Chapter 1

Fundamental of Power Plant

1.1 INTRODUCTION

The whole world is in the grip of energy crisis and the pollution manifesting itself in the spiraling cost of energy and uncomforted due to increase in pollution as well as the depletion of conventional energy resources and increasing curve of pollution elements. To meet these challenges one way is to check growing energy demand but that would show down the economic growth as first step and to develop nonpolluting energy conversion system as second step. It is commonly accepted that the standard of living increases with increasing energy consumption per capita. Any consideration of energy requirement and supply has to take into account the increase conservation measures. On the industrial font, emphasis must be placed on the increased with constant effort to reduce energy consumption. Fundamental changes in the process, production and services can affect considerable energy saving without affecting the overall economy. It need not be over emphasized that in house hold commercial and industrial use of energy has considerable scope in energy saving. Attempt at understanding the integrated relationship between environment and energy have given shape due to development of R-134a, (an non pollutant refrirgent) to emerging descipling of environmental management. The government of India has laid down the policy "it is imperative that we carefully utilize our renewal (*i.e.,* non-decaying) resources of soil water, plant and animal live to sustain our economic development" our exploration or exploitation of these is reflected in soil erosion, salutation, floods and rapid destruction of our forest, floral and wild life resources. The depletion of these resources often tends to be irreversible since bulk of our population depends on these natural resources. Depletion of these natural resources such as fuel, fodder, and housing power plant;

1.2 CONCEPT OF POWER PLANT

A power plant is assembly of systems or subsystems to generate electricity, *i.e.,* power with economy and requirements. The power plant itself must be useful economically and environmental friendly to the society. The present book is oriented to conventional as well as non-conventional energy generation. While the stress is on energy efficient system regards conventional power systems *viz.,* to increase the system conversion efficiency the supreme goal is to develop, design, and manufacturer the non-conventional power generating systems in coming decades preferably after 2050 AD which are conducive to society as well as having feasible energy conversion efficiency and non-friendly to pollution, keeping in view the pollution act. The subject as a whole can be also stated as modern power plants for power viz electricity generation in 21st century. The word modern means pertaining to time. At present due to energy crisis the first goal is to conserve energy for future while the second step is to develop alternative energy systems including direct energy conversion devices, with the devotion, dedication and determination remembering the phrase, “ Delve and Delve Again till wade into”.

1.3 CLASSIFICATION OF POWER PLANTS

- Power Plant
  - Conventional
    - Steam Engines Power Plants
    - Steam Turbine Power Plants
    - Diesel Power Plants
    - Gas Turbine Power Plants
    - Hydro-Electric Power Plants
    - Nuclear Power Plants
  - Non-conventional
    - Thermoelectric Generator
    - Therm-ionic generator
    - Fuel-cells Power Plants
    - Photovoltaic solar cells Power System
    - MHD Power Plants
    - Fussion Reactor NPP Power System
    - Biogas, Biomass Energy Power system
    - Geothermal Energy
    - Wind Energy Power System
    - Ocean Thermal energy conversion (OTEC)
    - Wave and Tidal Wave
    - Energy Plantation Scheme

A power plant may be defined as a machine or assembly of equipment that generates and delivers a flow of mechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to a prime mover runs the generator, the electricity is generated. The type of prime move determines, the type of power plants. The major power plants, which are discussed in this book, are,

1. Steam power plant
2. Diesel power plant
3. Gas turbine power plant
4. Nuclear power plant
5. Hydro electric power plant

The Steam Power Plant, Diesel Power Plant, Gas Turbine Power Plant and Nuclear Power Plants are called **THERMAL POWER PLANT,** because these convert heat into electric energy.

1.4 ENERGY

Energy is the capacity for doing work, generating heat, and emitting light. The equation for work is the force, which is the mass time the gravity times the distance.

Heat is the ability to change the temperature of an object or phase of a substance. For example, heat changes a solid into a liquid or a liquid into a vapor. Heat is part of the definition of energy.

Another part of the definition of energy is radiation, which is the light and energy emitted in the form of waves traveling at the speed of light.

Energy is measured in units of calorie, quad, and joule. A kilocalorie is the amount of energy or heat required to raise the temperature of 1 kilogram of water from 14.5°C to 15.5°C. The quad unit is used to measure energy needed for big countries. The final measurement of energy is joules.

Energy is an essential input for economic development and improving quality of life. India's per capita consumption of Commercial Energy (*viz.,* coal, petroleum and electricity) is only one-eighth of the Global Average and will increase with growth in Gross Domestic Production (GDP) and improvement in standard of living.

Commercial Energy accounts for a little over half of the total energy used in the Country, the rest coming from non-commercial resources like cow-dung, fuel wood and agricultural waste. Though the share of these non-commercial sources has been coming down, consumption has increased almost double since 1953.

These renewable, non-commercial sources have been used extensively for hundreds of years but in a primitive and ineffective way. Indiscriminate use of non-commercial energy sources is leading to an energy crisis in the rural areas. Seventh Plan laid emphasis on the development and accelerated utilisation of renewable energy sources in rural and urban areas. A major Policy of the Government is directed towards increasing the use of coal in household and of electricity in transport sector in order to reduce dependence on oil, which is becoming scarce gradually.

The Government has formulated an energy policy with objectives of ensuring adequate energy supply at minimum cost, achieving self-sufficiency in energy supplies and protecting environment from adverse impact of utilising energy resources in an injudicious manner. Main elements of the policy are:

1. Accelerated exploitation of domestic conventional energy resources-oil, coal, hydro and nuclear power;
2. Intensification of exploration to increase indigenous production of oil and gas;
3. Management of demand for oil and other forms of energy;
4. Energy conservation and management;
5. Optimisation of utilisation of existing capacity in the country;
6. Development and exploitation of renewable sources of energy to meet energy requirements of rural communities;
7. Intensification of research and development activities in new and renewable energy sources; and
8. Organisation of training far personnel engaged at various levels in the energy sector.

Development of conventional forms of energy for meeting the growing energy needs of the society at a reasonable cost is the responsibility of Government *viz.*, Department of Power, Coal and

Petroleum and Natural Gas. Development and promotion of non-conventional/alternate/new and renewable sources of energy such as Solar, Wind and Bio-energy, etc., are also getting sustained attention from the Department of Non-Conventional Energy Sources created in September, 1982. Nuclear Energy Development is being geared up by the Department of Atomic Energy to contribute significantly to overall energy availability in the Country.

Energy Conservation is being given the highest-priority and is being used as a tool to bridge the gaps between demand and supply of energy. An autonomous body, namely Energy Management Centre, has been set up on ten April, 1989, as a nodal agency for energy conservation projects.

1.5 TYPES OF ENERGY

There are various types of energy which, they include nuclear, electrical, thermal, chemical, and radiant energy. In addition, gravitational potential energy and kinetic energy that combines to produce mechanical energy.

Nuclear energy produces heat by fission on nuclei, which is generated by heat engines. Nuclear energy is the world's largest source of emission-free energy. There are two processes in Nuclear energy fission and fusion. In fission, the nuclei of uranium or plutonium atoms are split with the release of energy. In fusion, energy is released when small nuclei combine or fuse. The fission process is used in all present nuclear power plants, because fusion cannot be controlled. Nuclear energy is used to heat steam engines. A Nuclear power plant is a steam engine using uranium as its fuel, and it suffers from low efficiency.

Electricity powers most factories and homes in our world. Some things like flashlights and Game Boys use electricity that is stored in batteries as chemical energy. Other items use electricity that comes from an electrical plug in a wall socket. Electricity is the conduction or transfer of energy from one place to another. The electricity is the flow of energy. Atoms have electrons circling then, some being loosely attached. When electrons move among the atoms of matter, a current of electricity is created.

Thermal energy is kinetic and potential energy, but it is associated with the random motion of atoms in an object. The kinetic and potential energy associated with this random microscopic motion is called ***thermal energy***. A great amount of thermal energy (heat) is stored in the world's oceans. Each day, the oceans absorb enough heat from the sun to equal the energy contained in 250 billion barrels of oil (Ocean Thermal Energy Conversion Systems).

Chemical energy is a form of energy that comes from chemical reactions, in which the chemical reaction is a process of oxidation. Potential energy is released when a chemical reaction occurs, which is called ***chemical energy.*** A car battery is a good example, because the chemical reaction produces voltage and current to start the car. When a plant goes through a process of photosynthesis, what the plant is left with more chemical energy than the water and carbon dioxide. Chemical energy is used in science labs to make medicine and to product power from gas.

Radiant energy exists in a range of wavelengths that extends from radio waves that many be thousands of meters long to gamma rays with wavelengths as short as a million-millionth (10^{-12}) of a meter. Radiant energy is converted to chemical energy by the process of photosynthesis.

The next two types of energy go hand and hand, ***gravitational potential energy*** and ***kinetic energy.*** The term energy is motivated by the fact that potential energy and kinetic energy are different aspects of the same thing, mechanical energy.

Potential energy exists whenever an object which has mass has a position within a force field. The potential energy of an object in this case is given by the relation $PE = mgh$, where PE is energy in joules, m is the mass of the object, g is the gravitational acceleration, and h is the height of the object goes.

Kinetic energy is the energy of motion. An object in motion, whether it be vertical or horizontal motion, has kinetic energy. There are different forms of kinetic energy vibrational, which is the energy due to vibrational motion, rotational, which is the energy due to rotational motion, and transnational, which is the energy due to motion from one location to the other. The equation for kinetic energy is ½ mv^2, where m is the mass and v is the velocity. This equation shows that the kinetic energy of an object is directly proportional to the square of its speed.

1.6 POWER

Power is the rate doing work, which equals energy per time. Energy is thus required to produce power. We need energy to run power plants to generate electricity. We need power to run our appliances, and heat our homes. Without energy we would not have electricity.

