-energized; a contact that is closed under this condition is called a "closed" contact, and one that is open is called and "open" contact. When a relay operates, we say that it "picks up," and the smallest value of the actuating quantity that will cause such operation, as the quantity is slowly increased from zero, is called the "pickup" value. When a relay operates to close, or to move to a stop, we say that it "resets"; and the largest value of the actuating quantity at which this occurs, as the quantity is slowly decreased from above the pickup value, is called the "reset" value.

Operation Indicators:
Generally, a protective relay is provided with an indicator that shows when the relay has operated to trip a circuit breaker. Such "operation indicators" or "Flags" are distinctively colored elements that are actuated either mechanically by movement of the relay's operating mechanism, or electrically by the flow of contact current, and come into view when the relay operates. They are arranged to be reset manually after their indication has been noted, so as to be ready for the next operation. Electrically operated flags are generally preferred because they give definite assurance that there was a current flow in the contact circuit. Mechanically operated flags may be used when the closing of a relay contact always completes the trip

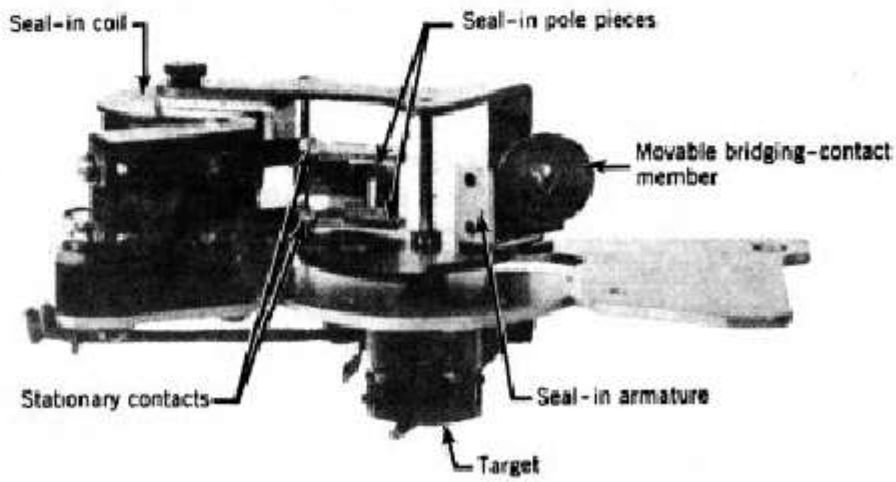


Fig: Contact element showing target & seal in arrangement.

Protective Device Numbering:
Every protective relay has an associated number. These are unique numbers and are adopted universally. Some of the standard designated numbers are: Over Current Relay – 51, Under Voltage Relay – 27, Time Delay Starting – 2, Interlocking Relay – 3, Over Speed Device – 12 etc. There are 94 numbers already allotted (with provision for future use). The number 95 to 99 is for specific use when none of the pre designated match.

Static & Microprocessor Relays:
Electromechanical relays have a long history of application. They are very rugged and reliable. They are still used in power system protection. But as these system have moving parts, there are problems of friction, wear & tear, low torque, high power consumption (for auxiliary relay) etc. With the advent of IC & chips, the static protective relays are coming up very fast. They have many advantages like low burden, precise, compact size etc. The only prohibitive factor is the cost.

It costs nearly 50 % higher at present, however like any other electronic device, the cost is bound to reduce over a period of time, when it may take over the entire protective functioning.

EXERCISE:

1. Describe the Function of Protective Relaying
2. What is meant by “Normal operation of a system “ when we are talking about the protection ?
3. What are the Features for prompt disconnection of an faulty element?
4. What does Primary OR Secondary Relaying mean? Explain with illustrative figure.
5. Describe the operation of a Induction Type of Relay.
6. Detail the General Consideration of protection.
7. What are operation indicators? How does it help the user?

In this chapter so far we have tried to understand the basic technology of electrical engineering i.e. from what is electricity to how it is generated & distributed. We have also seen how the protection system works. Now we move forward and will try to understand the means of power flow i.e. cables, the basic machine or the prime mover without which the industry will come to a stand still i.e. motors and its drives. At the end we shall see some of the essential statutory compliance for electrical installations.

TRANSMISSION OF POWER

Cabling & Wiring:

Having generated a power in a generating station, it has to be transmitted to the user. As seen earlier, the electricity boards (or distribution company) transmit this power from generating stations to the actual user. This transmission of power is normally done with overhead conductors. These o/h conductors are laid on steel / RCC towers. The conductors in this o/h system are generally un insulated. This is the reason why the tower height increases with higher voltage level.

As a plant engineer, we shall be concentrating on the distribution of power within the complex. The power within the complex is generally transmitted through cables.

What is CABLES?

Cables are current carrying conductors. Various types of insulated compound insulate this conductor. Some times, steel wire layer protects insulation & conductor. This is called as ARMOURING. While selecting a cable, one has to select the type of insulation and the material of conductor. Various factors play an important role in selection of the cable. A careful consideration is to be given to following factors:

Power Cable :

Following are some of the key factors that influence the choice of power cable:

- System voltage rating.
- Current loading requirements.
- External thermal conditions such as ambient temperature, proximity of other cables, adjacent sources of heat, thermal conductivity of soil, etc.
- Voltage drop considerations.
- Special conditions, such as the presence of corrosive agents, flexibility, and flame resistance.

Voltage Rating

The system voltage on which the cable is to operate determines the required cable voltage rating. Cables rated 5 kV and above are separated into two classifications: grounded neutral service (100 percent insulation level), and ungrounded neutral service (133 percent insulation level). In case of a phase to ground fault, it is possible to operate ungrounded systems for up to one hour with one phase conductor at ground potential. This condition results in full line-to-line voltage stress across the insulation of each of the other two-phase conductors. For this reason each phase conductor of such a cable has additional insulation.

Cables designed for use on grounded systems take advantage of the absence of this full line-to-line voltage stress across the insulation and use thinner insulation. The direct result of such a design is lower cost & reduced cable diameter.

Conductor Size

Conductor size is based principally on three considerations:

- Current-carrying capacity (ampacity).
- Short-circuit current.
- Voltage drop.

Primarily the permissible operating temperature of its insulation affects the current-carrying capacity of a cable. Higher the operating temperature of the insulation, the higher the current carrying capacity of a given conductor size.

The temperature at which a particular cable will operate is affected by the ability of the surrounding material to conduct away the heat. Therefore, the current-carrying capacity is materially affected by the ambient temperature as well as by the installation conditions.

When cables are run close together the presence of the other cables, in effect, increases the ambient temperature, which decreases the ability of the cable to dissipate its heat. As a result, many conditions must be known before an accurate current-carrying capacity can be assigned to a particular cable installation.

Short Circuit Current

A second consideration in selection of conductor size is that of the short circuit current which the cable must carry. The construction of cable is such that its mechanical strength is high and it can handle short-circuit currents without any mechanical difficulty. From a thermal standpoint, however, there is a limit to the amount of short-circuit current which can be carried.

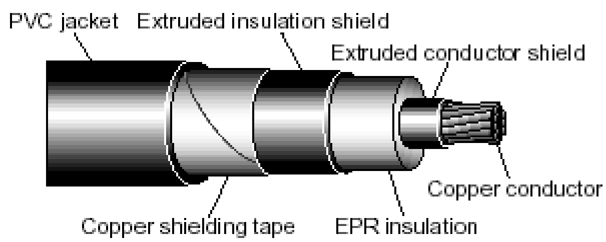


Figure 1–Typical tape shielded 11 kV power cable

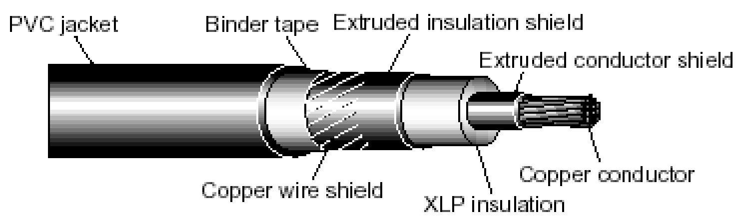


Figure 2–Typical wire shielded 11 kV power cable

Voltage Drop Considerations

Cable conductor size is sometimes governed by voltage drop rather than by heating. Generally, conductor size on long, low-voltage lines is governed by voltage drop; on short, high-voltage lines by heating. Due to voltage drop considerations, it might be necessary to increase conductor size, even though a smaller size conductor adequately handles the current load.