The units of power are watts, joules per second, and horsepower,

where ; 1 Watt = 1 joule per second

1 Kilowatt = 1,000 Watts

1 Megawatt = 1,000 kilowatts

= 1 horsepower

Electricity is the most convenient and versatile form of energy. Demand for it, therefore, has been growing at a rate faster than other forms of energy. Power industry too has recorded a phenomenal rate of growth both in terms of its volume and technological sophistication over the last few decades. Electricity plays a crucial role in both industrial and agricultural sectors and, therefore, consumption of electricity in the country is an indicator of productivity and growth. In view of this, power development has been given high-priority in development programme.

1.7 POWER DEVELOPMENT IN INDIA

The history of power development in India dates back to 1897 when a 200 kW hydro-station was first commissioned at Darjeeling. The first steam station was set up in Calcutta in 1899. By the end of 1920, the total capacity was 130 mW, comprising. Hydro 74 mW, thermal 50 mW and diesel 6 mW. In 1940, the total capacity goes to 1208 mW. There was very slow development during 1935-1945 due to Second World War. The total generation capacity was 1710 mW by the end of 1951. The development really started only after 1951 with the launching of the first five-year plan.

During the First Plan, construction of a number of Major River Valley Projects like Bhakra-Nangal, Damodar Valley, Hira Kund and Chambal Valley was taken up. These projects resulted in the stepping up of power generation. At the end of the First Plan, generation capacity stood at 34.2 lakh kW.

Emphasis in Second Plan (1956-61) was on development of basic and heavy industries and related need to step up power generation. Installed capacity at the end of Second Plan reached 57 lakh kw. comprising 3800 mW thermal and 1900 MW hydel.

During the Third Plan period (1961-66), emphasis was on extending power supply to rural areas. A significant development in this phase was emergence of Inter-state Grid System. The country was divided into Five Regions to promote power development on a Regional Basis. A Regional Electricity

Board was established in each region to promote integrated operation of constituent power system. Three Annual Plans that followed Third Plan aimed at consolidating programmes initiated during the Third Plan.

Fourth Plan envisaged need for central participation in expansion of power generation programmes at strategic locations to supplement activities in the State Sector. Progress during the period covering Third Plan, three Annual Plans and Fourth Plan was substantial with installed capacity rising to 313.07 lakh kW compression; 113.86 lakh kW from Hydro-electric Projects, 192.81 lakh kW from Thermal Power Projects and balance of 6.4 lakh kW from Nuclear Projects at the end of the Fifth Plan.

During the Sixth Plan, total capacity addition of 196.66 lakh kW comprising Hydro 47.68 lakh kW, Thermal 142.08 lakh kW and Nuclear 6.90 lakh kW was planned. Achievement, however, has been 142.26 lakh kW (28.73 lakh kW Hydro, 108.98 lakh kW Thermal and 4.55 lakh kW Nuclear) 72.3 per cent of the target.

The Seventh Plan power programme envisaged aggregate generating capacity of 22,245 mW in utilities. This comprised 15,999 mW Thermal, 5,541 mW Hydro and 705 mW Nuclear of the anticipated 22,245 mW additional capacity. Central Sector Programme envisaged capacity addition of 9,320 mW (7,950 mW Thermal, 665 mW Hydro and 705 mW Nuclear) during the Plan Period. During the Seventh Plan, 21401.48 mW has been added comprising 17104.1 mW Thermal 3,827.38 mW Hydro and 470 mW Nuclear. Year wise commissioning of Hydro, Thermal and Nuclear Capacity added during 1985-86 to 1989-90 is given in.

The Working Group on Power set up particularly the Planning Commission in the context of formulation of power programme for the Eighth Plan has recommended a capacity addition programme of 38,369 mW for the Eighth Plan period, out of which it is expected that the Central Sector Projects would add a capacity of 17,402 mW. The programme for the first year of the Eighth Plan (1990-91) envisages generation of additional capacity of 4,371.5 mW comprising 1,022 mW Hydro, 3,114.5 mW Thermal and 235 mW Nuclear.

The subject 'Power' appears in the Concurrent List of the Constitution and as such responsibility of its development lies both with Central and state governments. At the Centre, Department of Power under the Ministry of Energy is responsible for development of Electric Energy. The department is concerned with policy formulation, perspective planning, procuring of projects for investment decisions, monitoring of projects, training and manpower development, administration and enactment of Legislation in regard to power generation, transmission and distribution. The depart-ment is also responsible for administration of the Electricity (Supply) Act, 1948 and the Indian Electricity Act, 191() and undertakes all amendments thereto. The Electricity (Supply) Act, 1948, forms basis of administrative structure of electricity industry. The Act provides for setting up of a Central Electricity Authority (CEA) with responsibility, inter-alia, to develop a National Power Policy and coordinate activities of various agencies and State Electricity Boards. The act was amended in 1976 to enlarge scope and function of CEA and enable of creation of companies for generation of electricity.

The Central Electricity Authority advises Department of Power on technical, financial and economic matters. Construction and operation of generation and transmission projects in the Central Sector are entrusted to Central Power Corporations, namely, National Thermal Power Corpora-tion (NTPC), National Hydro-Electric Power Corporation (NHPC) and North-Eastern Electric Power Corporation (NEEPCU) under administrative control of the Department of Power. The Damodar Valley Corporation (DVC} constituted under the DVC Act, 1948 and the Bhitkra Beas, Management Board (BBMB) constituted under the Punjab Reorganization. Act, 1966, is also under administrative control of the Department of Power. In addition, the department administers Beas Construction Board (BCB) and National Projects Construction Corporation (NPCC), which are construction agencies and training and research organisations, Central Power Research Institute (CPRI) and Power Engineers Training Society (PETS). Programmes of rural electrification are within the purview of Rural Electrification Corporation (REC) which is a financing agency. "There are two joint venture Power Corporations under the administrative control of the Department of Power, namely, Nathpa jhakri Power Corporation and Tehri Hydro Development Corporation which are responsible for the execution of the Nathpa Jhakri Power Project and Projects of the Tehri Hydro Power Complex respectively. In addition to this, Energy Manage-ment Centre, an autonomous body, was established in collaboration with the European Economic Community, which is responsible for training, research, and information exchange between energy professionals. It is also responsible for conservation of energy programmes/activities in the Department of Power.

Significant progress has been made in the expansion of transmission and distribution facilities in the Country. Total length of transmission lines of 66 kV and above increased from 10,000 ckt (circuit) km in December 1950 to 2.02 lakh ckt Km in March, 1990. Highest transmission voltage in the Country at present is 400 kV and above 19800 ckt km of 400 kV lines had been constructed up to March, 1990 and about 18000 ckt km of these are in actual operation.

Prior to the Fourth Plan, Transmission Systems in the Country were developed more or less as state systems, as generating stations were built primarily in the State Sector. When State Transmission Systems had developed to a reasonable extent in the Third Plan, potentiality of inter-connected operation of individual state systems with other neighboring systems within the region (northern, western, southern, eastern and north-eastern) was thought of. Fairly well inter-connected systems at voltage of 220 kV with progressive overlay of 400 kV are presently available in all regions of the Country except North-eastern Region. With creation of Two Generation Corporations, namely National Thermal Power Corporation and National Hydro-Electric Power Corporation in 1975, the Centre had started playing an increasingly larger role in the development of grid systems.

The 400 kV transmission systems being constructed by these organisa-tions as part of their generation projects, along with 400 kV inter-state and inter-regional transmission lines would form part of the National Power Grid.

National Power Grid will promote integrated operation and transfer of power from one system to another with ultimate objective of ensuring optimum utilisation of resources in the Country. India now has well integrated Regional Power Systems and exchange of power is taking place regularly between a large numbers of state systems, which greatly facilitates better utilisation of existing capacity.

1.8 RESOURCES FOR POWER GENERATION

The hydel power source plays a vital role in the generation of power, as it is a non-conventional perennial source of energy. Therefore the French calls it "huile blanche"—white oil-the power of flowing water. Unlike black oil, it is a non-conventional energy source. A part of the endless cycle in which moisture is raised by the sun, formed into clouds and then dropped back to earth to feed the rivers whose flow can be harnessed to produce hydroelectric power. Water as a source of power is non-polluting which is a prime requirement of power industry today.

The world's total waterpower potential is estimated as 1500 million kW at mean flow. This means that the energy generated at a load factor of 50% would be 6.5 million kW-hr, a quantity equivalent to 3750 million tonnes of coal at 20% efficiency. The world hydel installed capacity (as per 1963 estimate is only 65 million kW or 4.3% of the mean flow.

India has colossal waterpower resources. India's total mean annual river flows are about 1675 thousand million cubic meters of which the usable resources are 555 thousand million cubic meters. Out of total river flows, 60% contribution comes from Himalayan rivers (Ganga, Indus and Brahmaputra). 16% from central Indian rivers (Narmada, Tapti and Mahanadi) and the remaining from the rivers drainning the Deccan plateau (Godavari, Krishna and Cauvery). India's power potential from hydel source as per the recent estimate is 41500 mW while its present hydel capacity is only 32000 mW. Still India has got enough hydel potential to develop to meet the increasing power needs of the nation. The abundant availability of water resources, its fairly even distribution and overall economy in developing this source of energy enhanced its development in India, The other factors responsible in its rapid development are indigenous technological skill, material and cheap labour. In the IX five-year plan; the Government considering the importance of this source has included a number of hydro-projects. The major difficulty in the development of hydroelectric projects is the relatively longer time required for it's hydrological, topographical and geological investigations. Lack of suitable. Site is an added problem for taking up hydro-projects.

Hydropower was once the dominant source of electrical energy in the world and still is in Canada, Norway and Switzerland. But its use has decreased in other countries since 1950s, as relatively less expensive fuel was easily available. In USA, only 10% of the total power production is water-generated. In the light of fuel scarcity and its up surging prices, the role of hydropower is again re-examined and more emphasis is being laid on waterpower development. As per Mr. Hays (Manager of Hydro Projects in USA), "It was less costly per mW to build a single 1000 mW thermal plant than 20 small hydro-plants. But, with the increased fuel cost and high cost of meeting environmental criteria for new thermal plants, interest in hydro is being revived". Small hydro-projects ranging from 10 to 1500 kW are becoming more feasible as standardization of major equipment reduces costs. India is yet to start in the field of micro-hydro projects, which is one major way for solving the present power problem.