Special Conditions

The following are only a few of the many special conditions, which may affect cable selection:

• The presence of large sources of heat (boilers, steam lines, etc.).

In conditions where ambient temperature is higher (Boilers, Furnace room eyc.), special heat resistant insulation is used such as Mineral or Butyl or Silicon.

• The effect of magnetic materials such as pipes or structural members close to large cables carrying heavy current loads.

In such a condition, magnetically screened cables are used to eliminate the effect of magnetization.

• The presence of corrosive reagents in the soil or other locations in which the cable is installed.

In conditions where the cables are exposed to corrosive atmosphere like acids or alkalis, the insulation is selected to be of PVC.

• The interference that may occur in telecommunication circuits because of adjacent power cables.

To avoid interference, copper screened cables are used.

• Flame and radiation resistance.
• Mechanical toughness.

For mechanical strength armoured cable is used.

• Moisture resistance.

For humid area, PVC / or MI/PVC cable is used.
All special conditions should be carefully investigated, and the advice of competent engineers obtained, before proceeding with an important cable installation.

Cable with Aluminum Conductors
Multi core, sheathed cables with Aluminum conductors is sometimes used instead of copper conductors, as they are cheap and not very heavy. The current carrying capacity of Al conductor is 78% of the rating for copper conductors. Thus the size of an Aluminum cable will be higher then the copper one for same current rating.

The use of aluminum conductors presents some problem, which require certain precautions to be taken. Aluminum, when exposed to air, quickly forms an oxide film which is a poor conductor of electricity, If allowed to remain, this can cause a high resistive joint and may result in overheating and eventually failure of cable. The second problem is due to different co-efficient of thermal expansion of Aluminum and copper. This causes problem when the two metals are joined with each other.

Armored Power and Control:

Armored cables comprise a group of cables that are designed to withstand severe mechanical and chemical environments. Armour PVC insulated cables are now being used very extensively for main and sub main cables and also for wiring in industrial installations. The armour are a galvanized steel wire protective layer under the outer insulation. This protects the conductor from external abuse. Their advantages over earlier PILC (Paper Insulated Lead Cover) are that:

- They are more pliable.
- They can be bent to a radius of 8 times the diameter as compared to 12 times in PILC cables.
- They are much lighter and easier to handle and the sealing of the end is much simpler.

Their main disadvantages are that:

- Thermoplastic insulation will sustain serious damage if subject to a prolonged exposure to temperature above 70* C.
- The insulation will become harden and brittle in temperature below 1* C and in freezing temperature the insulation may split.

Paper Insulated Lead Cover (PILC) Cables:

Paper Insulated Lead Cover Cables are generally protected by steel tape or steel wire armouring and served overall with hemp or PVC. The serving protects the steel armouring against oxidation and corrosion.

Mineral Insulated (MI) Cables:

These cables have an insulation of highly compressed magnesium oxide (MgO) powder between copper core and sheath. Generally MI cables need no additional protection as copper is corrosion resistant.

Cross Linked Poly Ethylene (XLPE) Cables:

With advancement in the insulation and hydrocarbon industry, a new compound named Cross Link Poly Ethylene is widely used in cable industry. This XLPE cables have an advantage of high temperature withstand capacity. This gives advantage in cable rating. A similar cross section of conductor can safely carry higher current in XLPE cables then PVC cables, or in other words, we can use a size lower XLPE cable then PVC cables for a same current. Also, under combined heat and mechanical pressure XLPE suffers less deformation compared to PVC or Paper insulated cables.

EXERCISE:

1. Explain the key factors influencing the selection of a power cable
2. What are the functional advantages of armoured cable ?

MOTORS & VARIABLE SPEED DRIVES

Basic Theory Of Induction Motor:

In many commercial, industrial, and utility applications electric motors are used to transform electrical energy into mechanical energy. Those electric motors may be part of a pump or fan, or they may be connected to some other form of mechanical equipment such as a conveyor or mixer. The electric motors are broadly divided in two types namely DC motors & AC motors.

This division is based on the type of electric supply being fed to the motor i.e. Direct Current (DC) or Alternating Current (AC).

While there are only three general types of DC motors, there are many different AC motor types. This is because each type is confined to a narrow band of operating characteristics. These characteristics include torque, speed, and electrical service (single-phase or polyphase). These operating characteristics are used to determine a given motor's suitability for a given application.

The three-phase motor is probably the simplest and most rugged of all electric motors. To get a perspective on how important the three-phase motor is, all you need to know is that this motor is used in nine out of ten industrial applications

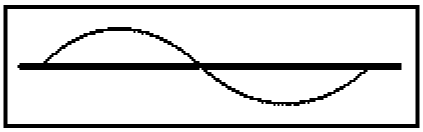
What makes an AC motor different from a DC motor?
In a DC motor, electrical power is conducted directly to the armature through brushes and a commutator. An AC motor does not need a commutator to reverse the polarity of the current, as AC changes polarity "naturally."

Also, where the DC motor works by changing the polarity of the current running through the armature (the rotating part of the motor), the AC motor works by changing the polarity of the current running through the stator. (The stationary part of the motor).

In simple words, what it means is that the construction of AC motor is much simpler then the DC motor.

The many types of AC motor may be split into two main groups: single-phase and polyphase.

Single Phase:
A single-phase power system has one coil in the generator. Therefore, one alternating voltage is generated. The voltage curve of a single-phase AC generator is shown in Figure

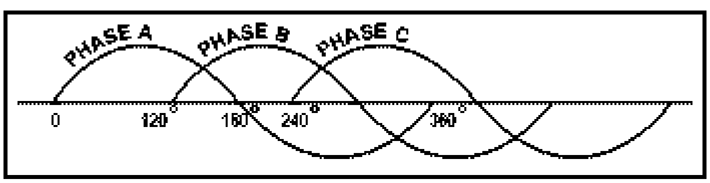


Single-phase motors are generally motors with KW ratings of one or below. (These are generally called fractional KW motors.) They are generally used to operate mechanical devices and machines requiring a relatively small amount of power.

Types of single-phase motors include: shaded-pole, capacitor, split-phase, repulsion, series (AC or universal) and synchronous.

However, the single-phase motor is generally not used because it is inefficient, expensive to operate, and is not self starting.

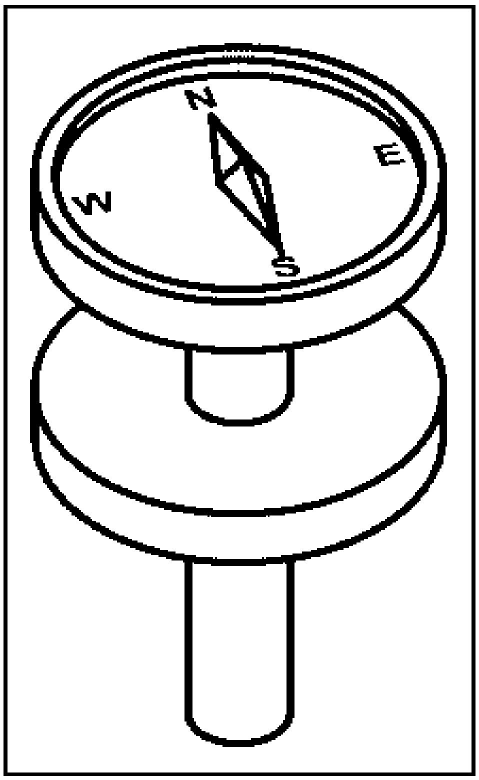
Three-Phase:

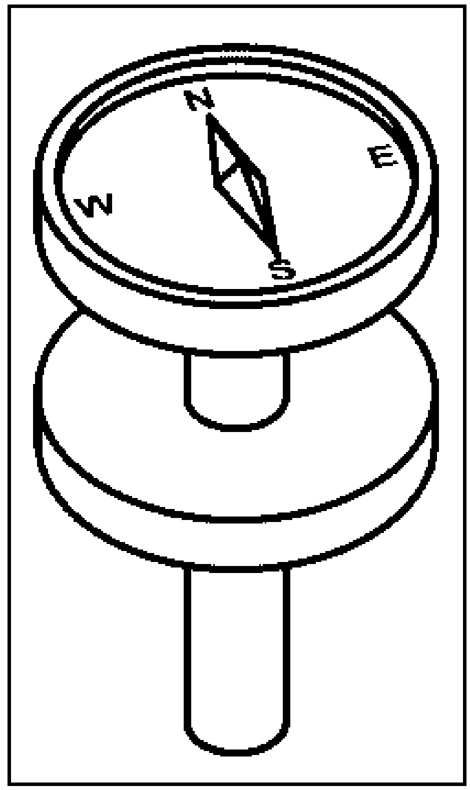


Three-phase or polyphase motors run on three-phase power. A three-phase power system has three coils in the generator. Therefore, three separate and distinct voltages will be generated. The voltage curve is shown in Figure
Types of three-phase motors include: induction (squirrel-cage or wound), rotor types, commutator, and synchronous.