Hydro-projects generate power at low cost, it is non conventional, easy to manage, pollution free and makes no crippling demands on the transportation system. But the major drawback is, it operates at the mercy of nature. Poor rainfall has on a number of occasions shown the dangers of over dependence on hydropower.

Let rivers flow and let rains shower the earth with prosperity is the ancient prayer chanted by Riches and continued to be chanted even now.

The development of hydropower systems as a back up for thermal systems has significant advantages. The flexible operation of hydraulic turbines makes them suitable for. Peak load operation. Therefore, the development of hydropower is not only economical but it also solves the major problem of peak load. The present Indian policy of power development gives sufficient importance for the hydel-power development. The next important source for power generation is fuel in the form of coal, oil or gas. Unfortunately, the oil and gas resources are very much limited in India. Only few power plants use oil or gas as a source of energy. India has to import most of the oil required and so it is not desirable to use it for power generation. The known resources of coal in India are estimated to be 121,000 million tonnes, which are localized in West Bengal, Bihar, Madhya Pradesh and Andhra Pradesh. The present rate of annual production of coal is nearly 140 million tonnes of which 40 million-tonnes are used for power generation. The coal used for power generation is mainly low-grade coal with high ash content (20-40%).

The high ash content of Indian coal (40–50%) is one of the causes for bad performance of the existing steam power plants and their frequency outages, as these plants have been designed for low ash coals. Due to the large resources of coal available in the country, enough emphasis has been given for thermal Power plants in the IX plan period.

The location of hydel-power plants is mostly determined by the natural topography available and location of thermal plants is dictated by the source of fuel or transportation facilities available if the, power plant is to be located far from coalmines. For nuclear power plant any site can be selected paying due consideration to safety and load. India has to consider nuclear generation in places remote from coal mines and water power sites. The states which are poor in natural resources and those which have little untapped conventional resources for future development have to consider the development of nuclear plants.

The nuclear fuel which is commonly used for nuclear power plants is uranium. Deposits of uranium have been located in Bihar and Rajasthan. It is estimated that the present reserves of uranium available in country may be sufficient to sustain 10,000 mW power plants for its thorium into nuclear Indian lifetime. Another possible nuclear power source is thorium, which is abundant in this country, estimated at 500,000 tonnes. But the commercial use of this nuclear fuel is tied up with development of fast breeder reactor which converts energy economy must wait for the development of economic methods for using thorium which is expected to be available before the end of twentieth century. The major hurdle in the development of nuclear power in this country is lack of technical facility and foreign exchange required to purchase the main component of nuclear power plant. Dr. Bhabha had envisaged 8000 mW of power from nuclear reactors by 1980–81 which was subsequently scaled down to a more realistic level of 2700 mW by Dr. Sarabhai out of this only 1040 MW has materialized which is less than 1.5% of the country's installed power capacity. Moreover the performance of nuclear plants has been satisfactory compared to thermal plants.

1.9 PRESENT POWER POSITION IN INDIA

The present power position in India is alarming as there are major power shortages in almost all states of the country leading to crippling of industries and hundreds of thousands of people losing jobs and a heavy loss of production.

The overall power scene in the country shows heavy shortages almost in all states. The situation is going to be aggravated in coming years as the demand is increasing and the power industry is not keeping pace with the increasing demand.

Many of the states in India depend to a large extent on hydro generation. The increase in demand has far outstripped the installation of new plants. Also there is no central grid to distribute excess energy from one region to another. The experience in the operation of thermal plants is inadequate. All these have led to heavy shortages and severe hardship to people.

Very careful analysis of the problem and proper planning and execution is necessary to solve the power crisis in our country.

Suitable hydrothermal mix, proper phasing of construction of new plants, training personnel in maintenance of thermal plants.

1.10 FUTURE PLANNING FOR POWER GENERATION

Considering the importance of power industry in the overall development of the country, power sector has been given high priority in the country's development plans. Energy sector alone accounts for about 29% of sixth plan investment. If investments in coal and oil transport and other infrastructures are taken into account, the total investment in the energy sector will account for about 40% of the plan investments. The fact alone is sufficient to exhibit the importance of power industry for the country's development. From a mere Rs. 149 crores in the First Plan, the outlay for power during sixth plan period has increased to Rs. 15750 crores. The installed generating capacity has grown ten-fold from 2300 mW in 1951 to 25900 mW in 1978. Of this, 11000 mW was in hydel, 14000 mW in thermal and less than 1000 mW in nuclear power stations. The total number of power stations of 20 mW capacities and above at the end of March 1978, was 127, of which 65 were hydel, 60 thermal and 2 nuclear. Power generation rose from 7514 million kWh in 1950–51 to 103754 million kWh in 1978–79, *i.e.,* nearly 15 times. The total users of electricity have risen from 15 lakhs in 1950 to 2641akhs in 1978–79. The per capita consumption of electricity rose from 18 kWh in 1950–51 to 121 kWh in 1978–79.

In spite of these measures, this industry is unable to meet the demands. Power shortages have become a recurrent feature in the country. Against an estimated requirement of 108656 million kWh in 1978-79, the actual availability was only a 97588 million kWh a deficit of about 11070 million kWh or 10.2°C.

With the programme of large-scale industrialization and increased agricultural activity, the demand for power in the country is increasing at a rapid rate. If the present trend continues, the demand for power by the end of year 2000 would be about 125 to 150 million kW. Allowing for adequate reserve margins required for scheduled maintenance, a total generating capacity of about 175 to 200 million kW would be needed by the year 2000 to meet the anticipated demands. This would mean 8 to 10 fold increase of the existing capacity.

Only proper development of hydel, thermal and nuclear resources of the country can achieve the required growth. Out of total available hydel-potential (41,000 mW), only 16% has been developed, therefore there is sufficient scope to develop this source of power in future. The major hydel potential is available in the northern region. Even if all the hydel potential is developed, it will not be possible to meet the growing demand. Therefore, it is necessary to supplement the hydel potentials with thermal. The coal deposits are rich and ample, though in terms of per capita it is hardly 176 tonnes in India which is certainly poor compared with other countries as 1170 tonnes in China, 13500 tonnes in the U.S.A. and 22000 tonnes in the former U.S.S.R. The available coal is also unevenly distributed in the country (60°C only in Bihar and Bengal). This further requires the development of transportation facilities.

Therefore, it is also not possible to depend wholly on thermal power development. The consideration for the use of nuclear fuel for power production in future is equally essential particularly in those states, which are far away from coal resources and poor in hydel potential.

The future planning in the power development should aim at optimum exploitation of resources available so that power mix of hydel, thermal and nuclear is achieved.

Another step to be taken in the power development industry is setting up super-thermal power plants the central sector at different places in the country. The super-thermal power stations are at Farakka, Ramagundam, Korba and Singrauli and these are supplying power for the past 20 years. Presently all of them are supplying power through the national grid to deficit states.

In our country even 20 mW hydro potentials have not been developed, whereas it appears to be advantageous to develop even 20 kW units. Development of small hydro potentials as in China has, to a great extent, reduced the strain in existing plants.

The development of biogas can ease the strain on oil supply to domestic users, which can otherwise diverted to power generation.

Another suggestion to face the present alarming power situation in the country is Energy Plantation. India receives large amount of solar radiation and photosynthesis is the process by which solar energy is converted into food and fuel by green plants. Fast growing species of trees give a yield of about 15 to 35 tonnes/hectare/year. The land, which is presently not used either for agriculture or forest, can be used for energy plantation where average rainfall is 80 to 100 cm per annum. With present Forest Technology, planned production forestry offers an unusual opportunity. If the forest area is increased from present 22 to 30%, increase in forest area is 30 million hectares of land) it can yield sufficient energy after next 20 years. The Government does not seriously think this phase of energy production but it looks a fruitful proposition.

As per the present planning of the Government, the problem of increased power demand will be solved only by proper mixed development of hydel, thermal and nuclear atleast during one more decade.

The severity of the power problem can be partly solved by the conservation of power. The efficiency hest thermal power plant is 35%. In India, it is hardly 25%. If auxiliary consumption and line loss are taken into account, the efficiency still goes to hardly 16%. The problem can be partly solved by proper maintenance and good quality of fuel supply.

The efficiency of the power plant operation is also defined as kWh generated per kW installed. The maximum kWh per annum per kW is 8760. The average figure in India is hardly 4000, which shows that the utilisation is only 45%. If this utilisation is increased, need for new capacity for power generation will be reduced.

Increasing load factors can reduce the capacity of the power industry. The proper planning to develop hydel, thermal and nuclear resources in India in addition to measures taken to reduce outages and with proper load management will definitely go a long way in meeting the increasing power demand of the country.

1.11 POWER CORPORATIONS IN INDIA

1.11.1 NATIONAL THERMAL POWER CORPORATION

National Thermal Power Corporation (NTPC) was incorporated in November, 1975, as a public sector undertaking with main objective of planning, promoting and organising integrated development of Thermal Power in the Country. The Authorized Capital of the corporation is Rs. 6,000 crore.

NTPC is currently constructing and operating the Nine Super Thermal Power Projects at Singrauli (UP), Korba (MP), Ramagundam.(AP), Farakka (WB), Vindhyachal (MP), Rihand (UP), Kahalgaon (Bihar), Dadri (UP), Talcher (Orissa) and Four Gas-based Projects at Anta (Rajasthan), Auraiya (UP), Dadri (UP) and Kawas (Gujarat) with a total approved capacity of 15,687 mW. The corporation is also executing transmission lines of total length of about 20,200 ckt. km. NTPC has been entrusted with management of Badarpur Thermal Power Station (720 mW) which is a major source of power to Delhi.