The Squirrel Cage Induction motor:
Induction refers to electrically charging a conductor by putting it near a charged body.

Induction Principle:
Arago first discovered the principle of the induction motor in 1824. He observed that if a non-magnetic metal disk and a compass are pivoted with their axes parallel, so that one (or both) of the compass poles are located near the edge of the disk, spinning the disk will





cause the compass needle to rotate. The direction of the induced rotation in the compass is always the same as that imparted to the disk.

You can prove it to yourself if you like. Mount a simple copper or aluminum disk and a large compass on a vertical stem, so that each may be rotated on its own bearing,

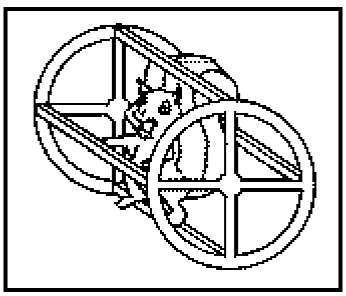
You can prove it to yourself if you like. Mount a simple copper or aluminum disk and a large compass on a vertical stem, so that each may be rotated on its own bearing, independently of the other. Spin the disk, and watch the compass needle. There is no more effective way to demonstrate the principle of induction.

Applying the Induction Principle to AC Motor-
So, how do we apply the concept of induction to a motor?
Recall that the AC motor works by changing the polarity of the current running through the stator (the stationary part of the motor). The stator plays the role of the metallic disk described above. A rotating magnetic field is established in the stator.

The conductor, called the Rotor, “follows” the rotating magnetic field by beginning to rotate, just like the compass needle described above.

The induction motor uses a rotor of a special design. It resembles a cage used for exercising squirrels. This is why it is called a squirrel cage rotor.

The rotor consists of circular end rings joined together with metal bars. Note that the metal bars are placed directly opposite each other and provide a complete circuit within the rotor, regardless of the rotor's position. Rotors normally have several bars, but only a few are shown here for clarity.



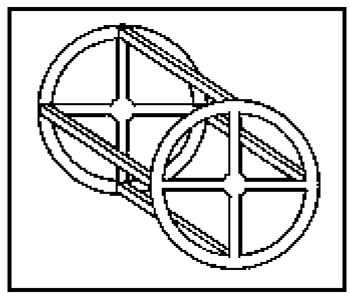


FIGURE: THE ROTOR OF A SQUIRREL CAGE INDUCTION MOTOR

Squirrel cage motors are usually chosen over other types of motors because of their simplicity, ruggedness and reliability. Because of these features, squirrel-cage motors have practically become the accepted standard for AC, all-purpose, constant speed motor applications. Without a doubt, the squirrel-cage motor is the workhorse of the industry.

The Squirrel Cage Induction Motor has certain advantages over the DC motor.

- **There are only two points of mechanical wear on the squirrel cage motor: the two bearings.**
- **Because it has no commutator, there are no brushes to wear. This keeps maintenance minimal.**
- **No sparks are generated to create a possible fire hazard**.

Three- Phase Motor:

An induction motor depends upon an electrically rotating magnetic field, not a mechanically rotating one. (A mechanically rotating field would work, but an electrically rotating magnetic field has significant advantages.) How is an electrically rotating field obtained? It all starts with the phase displacement of a three-phase power system.

Three-phase power can be thought of as three different single-phase power supplies. They are called A, B, and C. In the three-phase motor, each phase of the power supply is provided with its own set of poles, located directly across from each other on the stator, and offset equally from each of the other two phases' poles.

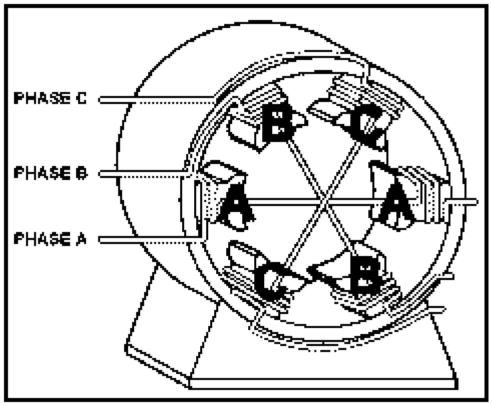


FIG: Three pairs of field coils on the stator, set 120* apart

The three currents start at different times. Phase B starts 120° later than phase A and phase C starts 120° later than phase B. This is shown on the sine wave graph in Figure, which indicates the way the magnetic field will point at various times in the cycle.

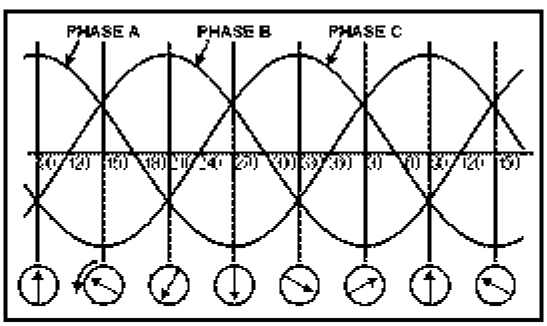


FIG: Magnetic Field Rotation Providing Torque To Turn The Motor

Introducing these different phase currents into three field coils 120° apart on the stator produces a rotating magnetic field, and the magnetic poles are in constant rotation.

The magnetic poles chase each other, simultaneously inducing electric currents in the rotor (generally, bars of copper imbedded in a laminated iron core). The induced currents set up their own magnetic fields, in opposition to the magnetic field that caused the currents. The resulting attractions and repulsions provide the torque to turn the motor, and keep it turning.

If each magnetic pole were to "light up" whenever it was energized, the effect would appear as though the lights were "running" around the stator, much as the lights on some electric signs simulate a running border.

Let's walk through one revolution of the motor to see how it works.
First, the A poles of the stator are magnetized by phase A. Then, the B poles are magnetized by phase B. The rotor turns, due to the induced current. Then, the C poles are magnetized by phase C. The rotor turns, due to the induced current. The rotor has completed one-half turn at this point.

Now, the A poles of the stator are magnetized again, but the current flow is in the opposite direction .

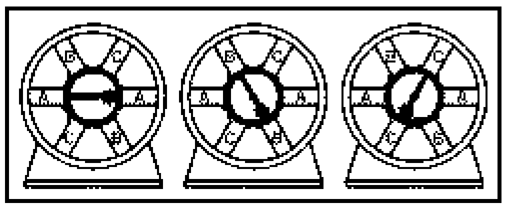
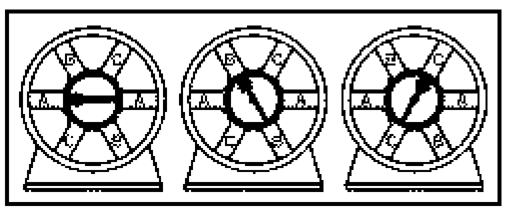


FIG: Rotating Magnetic Field Turns the Motor

This causes the magnetic field to continue to rotate, and the rotor follows. Then, the B poles are magnetized by phase B. The rotor turns, due to the induced current. Then, the C poles are magnetized by phase C. The rotor turns, due to the induced current.



The rotor has completed one full revolution at this point, and the process repeats itself.

Construction Of Three Phase Motors:

The three-phase motor is probably the simplest and most rugged of all electric motors.

All three-phase motors are constructed with a number of individually wound electrical coils. Regardless of how many individual coils there are in a three-phase motor, the individual coils will always be wired together (series or parallel) to produce three distinct windings, which are called phases. Each phase will always contain one-third of the total number of individual coils. As we mentioned, these phases are referred to as phase A, phase B and phase C.