Installed capacity of NTPC Projects stands at 9915 mW. The corporation has fully completed its projects at Singrauli (2,000 mW), Korba (2,100 mW) and Ramagundam (2,100 mW) and Rihand and Two Gas-based Projects at Anta (413 mW) and Auraiya (652 mW).

1.11.2 NATIONAL HYDRO-ELECTRIC POWER CORPORATION

The National Hydroelectric Power Corporation (NHPC) was incorporated in November 1975, with objectives to plan, promote and organize an integrated development of hydroelectric Power in the

Central Sector. NHPC is presently engaged in construction of Dulhasti, Uri and Salal (Stage-II) Hydro-electric Projects (all in Jammu and Kashmir), Chamera Stage-1 (Himachal Pradesh), Tanakpur Project (UP) and Rangit Project (Sikkim). NHPC is also responsible for operation and maintenance of Salal Project Stage-I (J & K), Baira Siul Project (Himachal Pradesh) and Loktak Project (Manipur).

NHPC has a shelf of projects ready with all statutory clearances awaiting Government Sanction for execution. These are Baglihar and Sawalkot (both in J & K), Chamera II (H.P.), Dhauliganga Stage-I (U.P.) and Koel Karo (Bihar). NHPC have completed investigation of Dhaleswari (Mizoram), Dhauliganga Intermediate Stage (U.P.) Goriganga Stage I and II (U.P.) and Kishenganga (J & K). These are under techno-economic appraisal by CEA. The Corporation is continuing investigations on Goriganga-III (U.P.). Two Mega Projects *viz.,* Teesta (Sikkim) and Katch Tidal Project (Gujarat) presently under techno-economic appraisal by CEA have also been entrusted to NHPC for execution.

The corporation has completed so far 3220 ckt kms of EHV transmission lines, along with the associated sub-stations. Besides, a giant transmission network encompassing 3170 ckt kms including 800 KV class is also under execution under World Bank Assistance for transfer for power in the Northern Region. In the snow-bound areas of J & K, a 400 kV Dulhasti Transmission Line is also under execution under Russian Assistance.

1.11.3 RURAL ELECTRIFICATION CORPORATION

The Rural Electrification Corporation (REC) was set up in July, 1969, with the primary objective of promoting rural electrification by financing rural Electrification Schemes and Rural Electric Cooperatives in the states.

REC have given loans aggregating to Rs. 4742.49 crore by 1989–90 to States and State Electricity Boards for the Rural Electrification Schemes. Loans during 1989–90 aggregated to Rs. 724.60 crore.

1.11.4 DAMODAR VALLEY CORPORATION

Damodar Valley Corporation (DVC) was established in 1948 under an Act of Parliament for unified development of Damodar Valley covering an area of 24,235 sq km in Bihar and West Bengal. Functions assigned to the corporation are: control of floods, irrigation, generation and transmission of power besides activities like navigation, soil conservation and afforestation, promotion of public health and agricultural, industrial and economic development of the valley. The corporation has Three Thermal Power Stations at Bokaro, Chandrapura and Durgapur with a total installed capacity (derated) of 1755 mw. It has four multi-purpose Dams at Tilaiya, Maithon, Panchet and Konar. There are three Hydel Stations appended to Tilaiya, Maithon and Panchet Dams with a capacity of 144 mW. DVC has also set up three Gas Turbine Units of 30 mW each at Maithon. The corporation is installing one more thermal units of 210 mW at Bokaro ‘B’, Three Thermal Units of 210 mW each at Mejia and the fourth units of 210 mW each at the right bank of Maithon.

1.11.5 NORTH-EASTERN ELECTRIC POWER CORPORATION LIMITED

The North-Eastern Electric Power Corporation Ltd., was constituted in 1976 under the Companies Act under the aim of developing the large electric power potential of the North-Eastern Region. The corporation is responsible for operation and maintenance of the 150 mW Kopili Hydro Electric Project which was commissioned in, June/July, 1988. The associated 220 kV and 132 kV transmission lines for supply power from this project to the constituent states of the region, namely; Assam, Manipur, Mizoram and Tripura, have also been completed.

The Corporation is presently executing the following projects: (*i*) Dovang Hydro-Electric Project (75 mW) Nagaland; (*ii*) Ranganadi Hydro Electric Project (405 mW) Arunachal Pradesh; (*iii*) Assam Gas Based Project (280 mW) Assam; (*iv*) Doyang Transmission Line Project; (*v*) Kanganaali Transmission Line Project; (*vi*) Gohpur-Itanagar Transmission Line Project and (*vii*) 400 kV Transmission Line System associated with the Assam Gas Based Project.

1.11.6 BHAKRA BEAS MANAGEMENT BOARD AND BEAS CONSTRUCTION BOARD

Under the Punjab Reorganization Act. 1966, Bhakra Management Board thereto managed management of Bhakra Darn and reservoirs and works appurtenant. The construction of Beas Project was undertaken by the Beas Construction Board. After completion of works of Beas Project, management of the project was taken over by Bhakra Management Board redesignated as Bhakra Beas Management Board (BBMB). BBMB now manages Hydro-electric Power Stations of Bhakra-Beas Systems, namely. Bhakra Right Bank (660 mW), Bhakra Left Bank (540 mW), Ganguwal (77 mW), Kotla (77 mW), Dehar Stage-I (660 mW), Debar Stage-II (330 mW). Pong Stage-I (240 mW) and Pong Stage-I1 (120 mW), all having a total installed capacity of 2,704 mW.

1.11.7 POWER ENGINEERS TRAINING SOCIETY (PETS)

The Power Engineers Training Society (PETS) was formed in 1980 as a autonomous body to function as an Apex National Body for meeting the training requirements of Power Sector in the Country. The society is responsible for coordinating training programmes of the various State Electricity Boards, Power stations, etc. and supplementing these with its own training activities. The society has Four Regional "Thermal Power Station Personnel Training Institutes at Neyveli, Durgapur, Badarpur (New Delhi) and Nagpur. These Training Institutes conduct regular induction courses, in-service refresher and short-term courses, on job and on plant training programmes for Power Engineers, operators and technicians of Thermal Power Stations/State Electricity Boards, etc. A Simulator installed at the Training Institute at Badarpur (New Delhi) provides training to engineers and operators of 210 mW Thermal Units.

1.11.8 CENTRAL POWER RESEARCH INSTITUTE (CPRI), BANGALORE

The Central Power Research Institute, which was set up in 1960 as a subordinate office under the erstwhile Central Water and Power Commission (Power Wing), was reorganised and registered as a Society under the Karnataka Societies Act, 1960, with effect from January, 1978. The CPRI functions as a National Laboratory for applied research in the field of Electric Power Engineering. While the Central Power Research Institute has a Switchgear Testing and Development Station at Bhopal, the main complex of its laboratories is at Bangalore. The institute is an Apex Body for Research and Development in the Power Sector and conducts tests of electrical apparatus in accordance with the National/International Standards so as to meet fully the research and testing needs of electrical, transmission and distribution equipment. The CPRI also serves as a National Testing and Certification Authority for transmission and distribution equipment. The institute possesses Highly Sophisticated Laboratories comparable to those in the Developed Countries.

1.11.9 NATHPA, JHAICRI POWER CORPORATION LIMITED

NJPC, a joint venture of the Centre and Government of Himachal Pradesh, was incorporated on May 24, 1988, for execution of Nathpa Jhakri Power Project (6 × 250 mW) with equity participation in the ratio of 3 : 1. The corporation has an authorized Share Capital of Rs 1,000 crore. It will also execute other Hydro-electric Power Projects in the region with consent of the state government.

The corporation has already taken up execution of Nathpa Jhakri Hydro-electric Project (6 × 250 mW) for which World Bank has agreed to extend financial assistance of 4370 lakh US dollar. The project is estimated to cost Rs. 1,678 crore (at September, 1988, price level). At present, infrastructure works on the project site are under execution. Drifts at Power House Site at Jhakri and Desalting Complex at Nathpa aggregating to a length of 2850 metres have been executed. Drill Holes at various locations totaling a length of 4300 metres as per recommendations of GSI have been made. About 76 hectares of land was acquired and acquisition proceedings for above 400 hectares are underway. About 26 kms of 22 kV double circuit HT Line and about 11 kms of 22 kV single circuit HT Line have also been completed for Construction Power. About 46 kms of roads have also been constructed. About 46250 sq. metres of buildings have been constructed. The project is expected to be completed within a period of about seven years and would yield benefits during the Eighth Plan.

1.12 REVIEW OF THERMODYNAMICS CYCLES RELATED TO POWER PLANTS

Thermodynamics is the science of many processes involved in one form of energy being changed into another. It is a set of book keeping principles that enable us to understand and follow energy as it transformed from one form or state to the other.

The zeroth law of thermodynamics was enunciated after the first law. It states that if two bodies are each in thermal equilibrium with a third, they must also be in thermal equilibrium with each other. Equilibrium implies the existence of a situation in which the system undergoes no net charge, and there is no net transfer of heat between the bodies.

The first law of thermodynamics says that energy can't be destroyed or created. When one energy form is converted into another, the total amount of energy remains constant. An example of this law is a gasoline engine. The chemical energy in the fuel is converted into various forms including kinetic energy of motion, potential energy, chemical energy in the carbon dioxide, and water of the exhaust gas.

The second law of thermodynamics is the entropy law, which says that all physical processes proceed in such a way that the availability of the energy involved decreases. This means that no transformation of energy resource can ever be 100% efficient. The second law declares that the material economy necessarily and unavoidably degrades the resources that sustain it. Entropy is a measure of disorder or chaos, when entropy increases disorder increases.

The third law of thermodynamics is the law of unattainability of absolute zero temperature, which says that entropy of an ideal crystal at zero degrees Kelvin is zero. It's unattainable because it is the lowest temperature that can possibly exist and can only be approached but not actually reached. This law is not needed for most thermodynamic work, but is a reminder that like the efficiency of an ideal engine, there are absolute limits in physics.

The steam power plants works on modified rankine cycle in the case of steam engines and isentropic cycle concerned in the case of impulse and reaction steam turbines. In the case of I.C. Engines (Diesel Power Plant) it works on Otto cycle, diesel cycle or dual cycle and in the case of gas turbine it works on Brayton cycle, in the case of nuclear power plants it works on Einstein equation, as well as on the basic principle of fission or fusion. However in the case of non-conventional energy generation it is complicated and depends upon the type of the system *viz.,* thermo electric or thermionic basic principles and theories et al.

1.13 CLASSIFICATION OF POWER PLANT CYCLE

Power plants cycle generally divided in to the following groups,

(1) Vapour Power Cycle

(Carnot cycle, Rankine cycle, Regenerative cycle, Reheat cycle, Binary vapour cycle)

(2) Gas Power Cycles

(Otto cycle, Diesel cycle, Dual combustion cycle, Gas turbine cycle.)

1.13.1 CARNOT CYCLE

This cycle is of great value to heat power theory although it has not been possible to construct a practical plant on this cycle. It has high thermodynamics efficiency.

It is a standard of comparison for all other cycles. The thermal efficiency (η) of Carnot cycle is as follows:

$$\eta = (T_1 - T_2)/T_1$$

where, T_1 = Temperature of heat source

T_2 = Temperature of receiver

1.13.2 RANKINE CYCLE

Steam engine and steam turbines in which steam is used as working medium follow Rankine cycle. This cycle can be carried out in four pieces of equipment joint by pipes for conveying working medium as shown in Fig. 1.1. The cycle is represented on Pressure Volume P-V and S-T diagram as shown in Figs. 1.2 and 1.3 respectively.

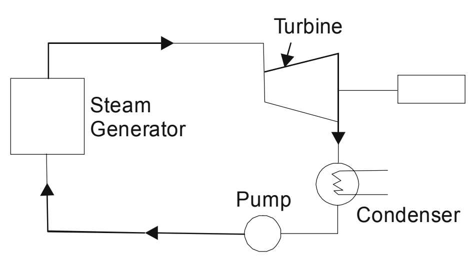

Fig. 1.1

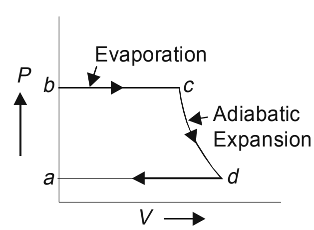

Fig. 1.2

Efficiency of Rankine cycle

$$= (H_1 - H_2)/ (H_1 - H_{w2})$$

where,

H_1 = Total heat of steam at entry pressure

H_2 = Total heat of steam at condenser pressure (exhaust pressure)

H_{w2}= Total heat of water at exhaust pressure

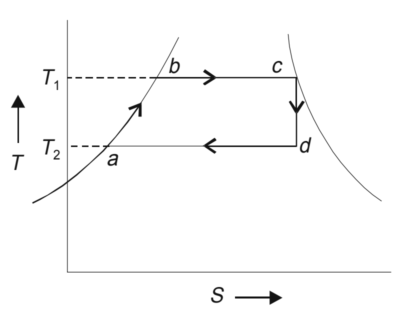

Fig. 1.3

1.13.3 REHEAT CYCLE

In this cycle steam is extracted from a suitable point in the turbine and reheated generally to the original temperature by flue gases. Reheating is generally used when the pressure is high say above 100 kg/cm^2. The various advantages of reheating are as follows:

(*i*) It increases dryness fraction of steam at exhaust so that blade erosion due to impact of water particles is reduced.

(*ii*) It increases thermal efficiency.

(*iii*) It increases the work done per kg of steam and this results in reduced size of boiler.

The disadvantages of reheating are as follows:

(*i*) Cost of plant is increased due to the reheater and its long connections.

(*ii*) It increases condenser capacity due to increased dryness fraction.

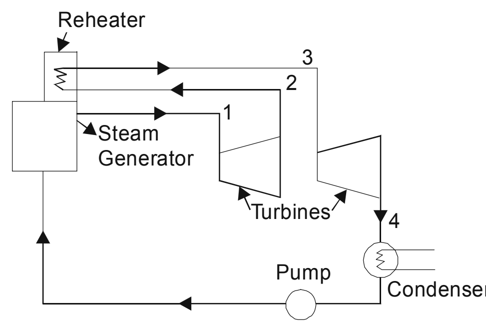

Fig. 1.4

Fig. 1.4 shows flow diagram of reheat cycle. First turbine is high-pressure turbine and second turbine is low pressure (L.P.) turbine. This cycle is shown on T-S (Temperature entropy) diagram (Fig. 1.5).

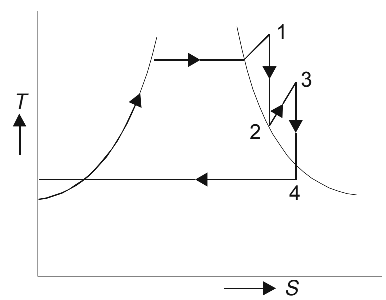

Fig. 1.5

If,

H_1 = Total heat of steam at 1

H_2 = Total heat of steam at 2

H_3 = Total heat of steam at 3

H_4 = Total heat of steam at 4

H_{w4} = Total heat of water at 4

Efficiency = $\{(H_1 - H_2) + (H_3 - H_4)\}/\{H_1 + (H_3 - H_2) - H_{w4}\}$

1.13.4 REGENERATIVE CYCLE (FEED WATER HEATING)

The process of extracting steam from the turbine at certain points during its expansion and using this steam for heating for feed water is known as Regeneration or Bleeding of steam. The arrangement of bleeding the steam at two stages is shown in Fig. 1.6.

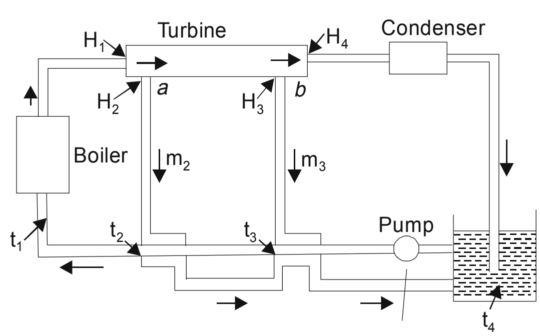

Fig. 1.6

Let,

m_2 = Weight of bled steam at a per kg of feed water heated

m_2 = Weight of bled steam at a per kg of feed water heated

H_1 = Enthalpies of steam and water in boiler

H_{w1} = Enthalpies of steam and water in boiler

H_2, H_3 = Enthalpies of steam at points *a* and *b*

t_2, t_3 = Temperatures of steam at points *a* and *b*

H_4, H_{w4} = Enthalpy of steam and water exhausted to hot well.

Work done in turbine per kg of feed water between entrance and *a*

$$= H_1 - H_2$$

Work done between *a* and *b* = $(1 - m_2)(H_2 - H_3)$

Work done between *b* and exhaust = $(1 - m_2 - m_3)(H_3 - H_4)$

Total heat supplied per kg of feed water = $H_1 - H_{w2}$

Efficiency (η) = Total work done/Total heat supplied

$$= \{(H_1 - H_2) + (1 - m_2)(H_2 - H_3) + (1 - m_2 - m_3)(H_3 - H_4)\}/(H_1 - H_{w2})$$

1.13.5 BINARY VAPOUR CYCLE

In this cycle two working fluids are used. Fig. 1.7 shows Elements of Binary vapour power plant. The mercury boiler heats the mercury into mercury vapours in a dry and saturated state.

These mercury vapours expand in the mercury turbine and then flow through heat exchanger where they transfer the heat to the feed water, convert it into steam. The steam is passed through the steam super heater where the steam is super-heated by the hot flue gases. The steam then expands in the steam turbine.

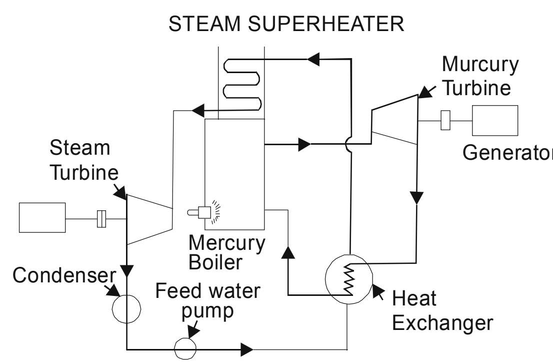

Fig. 1.7

1.13.6 REHEAT-REGENERATIVE CYCLE

In steam power plants using high steam pressure reheat regenerative cycle is used. The thermal efficiency of this cycle is higher than only reheat or regenerative cycle. Fig. 1.8 shows the flow diagram of reheat regenerative cycle. This cycle is commonly used to produce high pressure steam (90 kg/cm^2) to increase the cycle efficiency.

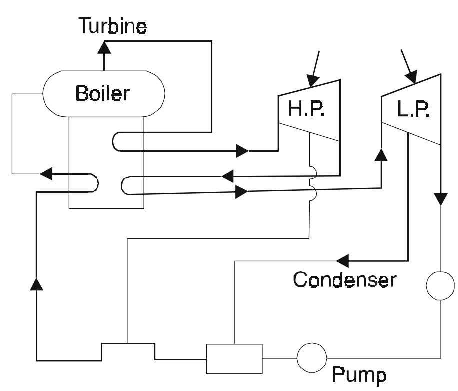

Fig. 1.8

1.13.7 FORMULA SUMMARY

1. Rankine efficiency

$$= (H_1 - H_2)/(H_1 - H_{w2})$$

2. Efficiency ratio or Relative efficiency

= Indicated or Brake thermal efficiency/Rankine efficiency

3. Thermal efficiency = $3600/m(H_1 - H_{w2})$, m = steam flow/kw hr

4. Carnot efficiency = $(T_1 - T_2)/T_1$

1.14 FUELS AND COMBUSTION

The working substance of the energy conversion device *viz.*, prime-mover (which convert the natural resources of energy into power or electricity) is called fuel. The most common fuel is fossil fuel *viz.,* Coal, petrol, diesel or water gas in the case of steam power plants, I.C. Engines, gas turbines, and hydro-electric power plants. Uranium 235($1U^{235}$) as fissionable and $1U^{238}$ as fertile fuel in the case of fission reactors of nuclear power plant and hydrogen as fuel in the case of fusion nuclear reactor. While fission reactor is conventional fusion reactor is supposed to be non-conventional due to its uncontrolled reaction rate; and it is believed that Russian's have developed it but keeping the whole world silence. In the case of non-conventional power plants the fuels are according to their characteristics *viz.,* Thermo-electric material (Bi_2Te_3, bismuth telluride, lead telluride etc.); thermionic materials (Na, K, Cs, W etc.); hydrogen or hydrocarbon or coal in the case of fuel-cells and further water and methane etc in the recent development of the sources of energy.