Three-phase motors vary from fractional KW size to several thousand KW. These motors have a fairly constant speed characteristic but a wide variety of torque characteristics. They are made for practically every standard voltage and frequency and are very often Dual Voltage Motors. (We will look briefly at dual voltage motors later.)

Dual Voltage

Many three-phase motors are made so that they can be connected to either of two voltages. The purpose in making motors for two voltages is to enable the same motor to be used with two different power line voltages. Usually, the dual voltage rating of industrial motors is 230/460V. However, the nameplate must always be checked for proper voltage ratings.

When the electrician has the choice of deciding which voltage to use, the higher voltage is preferred. The motor will use the same amount of power, giving the same HP output for either high or low voltage, but as the voltage is doubled (230 to 460), the current will be cut in half. With half the current, wire size can be reduced and savings can be realized on installation.

Speed Control

Speed control is essential in many applications. Mining machines, printing presses, cranes and hoists, elevators, and conveyors, among others, all depend on speed control.

In choosing the speed control method for an application, there are three main factors to consider:

- Type of equipment (load) the motor drives
- Application type
- Motor type

We will discuss each of these factors in turn.
Loads and application types are as varied as the types of motors available. However there are two fundamental motor types: AC and DC. Each type has its own ability to control different loads at different speeds.

In order to select the correct motor type for a given application, it is necessary to understand the load requirements first. To understand these requirements, you need to be familiar with the concepts of force, work, torque, power and KW, and how they relate to speed.

<u>Force, Work and Torque</u>

Work is done when a force overcomes a resistance.

Work = Distance x Force

In the case of an electric motor, force is not exerted in a line, but in a circle, about a cylindrical shaft. As you recall, turning force is called torque .
Torque = Radial Distance x Force

Power and KW

Power takes into consideration how fast work is accomplished. Power is the rate of doing work

Power = Work/Time

The reason for this difference is the amount of work that can be delivered in a given amount of time. Obviously, a larger motor should be able to deliver more work in a given time than one that is considerably smaller. It is this difference that determines the power rating of the motor.
Motors are rated in KW (HP). One KW is equal to 746 watts.

Putting It All Together
Torque, KW, and speed are all interrelated when turning a load. KW is proportional to torque and speed. The following formula ties them all together:

T=974*KW/rated speed

This means that if either speed or torque remains constant while the other increases, KW increases. Conversely, if either torque or speed decreases while the other remains constant, KW will decrease.

Speed Control for an AC Motor

Because each motor type has its own characteristics of KW, torque and speed, different motor types are more suited for different applications.

The basic characteristics of each AC motor type are determined by the design of the motor and the supply voltage used.

The induction motor is basically a constant speed device. The speed at which an induction stator field rotates is called its Synchronous Speed. This is because it is synchronized to the frequency of the AC power at all times. The speed of the rotating field is always independent of load changes on the motor, provided the line frequency is constant.

The number of poles that the motor has and the frequency being supplied to it determines synchronous speed. The equation for determining the synchronous speed of a motor is:

N = 120f/P Where:

N = the synchronous speed of the motor in revolutions per minute (RPM)

f = the frequency supplied to the motor in Hertz (Hz)

P = the number of poles the motor has

Motors designed for 50 Hertz use (standard in the INDIA) have synchronous speeds as follows:

Poles	**RPM**
2	3000
4	1500
6	1000
8	750
10	600

Induction motors do not run at synchronous speed; they run at Full Load Speed, which is the rotational speed of the rotor. Full load speed is always slower. The percent reduction in speed is called Percent Slip. The slip is required to develop rotational torque. The higher the torque, the greater the slip.

The motor speed, under normal load conditions, is rarely more than 10% below synchronous speed. If the motor is not driving a load, it will accelerate to nearly synchronous speed. As the load increases, the percent slip increases.

For example, a motor with a 2.8% slip and 1800-rpm synchronous speed would have a slip of 50 rpm, and a full load speed of 1750 rpm (1800 - 50 = 1750 rpm). It is this full load speed that will be found on the motor's nameplate.

From the formula, it is evident that the supply frequency and number of poles are the only variables that determine the speed of the motor.

Varying the voltage is not a good way to change the speed of the motor. In fact, if the voltage is changed by more than 10%, the motor may be damaged. This is because the starting torque varies as the square of the applied voltage.

Because the frequency or number of poles must be changed to change the speed of an AC motor, two methods of speed control are available. These are:

- **Changing the frequency applied to the motor**

Changing the frequency requires a device called an Adjustable Frequency Drive to be inserted upstream from the motor. This device converts the incoming 50 Hz into any desired frequency, allowing the motor to run at virtually any speed.
For example, by adjusting the frequency to 30 Hz, the motor can be made to run only half as fast.

Winding

Winding uses round enameled wires, inserted into the slots and self supported on overhang well tied to form a robust ring structure. The insulation materials used in the winding, make up an insulation system which has class F or class H temperature rating and mechanical strength high enough to withstand rapid auto-reclosing. The materials withstand the abuse of the winding work, and the impregnating resin/ varnish adheres strongly to them making a solid mass. The impregnating resin is an epoxy resin having a long-term temperature rating and mechanical characteristics, which remain almost unchanged over the entire operating temperature range.

MOTOR TERMINOLOGY

- **AC (Alternating Current)**
  The commonly available electric power supplied an AC generator and is distributed in single or three-phase forms. AC current changes its direction of flow (cycles).

- **AC Motors**
  A motor,(see motor definition) operating on AC current that flows in either direction(AC current).There are two general types viz induction and synchronous.

- **Active Iron**
  The amount of steel (iron) in the stator and rotor of a motor. Usually the amount of active iron is increased or decreased by lengthening or shortening the rotor and stator (they are generally the same length).

- **Adjustable Frequency Drive**
  This device converts the incoming 50 Hz power into any desired frequency, allowing an AC motor to run at virtually any speed.

- **Air Gap**
  The space between the rotating (rotor) and stationary (stator) member in an electric motor.

- **Anti-Friction Bearing**
  An anti-friction bearing is a bearing utilizing rolling elements between the stationary and rotating assemblies.

- **Base Speed**
  The speed, which a motor develops at, rated armature and field voltage with rated load applied.

- **Bearings**
  Are used to reduce friction and wear while supporting rotating elements. For a motor it must provide a relatively rigid support for the output shaft.

The bearing acts as the connection point between the rotating and stationary elements of a motor. There are various types such as roller, ball, sleeve (journal), and needle.

The ball bearing is used in virtually all types and sizes of electric motors. It exhibits low friction loss, is suited for high-speed operation and is compatible in a wide range of temperatures. There are various types of ball bearings such as open, single shielded or sealed.

- **Canopy**
  A protective cover placed on the top of a motor being mounted vertically to protect it from liquids or solids that might drop onto the motor. (It acts similar to an umbrella for the motor.)

- **Conductor**
  A material, such as copper or aluminum, which offers low resistance or opposition to the flow of electric current.

- **Conduit Box**
  The metal container usually on the side of the motor where the stator (winding) leads are attached to leads going to the power supply.

- **Coil**
  The electrical conductors wound into the core slot, electrically insulated from the iron core. These coils are connected into circuits or windings which carry independent current. It is these coils that carry and produce the magnetic field when the current passes through them. There are two major types: "Mush" or "random" wound, round wire found in smaller and medium motors where coils are randomly laid in slot of stator core; and formed coils of square wire individually laid in, one on top of the other, to give an evenly stacked layered appearance.

- **Core**
  The iron portion of the stator and rotor; made up of cylindrical laminated electric steel. The stator and rotor cores are concentric separated by an air gap, with the rotor core being the smaller of the two and inside to the stator core.

- **Coupling**
  The mechanical connector joining the motor shaft to the equipment to be driven.

- **Current**
  The time rate of flow of electrical charge and is measured in amps (amperes).

- **Cycles per second (Hertz)**
  One complete reverse of flow of alternating current per rate of time. (A measure of frequency.)

- **Drip-Proof Motor**
  An open motor in which the ventilating openings are so constructed that drops of liquid or solid particles falling on it, at any angle not greater than 15 degrees from the vertical, cannot enter either directly or by striking and running along a horizontal or inwardly inclined surface.

- **Duty Cycle**
  The relationship between the operating and rest times or repeatable operation at different loads. A motor which can continue to operate within the temperature limits of its insulation system, after it has reached normal operating (equilibrium) temperature is considered to have a continuous duty (CONT.) rating. One, which never reaches equilibrium temperature, but is permitted to cool down between operations is operating under intermittent duty (INT.) conditions such as a crane and hoist motor which are often rated 15 or 30 min. duty.