Combustion of the fuel is a must in any energy conversion device. It is defined as rapidly proceeding chemical reaction with liberation of heat and light. This phenomenon incurved in the case of thermal power plants especially in I.C. engines and gas turbines. But in the case of fuel cell it is of the nature of chemical reaction *i.e.,* transfer of ions, similarly in the case of thermo-electric generator it is conduction of electron and holes, in the case of MHD power plant it is drifting of positive and negative ion etc.

1.15 STEAM GENERATORS

Steam is mainly required for power generation, process heating and pace heating purposes. The capacity of the boilers used for power generation is considerably large compared with other boilers.

Due to the requirement of high efficiency, the steam for power generation is produced at high pressures and in very large quantities. They are very large in size and are of individual design depending the type of fuel to be used.

The boilers generating steam for process heating are generally smaller in size and generate steam at a much lower pressure. They are simpler in design and are repeatedly constructed to the same design. Though most of these boilers are used for heating purposes, some, like locomotive boilers are used for power generation also. In this chapter, some simple types of boilers will be described.

A steam generator popularly known as boiler is a closed vessel made of high quality steel in which steam is generated from water by the application of heat. The water receives heat from the hot gases though the heating surfaces of the boiler. The hot gases are formed by burning fuel, may be coal, oil or gas. Heating surface of the boiler is that part of the boiler which is exposed to hot gases on one side and water or steam on the other side. The steam which is collected over the water surface is taken from the boiler through super heater and then suitable pipes for driving engines or turbines or for some industrial heating purpose. A boiler consists of not only the steam generator but also a number of parts to help for the safe and efficient operation of the system as a whole. These parts are called mountings and accessories.

1.16 STEAM PRIME MOVERS

The prime mover convert the natural resources of energy into power or electricity.

The prime movers to be used for generating electricity could be diesel engine, steam engine, steam turbines, gas turbines, and water turbine.

Since we know that, a power plant generated a flow of mechanical or electrical energy by means of generators. When coupling runs the generator, then the generator is a prime mover.

In case of steam power plant, the prime movers is steam engine or steam turbine, which is called, steam prime movers. Presently, the steam turbine has totally replaced steam engine. The steam is generated in a boiler and is then expanded in the turbine. The output of the steam turbine is utilized to run the generator. The fuel used in the boiler is coal or oil.

1.17 STEAM CONDENSERS

Thermal efficiency of a closed cycle power developing system using steam as working fluid and working on Carnot cycle is given by an expression $(T_1 - T_2)/T_1$. This expression of efficiency shows that the efficiency increases with an increase in temperature T_1 and decrease in temperature T_2. The maximum temperature T_1 of the steam supplied to a steam prime mover is limited by material considerations. The temperature T_2 (temperature at which heat is rejected) can be reduced to the atmospheric temperature if the exhaust of the steam takes place below atmospheric pressure. If the exhaust is at atmospheric pressure, the heat rejection is at 100°C.

Low exhaust pressure is necessary to obtain low exhaust temperature. But the steam cannot be exhausted to the atmosphere if it is expanded in the engine or turbine to a pressure lower than the atmospheric pressure. Under this condition, the steam is exhausted into a vessel known as condenser where the pressure is maintained below the atmosphere by continuously condensing the steam by means of circulating cold water at atmospheric temperature.

A closed vessel in which steam is condensed by abstracting the heat and where the pressure is maintained below atmospheric pressure is known as a condenser. The efficiency of the steam plant is considerably increased by the use of a condenser. In large turbine plants, the condensate recovery becomes very important and this is also made possible by the use of condenser.

The steam condenser is one of the essential components of all modern steam power plants.

Steam condenser are of two types:

1. Surface condenser. 2. Jet condensers

1.17.1 SURFACE CONDENSERS

In surface condensers there is no direct contact between the steam and cooling water and the condensate can be re-used in the boiler: In such condenser even impure water can be used for cooling purpose whereas the cooling water must be pure in jet condensers. Although the capital cost and the space needed is more in surface condensers but it is justified by the saving in running cost and increase in efficiency of plant achieved by using this condenser. Depending upon the position of condensate extraction pump, flow of condensate and arrangement of tubes the surface condensers may be classified as follows:

(*i*) **Down flow type.** Fig. 1.9 shows a sectional view of dawn flow condenser. Steam enters at the top and flows downward. The water flowing through the tubes in one direction lower half comes out in the opposite direction in the upper half Fig. 1.10 shows a longitudinal section of a two pass down-flow condenser.

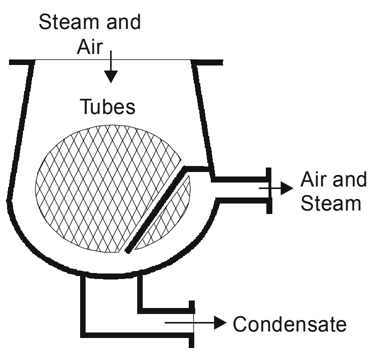

Fig. 1.9

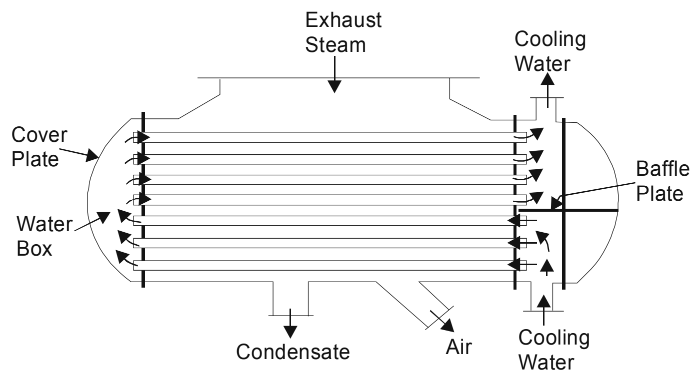

Fig. 1.10

(*ii*) **Central flow condenser.** Fig. 1.11 shows a central flow condenser. In this condenser the steam passages are all around the periphery of the shell. Air is pumped away from the centre of the condenser. The condensate moves radially towards the centre of tube nest. Some of the exhaust steams while moving towards the centre meets the undercooled condensate and pre-heats it thus reducing undercooling.

(*iii*) **Evaporation condenser.** In this condenser (Fig. 1.12) steam to be condensed is passed through a series of tubes and the cooling waterfalls over these tubes in the form of spray. A steam of air flows over the tubes to increase evaporation of cooling water, which further increases the condensation of steam.

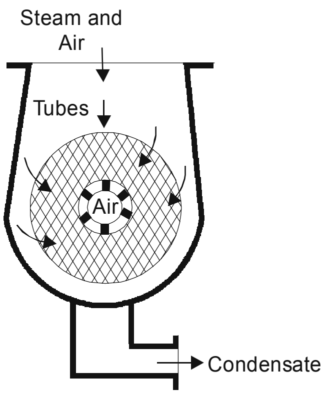

Fig. 1.11

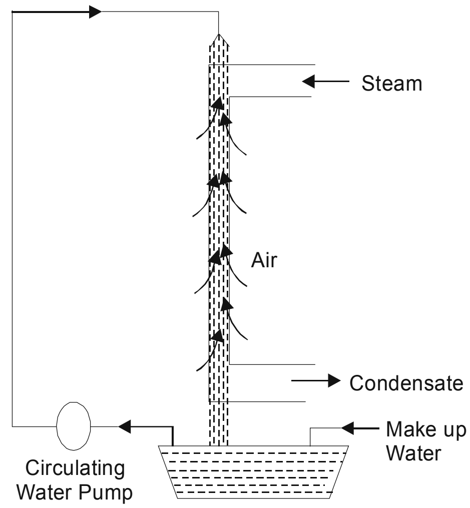

Fig. 1.12

ADVANTAGES AND DISADVANTAGES OF A SURFACE CONDENSER

The various advantages of a surface condenser are as follows:

1. The condensate can be used as boiler feed water.
2. Cooling water of even poor quality can be used because the cooling water does not come in direct contact with steam.
3. High vacuum (about 73.5 cm of Hg) can be obtained in the surface condenser. This increases the thermal efficiency of the plant.

The various disadvantages of' the surface condenser are as follows:

1. The capital cost is more.
2. The maintenance cost and running cost of this condenser is high.
3. It is bulky and requires more space.

REQUIREMENTS OF A MODERN SURFACE CONDENSER

The requirements of ideal surface condenser used for power plants are as follows:

1. The steam entering the condenser should be evenly distributed over the whole cooling surface of the condenser vessel with minimum pressure loss.
2. The amount of cooling water being circulated in the condenser should be so regulated that the temperature of cooling water leaving the condenser is equivalent to saturation temperature of steam corresponding to steam pressure in the condenser.

This will help in preventing under cooling of condensate.

3. The deposition of dirt on the outer surface of tubes should be prevented.

Passing the cooling water through the tubes and allowing the steam to flow over the tubes achieve this.

4. There should be no air leakage into the condenser because presence of air destroys the vacuum in the condenser and thus reduces the work obtained per kg of steam. If there is leakage of air into the condenser air extraction pump should be used to remove air as rapidly as possible.