- **Efficiency**
  The efficiency of a motor is the ratio of mechanical output to electrical input. It represents the effectiveness with which the motor converts electrical energy into mechanical energy.

- **Encapsulated Winding**
  A motor which has its winding structure completely coated with an insulating resin (such as epoxy). This construction type is designed for exposure to more severe atmospheric conditions than the normal varnished winding.

- **Enclosures**
  The housing, frame, of the motor of which there are two broad classifications; open and totally closed.

- **Endshield**
  The part of the motor housing which supports the bearing and acts as a protective guard to the electrical and rotating parts inside the motor.

- **Explosion-Proof Enclosure**
  An enclosure for electrical machinery or apparatus that will withstand, when the covers or other access doors are properly secured, an internal explosion of the flammable gas or vapor which may enter or which may originate inside the enclosure, without suffering damage and without communicating the internal explosion to the external flammable gas in which it is designed to be used, through any joints or other structural openings in the enclosure.

- **Explosion Proof Hazardous Locations**
  Hazardous areas worldwide are classified by zones, according to the risk posed by explosive gas or dust in the atmosphere
  - ✓ Zone 0/20 Continuously – Permanent presence of explosive atmosphere (>1000H per year)
  - ✓ Zone 1/21 Occasionally – Incidental presence of explosive atmosphere during normal duty (10-1000 H per year)
  - ✓ Zone 2/22 Abnormal Condition – Presence of explosive atmosphere only by accident, but not during normal duty (<= 10 H per year)

- **Externally Ventilated**
  A motor using an external cooling system. This is required in applications where the motor's own fan will not provide sufficient cooling; this is true for certain duty cycle applications, slow speed motors, also in environments with extreme dirt. Often a duct with an external blower is used to bring clean air into the motor's air-intake.

- **Frame**
  The supporting structure for the stator parts of an AC motor.

- **Full Load Current**
  The current flowing through the line when the motor is operating at full-load torque and full-load speed with rated frequency and voltage applied to the motor terminals.

- **Induction Motor**
  An induction motor is an alternating current motor in which the primary winding on one member (usually the stator) is connected to the power source and a secondary winding or a squirrel-cage secondary winding on the other member (usually the rotor) carries the induced current. There is no physical electrical connection to the secondary winding, its current is induced.

- **Insulator**
  A material, which tends to resist the flow of electric current (paper, glass, etc.) In a motor the insulation serves two basic functions:
  1. Separates the various electrical components from one another.
  2. It protects itself and the electrical components from attack of contaminants and other destructive forces.

- **Load**
  The burden imposed on a motor by the driven machine. It is often stated as the torque required to overcome the resistance of the machine it drives. Sometimes "load" is synonymous with "required power."

- **Lubrication**
  In order to reduce wear and avoid overheating certain motor components require lubricating (application of an oil or grease). The bearings are the major motor component requiring lubrication (as per manufacturer's instructions). Excess greasing can however damage the windings and internal switches, etc.

- **Nameplate**
  The plate on the outside of the motor describing the motor, HP, voltage, RPM's, efficiency, design, enclosure, etc.

- **Phase**
  Indicates the space relationships of windings and changing values of the recurring cycles of A.C. voltages and currents. Due to the positioning (or the phase relationship) of the windings, the various voltages and currents will not be similar in all aspects at any given instant. Each winding will lead or lag another, in position. Each voltage will lead or lag another voltage, in time. Each current will lead or lag another current, in time. The most common power supplies are either single (10) or three phase (with 120 electrical degrees between the 3 phases).

- **Primary Winding**
  That winding of a motor, transformer or other electrical device, which is connected to the power source.

- **RTD (Resistance Thermal Detectors)**
  - ✓ Winding RTD

  A resistance device used to measure temperature change in the motor windings to detect a possible over heating condition. These detectors would be embedded into the winding slot and their resistance varies with the temperature.
  - ✓ Bearing RTD

  A probe used to measure bearing temperature to detect an overheating condition. The RTD's resistance varies with the temperature of the bearings.

- **Roller Bearing**
  A special bearing system with cylindrical rollers capable of handling belted applications, too large for standard ball bearings.

- **Rotor**
  The rotating member of an induction motor made up of stacked laminations. A shaft running through the center and a squirrel cage made in most cases of aluminum which holds the laminations together and act as a conductor for the induced magnetic field. The squirrel cage is made by casting molten aluminum into the slots, cut into each lamination.

- **Shaft**
  The rotating member of the motor which protrudes past the bearings for attachment to the driven apparatus.

- **Slip**
  The difference between the speed of the rotating magnetic field (which is always synchronous) and the rotor in a non-synchronous induction motor is known as slip and is expressed as a percentage of a synchronous speed. Slip generally increases with an increase in torque.

- **Space Heater**
  Small resistance heater units mounted in a motor, that are energized, during motor shutdown, to prevent condensation of moisture on the motor windings.

- **Speed**
  The speed of the motor refers to the RPM's (revolutions per minute) of the shaft.

- **Starting Current**
  Amount of current drawn at the instant a motor is energized – in most cases much higher than that required for running. Same as locked rotor current.

- **Stator**
  That part of an AC induction motor's magnetic structure which does not rotate. It usually contains the primary winding. The stator is made up of laminations with a large hole in the center in which the rotor can turn; there are slots in the stator in which the windings for the coils are inserted.

- **Totally Enclosed Enclosure**
  A motor enclosure which prevents free exchange of air between the inside and the outside of the enclosure but is not airtight. Different methods of cooling can be used with this enclosure.

Speed Variation of Motor:
In many of the applications the speed of the system is determined primarily by its mechanical design and loading. For an increasing number of these applications, owever, it is necessary to control the speed of the system by controlling the speed of the motor.

Variable Speed Drives
The speed of a motor can be controlled by using some type of electronic drive equipment, referred to as variable or adjustable speed drives. Variable speed drives used to control DC motors are called DC drives.

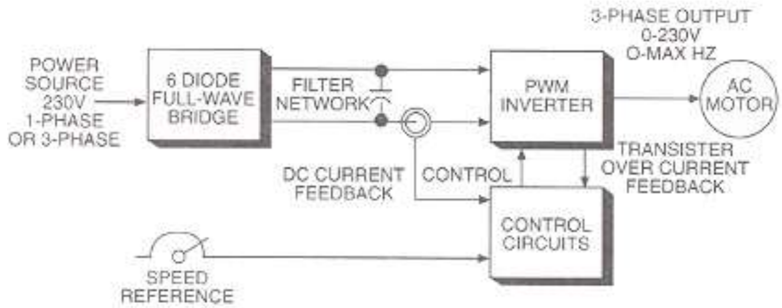
Variable speed drives used to control AC motors are called AC drives. The term inverter is also used to describe an AC variable speed drive. The inverter is only one part of an AC drive, however, it is common practice to refer to an AC drive as an inverter.
AC drives receive AC power and convert it to an adjustable frequency, adjustable voltage output for controlling motor operation. A typical inverter receives 440 VAC, three-phase, 50 Hz input power and in turn provides the proper voltage and frequency for a given speed to the motor. The three common inverter types are the variable voltage inverter (VVI), current source inverter (CSI), and pulse width modulation (PWM)..

Another type of AC drive is a cycloconverter. These are commonly used for very large motors All AC drives convert AC to DC, and then through various switching techniques invert the DC into a variable voltage, variable frequency output.

Basic working of AC Drive:
The block diagram below indicates the basic working module of a variable speed AC drive. The standard 440 V, 50 Hz supply connected to the drive is first converted in to a DC supply through a 6 diode full wave rectifier bridge. This DC supply is now converted in to a AC supply of desired frequency. The Control Circuit module does this critical task. This controls the number of switching and accordingly a desired output frequency is obtained. This AC supply of variable frequency, when supplied to an ac motor, gives corresponding variable speed.

There are various techniques of switching the DC supply and getting a variable frequency AC supply.

For the purpose of this lesson, we need not go in to the finer technicality of these switching methods.