1.17.2 JET CONDENSERS

In jet condensers the exhaust steam and cooling water come in direct contact with each other.

The temperature of cooling water and the condensate is same when leaving the condensers.

Elements of the jet condenser are as follows:

1. Nozzles or distributors for the condensing water.
2. Steam inlet.
3. Mixing chambers: They may be (*a*) parallel flow type (*b*) counter flow type depending on whether the steam and water move in the same direction before condensation or whether the flows are opposite.
4. Hot well.

In jet condensers the condensing water is called injection water.

1.17.3 TYPES OF JET CONDENSERS

1. Low level jet condensers (Parallel flow type). In this condenser (Fig. 1.13) water is sprayed through jets and it mixes with steam. The air is removed at the top by an air pump. In counter flow type of condenser the cooling water flows in the downward direction and the steam to be condensed moves upward.

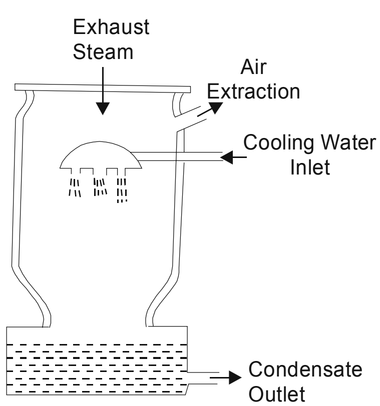

Fig. 1.13

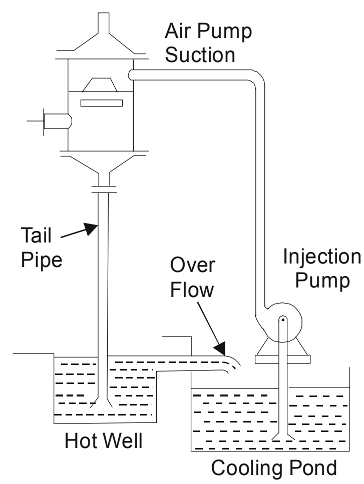

Fig. 1.14

2. High level or Barometric condenser. Fig. 1.14 shows a high-level jet condenser. The condenser shell is placed at a height of 10.33 m (barometric height) above the hot well. As compared to low level jet condenser. This condenser does not flood the engine if the water extraction pump fails. A separate air pump is used to remove the air.

3. Ejector Condenser. Fig. 1.15 shows an ejector condenser. In this condenser cold water is discharged under a head of about 5 to 6 m through a series of convergent nozzles. The steam and air enter the condenser through a non-return valve. Mixing with water condenses steam. Pressure energy is partly convert into kinetic energy at the converging cones. In the diverging come the kinetic energy is partly converted into pressure energy and a pressure higher than atmospheric pressure is achieved so as to discharge the condensate to the hot well.

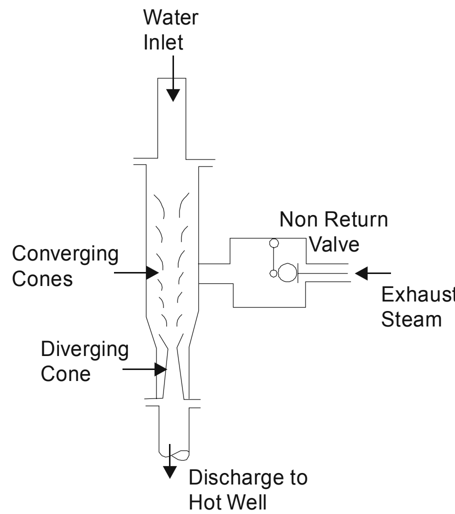

Fig. 1.15

1.18 WATER (HYDRAULIC) TURBINES

Turbine is a machine wherein rotary motion is obtained by centrifugal forces, which result from a change in the direction of high velocity fluid jet that issues from a nozzle.

Water turbine is a prime mover, which uses water as the working substance to generate power.

A water turbine uses the potential and kinetic energy of water and converts it into usable mechanical energy. The fluid energy is available in the natural or artificial high level water reservoirs, which are created by constructing dams at appropriate places in the flow path of rivers. When water from the reservoir is taken to the turbine, transfer of energy takes place in the blade passages of the unit. Hydraulic turbines in the form of water wheels have been used since ages; presently their application lies in the field of electric power generation. The mechanical energy made available at the turbine shaft is used to run an electric generator, which is directly coupled, to the turbine shaft. The power generated by utilizing the potential and kinetic energy of water has the advantages of high efficiency, operational flexibility, low wear tear, and ease of maintenance.

Despite the heavy capital cost involved in constructing dams and reservoirs, in running pipelines and in turbine installation (when compared to an equivalent thermal power plant) different countries have tried to tap all their waterpower resources. Appropriate types of water turbines have been installed for most efficient utilization. A number of hydro-electric power plants have and are being installed in India too to harness the available waterpower in the present crisis of fast idling energy resources. Hydro-electric power is a significant contributor to the world’s energy sources.

Water (hydraulic) turbines have been broadly classified as,

1. Impulse 2. Reaction

1.18.1 IMPULSE AND REACTION TURBINES

Hydraulic turbines are required to transform fluid energy into usable mechanical energy as efficiently as possible. Further depending on the site, the available fluid energy may vary in its quantum of potential and kinetic energy. Accordingly a suitable type of turbine needs to be selected to perform the required job.

Based upon the basic operating principle, water turbines are categorized into impulse and reaction turbines depending on whether the pressure head available is fully or partially converted into kinetic energy in the nozzle.

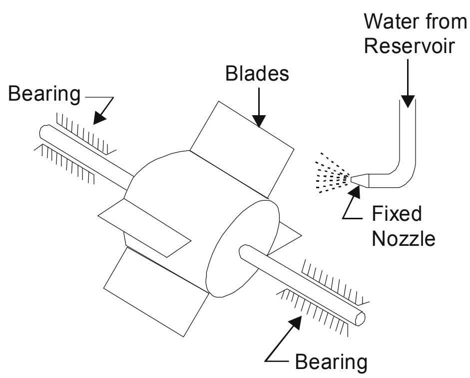

Fig. 1.16. Impulse Turbine.

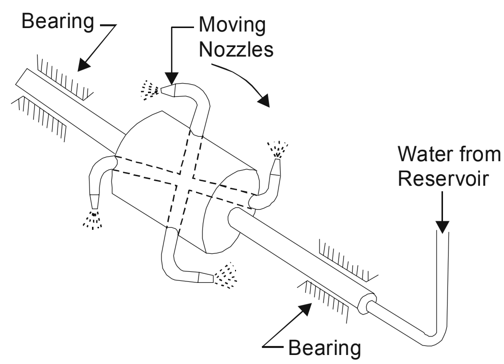

Fig. 1.17. Reaction Turbine.

Impulse Turbine wherein the available hydraulic energy is first converted into kinetic energy by means of an efficient nozzle. The high velocity jet issuing from the nozzle then strikes a series of suitably shaped buckets fixed around the rim of a wheel (Fig. 1.16). The buckets change the direction of jet without changing its pressure. The resulting change in momentum sets buckets and wheel into rotary motion and thus mechanical energy is made available at the turbine shaft. The fluid jet leaves the runner with a reduced energy. An impulse turbine operates under atmospheric pressure, there is no change of static pressure across the turbine runner and the unit is often referred to as a free jet turbine. Important impulse turbines are: Pelton wheel, Turgo-impulse wheel, Girad turbine, Banki turbine and Jonval turbine etc., Pelton wheel is predominantly used at present.

Reaction Turbine wherein a part of the total available hydraulic energy is transformed into kinetic energy before the water is taken to the turbine runner. A substantial part remains in the form of pressure energy. Subsequently both the velocity and pressure change simultaneously as water glides along the turbine runner. The flow from inlet to outlet of the turbine is under pressure and, therefore, blades of a reaction turbine are closed passages sealed from atmospheric conditions.

Fig. 1.17 illustrates the working principle of a reaction turbine in which water from the reservoir is taken to the hollow disc through a hollow shaft. The disc has four radial openings, through tubes, which are shaped as nozzles. When the water escapes through these tubes its pressure energy decreases and there is increase in kinetic energy relative to the rotating disc. The resulting reaction force sets the disc in rotation. The disc and shaft rotate in a direction opposite to the direction of water jet. Important reaction turbines are, Fourneyron, Thomson, Francis, Kaplan and Propellor turbines Francis and Kaplan turbines are widely used at present.

The following table lists salient points of difference between the impulse and reaction turbines with regard to their operation and application.

Table 1.1

Impulse Turbine	Reaction Turbine
1. All the available energy of the fluid is converted into kinetic energy by an efficient nozzle that forms a free jet.	1. Only a portion of the fluid energy is transformed into kinetic energy before the fluid enters the turbine runner.
2. The jet is unconfined and at atmospheric pressure throughout the action of water on the runner, and during its subsequent flow to the tail race.	2. Water enters the runner with an excess pressure, and then both the velocity and pressure change as water passes through the runner.
3. Blades are only in action when they are in front of the nozzle.	3. Blades are in action all the time.
4. Water may be allowed to enter a part or whole of the wheel circumference.	4. Water is admitted over the circumference of the wheel.
5. The wheel does not run full and air has free access to the buckets.	5. Water completely fills the vane passages throughout the operation of the turbine.
6. Casing has no hydraulic function to perform; it only serves to prevent splashing and to guide the water to the tail race.	6. Pressure at inlet to the turbine is much higher than the pressure at outlet ; unit has to be sealed from atmospheric conditions and, therefore, casing is absolutely essential.
7. Unit is installed above the tail race.	7. Unit is kept entirely submerged in water below the tail race.
8. Flow regulation is possible without loss.	8. Flow regulation is always accompanied by loss.
9. When water glides over the moving blades, its relative velocity either remains constant or reduces slightly due to friction.	9. Since there is continuous drop in pressure during flow through the blade passages, the relative velocity does increase.