As the applied frequency is changed, the motor will run faster or slower. Standard three-phase AC motors, designed for fixed speed operation at standard line frequency, may be easily adapted for use with the AC controller by considering the following:

a. A slight increase in motor losses occurs with inverter power.
b. The motor thermal capacity must typically be de-rated as a function of the minimum, continuous operating speed, due to the reduced ventilation.

EXERCISE:

1. What is an electric motor ? What is the difference between AC & DC motors?
2. Describe the principle of Induction.
3. How the principle of induction is applied to AC motor?
4. Describe the advantages of AC squirrel cage induction motor over DC motor.
5. Describe the working principle of 3-phase induction motor.
6. Describe the construction of 3-phase induction motor.
7. What is Variable Frequency Drive (A.C. Drive)?
8. Explain following terms:

   a) Alternating Current b) Adjustable Frequency Drive
   c) Air Gap d) Bearing
   e) Conductor f) Canopy
   g) Coil h) Cycles per Second (Hertz)
   i) Drip Proof Motor j) Encapsulated Winding
   k) Duty Cycle l) Explosion proof Enclosure
   m) Insulator n) Name Plate
   o) RTD p) Stator

STATUTORY REQUIREMENT

When any new electrical installation is to be carried out, it is a statutory requirement to get the drawings for electrical installations approved by Chief Electrical Inspectorate (or Commissioner of Electricity) of State Govt. Before starting the erection jobs of electrical equipment, such approval, in writing, becomes statutory. There are various drawings and information/records to be sent to Electrical Inspectorate Office working under Industry, Mining & Power Department (I M & P Dept).

Main records / drawings to be sent are as under:

(a) Layout of electrical equipment like HT/LT switch gear, Power/Distribution transformers, HT/LT motors, Earthing Layout etc.

(b) Name plate details of major equipment like Power transformers, HT motors, switchgear etc.

(c) For transformers, the distances from walls/fencing, earthing pits, neutral CT arrangement etc.

(d) Substation floor layout panels' layout, dimensions and distances from walls

(e) Various design data like rupturing capacity (in KA or MVA) for HT switchgear.

(f) For hazardous area, the type of enclosures of Electrical equipment used in the plant.

Purpose of such approval is obviously electrical safety. From electrical point of view, Electrical Inspectorate Office checks whether the installation meets the requirements or not. If necessary, they can recommend some modification or addition/deletions. Approved drawings are duly stamped, signed and sent to the applicant. These drawings are to be preserved as important records. Any major modification or extension in Electrical installation needs to be approved by the competent authority. The existing (earlier approved) drawing and proposed modification drawings are to be sent to Electrical Inspectorate, for approval.

Following main points are scrutinized, from the safety point of view.

- Distances of switchgear, transformers etc. from the wall. This is for safe movement of the personnel during working and exit during emergency.
- Earthing - Size of earthing depends upon the equipment. Also, in earthing of generator or transformer is checked from safety point of view.
- Size of cable or GI strips or copper strips used for earthing network.
- Volume soak pit in case of higher rating power transformers.
- Type of enclosures in case of hazardous area.

Electrical Inspectorate is to be informed before starting the installation and on the completion of the installation. Electrical Inspectorate visits and checks that the installation is as per approval. Clearance for energizing the installation is given, in writing, by Electrical Inspectorate.

Commissioner of Electricity or Chief Electrical Inspector has his office in the state capital. They appoint electrical Inspectors for each District. Asst Electrical Inspectors assist the Electrical Inspector for the entire job/procedure. CEO or CEI approves initial drawings.

Once the installation is energized, Electrical Inspectorate or CEI inspects it every year, with prior intimation to the owner. They check following documents:

- Maintenance records for major equipment like transformers, HT/LT motors, switchgear etc.
- Test results of transformer oil
- Earthing record & Earthing conditions for the installation

After inspection, if electrical Inspector has any observation, it is intimated in writing to the owners for compliance, within the stipulated time.

For Public Undertakings, statutory approvals/inspections are carried out by the Central Electricity Authority, Panaji, Goa. Therefore, all Public Undertakings do not come under the purview of State Govt., Electrical Inspectorate.

Lifts:

All new lift installations need to be approved similar to that for electrical installations. Also, every year, load test is to be carried out and lift is to be certified by chartered engineer or agency authorized by Lift inspector.

Lift Inspector inspects lift once a year.

Electricity Duty :

Based on the generation capacity installed (GTG, STG & Emergency DG sets), Electricity duty is to be paid every month, to state govt. Amount is fixed, irrespective of actual generation. All energy meters in generation systems are to be tested by Authorized Test House & to be sealed.

CVSRTA

It can be seen from above that for electrical installation and for lifts, Industrial Mining and Power (IM&P) Department has got very important responsibility. Keeping Indian Electricity rules and changing technology in view, they fulfill their role, with updated knowledge. They see that safety is observed and new regulations are enforced for safety of the industry in general and public at large.

EXERCISE:

1. List the drawings / records to be sent to Chief Elect Inspector before approval.
2. List the documents which the electrical inspector would check during annual inspection.
3. Why and when a lift is inspected ?

UNIT- 05
VALUATION TECHNIQUES & CASE STUDY

In the previous chapters you have learnt the basics of engineering. The intention of the previous chapters is not to make an engineer but to have some understanding of engineering aspects of the general machinery a valuer might come across in his day-to-day professional life. Some idea of basic engineering will help in understanding the variations in the industry.

The detail theory and principal of Valuation do not come under the scope of this subject, you have studied it else where. In day-to-day action, a valuer will surely come across a situation, which is peculiar to some situation. The copybook method of valuation may not give us a right indication. These are the occasions when experience of a valuer comes in handy. An attempt is made to visualize a couple of such situation for guidance.

A valuer during his professional carrier would deal with various types of installations, ranging from a small scale plastic injection molding unit to a large size multi product unit to a software development unit with practically no machinery and only intellectual installations like software. A valuer cannot be an expert in the field of his client unit. However, he need to have a macro view of the entire set up, extract maximum amount of relevant data, generate certain data from the market and then use his own judgment and wisdom to arrive at a value which will be closest to the actual.

When a valuer starts a project, he would get certain data from the client like date of manufacturing, expenditure made on the plant for maintenance or renovation, maintenance history and schedule etc.

All these data have some significance with respect to valuation. Let us have a brief look at these and discuss the significance of each with respect to the valuation process:

Date of Purchase & Commissioning Date:
This will give an idea of the age of the equipment. In general this will determine the value of the equipment, but there is certain typical situation where the expertise & judgment ability of the valuer plays an important role.

There can be an instance where equipment might not have been commissioned for a long time after purchase. In such cases the wear & tear is to be considered accordingly. The value of two similar plants procured during same period say 10 years back, one commissioned immediately and running continuously and other not used at all due to some reason or the other can not have same valuation. If the valuer follow the book value route, the result can be misleading.

In such case one has to look for the reason of non operation of the plant. E.g. a chemical unit needing lot of water for process is set up in a area where there is scarcity of water, can not be valued equally even if the machinery is un used. The unit as a whole has no value, but the equipment in isolation can be sold and re installed at other location, so individual equipment can have value.

Production Rate:

Valuer can not be an expert to know the intricacy of a equipment. Even if he is an expert engineer, he may not have time and/or an opportunity to open the machine and inspect. Production rate data will indicate the condition of the machine. If all other conditions which can effect the production like market availability, labour un rest, power situation etc are normal then a low production rate data, indicates that the equipment is not very healthy.

Operating Hours:

The total operating hours can indicates about the healthy ness of the machine on one hand while as on other hand it also indicates the wear & tear of the machine.

Maintenance Schedule & it's implementation:

Any plant and machinery has to be maintained properly. Maintenance does not mean only break down maintenance. It need to have a preventive maintenance also i.e one has to take care of the machine and nurish it so that it does not fail prematurely. A simple example is lubrication or greasing. To ensure that a machine bearing does not run dry, we put oil or grease at a regular interval. This prevents the bearing from failure.

By looking at the maintenance schedule and confirming that this schedule is really adhered to, the valuer can judge the condition of the machine. A poorly maintained machine is likely to fail earlier then the other which is regularly maintained.

History Of Breakdowns & major maintenance:

The valuer should critically examine this data, because any repetitive major failure indicates that there may be something wrong with the machine. Such failure also reduces the Residual Life (Remaining Life) of the equipment.

The valuation has an analogy of our purchasing a second hand car. Knowingly or unknowingly all above factors are pressed in service by us When we go for buying a second hand car we will select a one either of the doctor because it might have run less OR of an engineer because it might have been maintained well. We will enquire about any major accident or repair of the engine to judge the residual life.

Expenditure Made:
In case you as a valuer do not get the engineering data mentioned above, you can ask for the data of the expenditure incurred on maintenance and modifications. A high amount of maintenance expenditure does not necessarily indicate very good maintenance. It may mean poor health of the machine.

A valuer will be satisfied if he gets above data. By using the data as a tool, he can derive a near actual valuation. But in the professional life, he may not be always so lucky to get all the data. Even if gets some of the above, he can still work out, but what if the unit do not have majority of these data? In such a situation the wisdom and expertise comes in to play an important role.

The valuer has to now arrive at the value based on external factors. These factors though widely remain same but may vary depending on the type of the equipment. In the following paragraphs we will examine certain factors with examples and see how best a value can be judged. Student should remember that these examples should be taken as a guideline only and not as a valuation principal, since the methodology will vary from equipment to equipment and also for similar equipment from case to case.

Case Study 1: Pump
If the equipment under valuation is a pump and there is no useful data is available then the valuer should find out the capacity of the pump, the liquid it is handling, the MOC (Material Of Construction), HP of the motor etc. The capacity of the pump & the liquid handled can help in finding out an equivalent pump. If the pump is in a scrape condition the MOC & Motor capacity can indicate the scrape value i.e. if the MOC is SS then the scrape value will be Rs 75 / Kg , if it is Cast Iron it will be Rs 7 / Kg but if it is Brass then it would be Rs 225 / Kg. The cost of scrape copper (Electrical Grade) would be Rs 350 / Kg. All the rates are indicative and on 2006 price base. A valuer is advised to check the current market price since there may be some fluctuation in these rates. The HP of the motor can give an approximate idea of the copper conductor used in side which can be retrieved and sold as scrape. As a thumb rule one can consider 1 Kg of Copper per HP of motor.

The table under gives a estimate of material cost of some of the commonly used MOC:

Material	Market Rate (2006)
Lead	65
Gun Metal	225
Brass	225
Copper	350
Aluminium	130
Mild Steel	25
Cast Iron	07

Case Study 2: Lancashire Boiler

In earlier days the Lancashire boiler was the most popular boiler and was almost omni present. These boiler were very sturdy and comperatively easy to maintain. Many of the boilers are in use even today and is performing reasonably satisfactorily. With the passage of time, new technology has taken over. The new boilers are designed and manufactured and have gradually phased out the good old Lancashire boilers from manufacturing floor.The new boilers These are much larger in capacity, better in efficiency, flexible in type of fuel used and reduced in size.

Now, when a valuer come across a Lancashire boiler, what he will do ?

- If he takes the route of book value, then the book value by now will be practically zero. The boiler is still operative, so he can not value it as zero.
- Other method is by weight of the material. This route is chosen for a scrape item but in this case this also is not applicable since boiler is in working condition.
- He can not have the price of a new Lancashire Boiler since it is out of manufacturing range of all the manufacturers.
- He can not straight away take the price of a new version boiler since it is different then the object in question in many aspects and much superior in technological design.

A wise valuer will get the price of a modern boiler of almost the same capacity and using the same type of fuel. Though the new and the old ones are similar in capacity, there are certain major differences, like –

- This new version boiler will be better in efficiency. Find out the efficiency of the old boiler and de-rate the new boilers value to that extent.
- The size of the new boiler will be much less. Compare this with the Lancashire boiler and take the value of the space in to consideration. One has to deduct the land and building price for this additional space. For major cities where land price is very high, this is a very dominant factor.
- The controls of the new boiler would be very sophisticated, presumably a PLC or a micro processor based. The old boiler would have a hard wire relay logic type of control. Find out the price of such control panel and take in to account while deriving the value.

Thus the cost of the new version boiler minus the de rating factors due to above will give us the equivalent price of a new Lancashire boiler if it would have manufactured today. Now, the valuer can use his standard copy book methodology for deriving the value of this old but still operative boiler.

Case Study 3: Lancashire Boiler

In the situation of case study 2 above, there is one more method of accessing the value. It is a market based method. There exists a very large market of second hand machinery & equipment. The valuer can explore the market through traders, engineering magazines publishing advertisements and data for used equipment and also on various web sites dealing in such items. Having compared the age and the capacity of the second hand boiler, with the installed one, check the condition of the boiler. The price offered (after negotiations) can be considered as the value for the installed boiler. This can be termed as market derived depreciation.

The value so derived is generally accurate one but one has to be very careful since one should select a similar equipment not only in terms of type, age and capacity but also it should be similar in condition.

Case Study 4: Minimum Oil Circuit Breaker:

The electrical system of an old unit will have Minimum Oil type of circuit breaker. These were very popular and were widely accepted technology till eighties. From nineties the use of vacuum and SF6 (gas filled) circuit breakers started and manufacturer gradually phased out the old technology breakers from manufacturing range. The MOCB however are still in use in many electrical sub stations.

If a valuer wants to find out the value of a MOCB, he may not find a manufacturer to get today's price. What is widely used today is a Vacuum Circuit Breaker (VCB). The VCB is sturdy, compact and have no hazardous consumable like oil in the system. The breaking capacity of the VCB is much higher then the MOCB. We may not get the exact similar characteristic breaker because the datum level has gone up. In such case, the valuer can get the rate of a VCB, de-rate by say 20% for space utilization and 15 to 20 % for technology difference. Thus this de rated value will be our replacement value. By using other standard valuation tools, we can derive the true value. Just to give an idea of this method, let us take a real life example. The price of a MOCB in 1985 was Rs. 75000/-. We do not have a replacement price today since it is out of manufacturing range. A new VCB will cost Rs 4,00,000/- , with the de rating of 20% for space utilisation + 20% for technology difference, the replacement cost will work out to be Rs 2,40,000/ -. Now, using the standard tools, the valuer can find out the value as on date.

The other method of finding the value is market-derived value, which is discussed, in earlier case study.

Case Study 5: Non Standard Make:

When one is out in the market to buy machinery, one is bound to get various widely varied offers. The highest price offer of a branded / high repute manufacturer, with very high quality standard and the lowest will be from a local unknown manufacturer with not so high quality checks. The variation in price is due to various reasons like difference in input cost, over heads, brand equity etc. Any manufacturing unit while procuring machinery will evaluate the offers keeping a question of "How much for how much" in mind. If the product of a local manufacturer meets the requirement, the user will surely go for it. While doing the valuation of such similar functioning & similar looking items, valuer must give due consideration to the "Make" of the item, with above aspect in mind.

As an example let us consider an electrical panel. (or Motor Control Centre – MCC) There are numerous manufacturers of electrical panels. On one hand there are brands like Siemens, L & T, Crompton etc. All these are giants in the field and manufacture panels using their own branded components like switch, fuse etc. However, there are other small and medium scale units, who fabricate a panel, buy components of various make from the market and wire them in the panel. The components used in the panel can be of varied make from say Siemens Switch to a local hand mould fuses. The quality of fabrication and painting can be different. Their overheads are also less. Many a times they are out of Excise Duty regime. Due to all above reasons the cost of the locally manufactured panel can be cheaper up to 30%. A valuer must open the locally manufactured panel and access the brand of the components, material of construction of bus bars (copper or aluminum) etc before judging the value.

Plant and equipment valuation situations are varied, and circumstances may even require the estimation of more than one type of value in a single assignment. Accordingly, plant and equipment will be valued on a basis that is appropriate for the circumstances, and that basis will be appropriately defined in the valuation Report.

The Time effect in valuation:

When we talk of valuation of an old unit, it includes all equipment & facility installed in the company i.e. one has to take in to account the procurement cost as well as labour cost involved for installation. In the previous paragraphs we have seen how the value of the equipment procured is arrived at especially in case of old equipment. Now, we will try to analyze the effect of labour cost in valuation of such old equipment. With increase in standard of leaving and the inflation, the cost of labour is constantly going up. The statutes have also raised the minimum wages of the labour to protect them from exploitation.

It is interesting to note that the unit rate of the work have not increased proportionate to the increase in wages of labour mainly due to increase in competition. The effect of inflation is some what nullified by reduction in profit margin. There are many contractors today as compared to the earlier days and as a result of stiff competition amongst them, the industry has gained. Just to give an example of rise in labour cost vis-à-vis the competitive market; let us consider an item of cable laying. Cost of laying a 3 core, 2.5 sq mm cable was Rs 5 / Mtr in 1978, Rs 6 / Mtr in 1991 and Rs 9 / Mtr in 2006.

Though the labour cost have defeated the law of inflation to some extent, due to increase in the raw material cost , the cost of equipment have surely gone up with passage of time. Also as we have seen in above paragraphs, the type of material used has widely varied over a period of time. A valuer while valuing an old asset should keep both these factor in mind.

There are numerous types of equipment in the industries. The variation in cost and the type will be different in each case. However, to understand the effect of time in valuation, let us consider an example of a electrical sub station with a HT over head in-comer, HT breaker, a transformer and cable for connecting the transformer. We have not included LT side equipment in this example for simplicity. The following table gives an idea of varying cost and type of equipment in such typical electrical sub station.

Sr No	Description	Cost Of Equipment (Type of Equipment) in Rs in respective Year of Installation		
		1977	1991	2006
1	DP Structure for out door tapping	8000	20000	30000
2	Transformer 250 KVA 11KV/415V	30000	80000	200000
3	HT Circuit Breaker Panel (Cost/Type/Size)	100000/MOCB/3 sq mtrs	200000/MOCB/2 sq mtrs	400000/VCB/1 sq mtrs
4	HT Cable (Cost per Mtr / Type)	300 (Paper Insulated)	500 (PVC Insulated)	900 (XLPE Insulated)

If one has to find out a valuation of the sub station mentioned above, the table above can help in deciding various factors discussed in the chapter.

Indirect Costs:

The Market Value of plant and equipment rests upon the belief that a prudent purchaser would pay no more for an asset or a group of assets than the cost of acquiring (an) equally desirable substitute(s) in the market. In the valuation of plant and equipment, the cost of the substitute(s) often includes costs to make the asset(s) productive. These costs are called make-ready and/or indirect costs. Often included in these costs are necessary, associated expenses such as engineering, interest during construction, transportation, installation, attachment to utilities, and start-up.

Plant and equipment includes installations and support facilities for processes or manufacturing which are designed to perform a specific predetermined function. These include all non-realty devices in fixed or movable form deployed in the processing, manufacturing, or assembling of products from the stage of raw materials to finished goods. Separately reported items such as materials inventories, finished products, patents, and the like are not included. Thus, it is essential to the valuation Process that all items to be valued are neither omitted nor accounted for twice in the valuation and related reporting.

Assignment 1

1. Define a boiler.
2. Describe significance of "Boiler Specifications"
3. What is IBR ? Where it is applicable.
4. Describe the classification of boilers by the type of construction.
5. Discuss various systems of a boiler.
6. Describe "Fire Tube", :Water Tube" & "Package" boilers.
7. Discuss "High Temperature Hot Water Boilers" covering Advantages – Disadvantages & heat transfer liquid used.
8. What is "Waste heat boilers"?
9. Write note & describe the following :
    a. Fire Tube Boilers
    b. Scotch Marine Boilers
    c. Lancashire Boilers.
    d. Utility Boilers.
    e. High temperature Hot Water Boilers with Advantages & Dis advantages.
    f. High temperature heat transfer methods.
    g. Waste Heat Boilers.
    h. Waste fuel Boilers.
    i. Fluidised Bed Boilers.
10. Describe the components of pipe work
11. What is a pump & what is a compressor?
12. What are different parts of pumps?
13. Describe a Centrifugal pump with construction and working details.
14. List types of Pumps.
15. What are the technical factors considered in selection of a pump?
16. Describe basic concept of a centrifugal pump operation OR Describe working mechanism of a Centrifugal pump.
17. Discuss the statement :Pump can pump only liquid and not vapour"

Assignment 2

1. Write note on classifications of compressors.
2. Describe in brief the methods to compress gas.
3. Draw a sketch and describe Reciprocating Compressor.
4. Describe a Centrifugal Compressor.
5. What is Geared Compressor ? What are advantages of geared compressor ?
6. Write notes on following :
    a. Fans & Blowers
    b. Centrifugal Compressor
7. What is Prime Mover ? Name important primemovers.
8. Describe different types of prime movers.
9. What is Gas Turbine?

10. What is air conditioning? What one would expect to find in an a/c installation?
11. Where a/c system for raising ambient temperature is used? Name the systems for raising ambient temperature. Describe one of them.
12. What are the basic parts of a/c cooling system? Describe the cooling cycle
13. Draw and describe refrigeration cycle.
14. Describe an absorption cycle.
15. Explain the parts & working of window a/c.
16. Why one need Humidifiers ? Explain the working in brief.
17. Name circulating / distribution equipment.
18. Write note on Fan & Blowers.
19. Define the terms
    Force, Energy, Power, Voltage & Current
20. Describe Voltic cell and it's analogy with water pump.
21. What is Ohm's Law. Explain in brief the relation between Voltage applied, Current passing through and the resistance.

Assignment 3

1. Draw and describe the general electrical distribution diagram. What are the elements involved .
2. Explain the power flow concept in electrical engineering. Explain the same giving analogy.
3. How is the transmission voltage determined? Why the transmission voltage is kept high ?
4. Describe the types of primary distribution system.
5. What are the requirement of electrical sub station room ?
6. What are the equipment one will normally find in an electrical sub station ?
7. Write brief note on following :
    a. Switchgear Breaker
    b. Unit s/s
    c. Motor Control Centre (MCC)
    d. Transformer
    e. Types of switch boards
    f. Types of distribution boards.
8. What is Power factor Correction ? Why it is done ?
9. Describe all three types of Distribution boards.
10. Explain the advantages of circuit breaker over fuse.
11. What is MCB?
12. Explain Trickle (or Float) and Boost charging in a battery.
13. What is meant by Primary battery? List the basic application of primary battery.
14. Describe the Function of Protective Relaying

15. What is meant by “Normal operation of a system “ when we are talking about the protection ?
16. What are the Features for prompt disconnection of an faulty element?
17. Detail the General Consideration of protection.
18. What is “cable”?
19. List the key factors governing the selection of a cable.
20. What is XLPE cable ?
21. Describe the basic theory of an induction motor.
22. What is meant by AC motor or DC motor ?
23. Explain construction of Squiral cage induction motor stating advantages.
24. Describe speed variation in AC motors.
25. What is meant by Explosion proof motor ? Where it is used?
26. Explain any three important terminology used in motors.
27. What are the documents required to be sent to Electrical inspector for statutory permissions?
28. What are the points scrutinized by Electrical Inspector?
29. Who is the statute body for PSU and Private sector industries.
30. Do you agree with the statement “A valuer cannot be an expert in the field of his client unit.” – Why ?
31. What data a valuer should collect while doing the project ? What is the significance of each data ? Describe each.
32. Describe & discuss with case study the effect of external factors on valuation.

VI. Impact of Indian accounting standards, International Valuation Standards and Standards to be published by Ministry of Corporate Affairs, GOI on valuation of plant and machinery

According to Indian Accounting Standard (Ind. AS) 16 -*Property, Plant and Equipment* - An item of property, plant and equipment that qualifies for recognition as an asset shall be measured at its cost.

The cost of an item of property, plant and equipment comprises:

(a) its purchase price, including import duties and non-refundable purchase taxes, after deducting trade discounts and rebates.

(b) any costs directly attributable to bringing the asset to the location and condition necessary for it to be capable of operating in the manner intended by management.

(c) the initial estimate of the costs of dismantling and removing the item and restoring the site on which it is located, the obligation for which an entity incurs either when the item is acquired or as a consequence of having used the item during a particular period for purposes other than to produce inventories during that period.

The examples of directly attributable costs are:

(a) costs of employee benefits (as defined in Ind. AS 19, *Employee Benefits*) arising directly from the construction or acquisition of the item of property, plant and equipment;

(b) costs of site preparation;

(c) initial delivery and handling costs;

(d) installation and assembly costs;

(e) costs of testing whether the asset is functioning properly, after deducting the net proceeds from selling any items produced while bringing the asset to that location and condition (such as samples produced when testing equipment);

and

(f) professional fees.

Please refer to General Standards IVS 101 to 105 and IVS 300 Plant and Machinery of 2017 document of International valuation Standards Committee.

At the time of publication of this material in Dec.2017 the Ministry of Corporate Affairs, Govt. of India have not published the standards.