1.19 SCIENCE VS. TECHNOLOGY

The difference between science and technology is science is the knowing of what is going on, what is happening in nature, and to increase knowledge. Science is a lot slower than technology. Technology is to control and use of science to provide a practical use.

1.19.1 SCIENTIFIC RESEARCH

INDIA has had a long and distinguished tradition in Science from accomplishments of ancient times to great achievements during this century; the latter half, prior to Independence has been related largely to pure research. At the time of Independence, our scientific and technological infrastructure was neither strong nor organised in comparison with that of the Developed World. This had resulted in our being technologically dependent on skills and expertise available in other countries during early years of Independence. In the past four decades, an infrastructure and capability largely commensurate with meeting national needs has been created minimising our dependence on other countries. But, we still have a long way to go in this field to be self-sufficient. A range of industries from small to the most sophisticated has been established covering wide-range of utilities, services and goods. There is now a reservoir of expertise well acquainted with the most modern advances in basic and applied areas that is equipped to make choices between available technologies, to absorb readily new technologies and provide a framework for future national Development.

1.19.2 SCIENCE AND TECHNOLOGY INFRASTRUCTURE

Scientific research in India is carried out fewer than three major sectors, *viz.,* Central Government, state governments and various in-house research and development units of industrial undertakings, both under public and private sectors besides cooperative Reserved & Development associations. Bulk of research effort in the country is financed by major scientific departments/agencies such as Departments of Science and Technology, Atomic Energy, Space, Scientific and Industrial Research, Electronics, Non-Conventional Energy Sources, Environment, Ocean Development, Biotechnology Agencies *i.e.,* Indian Council of Medical Research, Council of Scientific and Industrial Research, Indian Agricultural Research Institute. etc. There are about 200 research laboratories within the purview of these major scientific agencies carrying out research in different, areas. Besides. There are a large number of scientific institutions under the Central ministries departments which carryout research programmes of practical relevance to their areas of responsibility. States supplement the efforts of Central government in areas like agriculture, animal husbandry, fisheries, public health, etc. Institutions of higher education carryout sizeable work in science and technology and are supported by the University Grants Commission and Central and state governments. They also carryout sponsored research projects financed by different agencies.

Government is providing a number of incentives to industrial establishments in private and public sectors to encourage them to undertake research and development activities. Consequently, scientific research is gaining momentum in several industrial establishments. As on January 1990, there were over 1,200 in-house research and development units in public and private sectors, reorganised by the Department of Scientific and Industrial Research. Also, recently public funded research institutions through Department of Science and Technology have introduced a ‘Pass Book’ Scheme for import of scientific equipment liberally.

1.20 FACTS VS. VALUES

Fact is the regulatory ideas without false ability not arguments. Values are the judgment of good and bad regulations. The Indian constitution is based on values, which are a shared set of understandings of what is good or bad. Science is above the plane of values, free from what is good and bad, because science is an objective.

1.21 ATOMIC ENERGY

India is recognized as one of few countries in the world, which have made considerable advances in the field of atomic energy. Despite the closely guarded nature of this technology at the international level, the country is self-reliant in the same and has established competence in carrying out activities over the entire nuclear fuel cycle. The executive agency for all activities pertaining to atomic energy in the country is the Department of Atomic Energy (DAE), which was set-up in 1954. The Atomic Energy Commission (AEC) lays down policies pertaining to the functioning of DAE, which was set-up in 1948. The portfolio of DAE has all along been under the charge of the Prime Minister.

The activities of DAE are primarily in the area of nuclear power generation, research and development in atomic energy and in the industries and minerals sector. 'These activities are carried out by its constituent units, Public Sector Units (PSUs) and by institutions which are given financial assistance by DAE. India has also been offering training facilities, fellowships, scientific visits, etc., and makes available the service of its scientists and engineers for expert assignments in several countries both through the International Atomic Energy Agency (IAEA) and through bilateral agreements.

1.22 HIGHLIGHTS OF THE NUCLEAR POWER PROGRAMME

When the country's atomic energy programme was launched in the 1940s, a three-stage nuclear energy programme was envisaged to use the available Uranium and vast Thorium Resources. The first stage was to comprise of Natural Uranium Fuelled Pressurised Heavy Water Reactors (PHWRs), which would produce power, and Plutonium as a by-product. The second stage is expected to have Plutonium Fuelled Fast Breeder Reactors (FBRs), which in addition to producing power and Plutonium, will also yield Uranium-233 from Thorium. The third stage reactors would be based on the Thorium Cycle to produce more Uranium-233 for fuelling additional breeder reactors.

The present installed capacity of nuclear power reactors in India is 1,465 MWe. The total electricity generated by nuclear power stations during 1988–89 and 1989–90 was 5,817 and 4,625 million kW hours respectively, and the target for 1990–91 has been fixed at 6850 million units. Excepting for the first two units at Tarapur, which are of the Boiling Water Reactor (BWR) type and were set-up as a turnkey by a United States of America's company, other power reactors in the country are of the PHWR Type which constitute the first stage of the programme. DAE aims at establishing about 10,000 mW of nuclear power generation capacity from PHWRs during the coming ten to fifteen years. In addition, two reactors o£ the Pressurised Water Reactor (PWR) type of 1000 mW each are being set-up at Kudankulam, TamilNadu, with the assistance of the USSR. Further, work on a Prototype Fast Breeder Reactor (PFBR) of 500 mW capacities is also expected to be taken up in the near future.

Important inputs for the PHWRs are heavy water and nuclear fuel, which are made available by organisations within DAE. Amongst these, there are units which carry out exploration and survey of Uranium resources and subsequently mining and processing them for production of Uranium Concentrates. Other units are responsible for production of nuclear fuel and heavy water. Facilities are also available for the back-end of the nuclear fuel cycle to reprocess spent fuel from nuclear power reactors and for management of radioactive wastes.

A significant feature of the Indian Atomic Energy Programme is that it has all long been backed-up by a comprehensive R and D programme encompassing a wide-range of multi-disciplinary activities relating to atomic energy. This includes fundamental research in basic sciences to disciplines like Nuclear Engineering, Metallurgy, Medicine, Agriculture, Isotopes, etc. Research is also being carried out in FBR technology and frontline areas like fusion, lasers and accelerators.

All the organisations of DAE which are engaged in these activities, can be considered to be one of the following categories, namely, R and D units, PSUs, Industries and Mineral (I and M) sector units, Aided Institutions or Service Sector Units.

1.23 NUCLEAR POWER CORPORATION OF INDIA LIMITED

This is the most recent and largest of the PSUs. It was set-up in 1987 to implement the nuclear power generation programme on commercial lines by converting the erstwhile Nuclear Power Board into Nuclear Power Corporation of India Limited (NPCIL). It is responsible for designing, constructing, commissioning and operating all Nuclear Power Reactors in the country. The seven operating reactors have a total installed capacity of 1435 mW and comprise of : two units of 160 mW each at Tarapur near Bombay; two units of 220 mW each at Rawatbhata near Kota in Rajasthan; two units of 235 mW each at Kalpakkam near Madras, and one unit of 235 mW at Narora in Uttar Pradesh. Excepting Tarapur units, which are of the Boiling Water Reactors (BWR) type, all others are of the PHWR Type. While the Rajasthan Reactors were set-up with the assistance of Canada, all subsequent reactors are of indigenous design and construction.

Several more 235 mW PHWRs are in various stages of construction. The second unit at Narora is nearing completion and is expected to become critical during 1990–91. Construction of two reactors at Kakrapar near Surat in Gujarat is also in an advanced stage and the first of these is also expected to be commissioned during 1991–92. Work is in progress on four more reactors two each at Kaiga in Karnataka and Rawatbhata in Rajasthan, which are expected to be completed during 1995–96.

As regards future power reactors advance action has been initiated on four more 235 mW units and four PHWR units of 500 mW each. Detailed design and engineering of the 500 mW PHWR units are also being done in house by NPCIL. To meet the growing demand for electricity in southern region, it has also been decided to set-up two 1,000 mW VVWR units (of the Pressurised Water Reactor type) in Kudankulam, Tamil Nadu, with Soviet assistance.

1.24 OCEAN ENGINEERING APPLICATIONS

Software to retrieve and analyse the raw data on heave/pitch/roll time series to obtain Directional Wave Spectra has been developed by NIO. The European Molecular Biology Laboratory (EMBL) for worldwide distribution as DNACLONE package has adopted software generated by IMTECH scientists associated with the National Facility of Distributed Information Centre on Enzyme Engineering, Immobilized Biocatalysts, Microbial Fermentation and Bioprocessing Engineering.

The computer software packages developed by SERC (M) continued to attract several user agencies in the Government and Public and Private Sectors. Fifty-four packages were licensed to twenty parties in different parts of India. An improved version of the Flosolver Parallel Computer with sixteen Intel 80386–80387 Processors (32 bit) has become operational during the year, marking a significant advance in NAL’s Parallel Computer Development Programme. The new version attains a sustained speed of three-four MFLOPS.

Inherently present Josephson junctions have been exploited in making a two hole SQUID which operates at Liquid Nitrogen Temperature (77 K). It is an r.f. SQUID and is made out of bulk yttrium-barium-copper oxide (YBCO) Superconductor which remains super conducting up to about 90 K.

OCEAN DEVELOPMENT

For centuries, people of India have been using the seas around the Indian Sub-continent for transport, communication and food During the last few years, exploration and exploitation of living and non-living resources of the seas have acquired a new thrust. The new ‘Ocean Regime’ established by United Nations Convention on the Law of the Sea, 1982, which has been signed by 159 countries including India and ratified by 42 countries besides United Nations Council of Namibia as on 25 November, 1989, assigns much of the World Ocean to Exclusive Economic Zones where coastal states have jurisdiction over exploration and exploitation of resources and for other economic purposes.

Recognizing the importance of oceans in economic development and progress of the Nation, the Government set-up Department of Ocean Development in July, 1981, for planning and coordinating oceanographic survey, research and development, management of ocean resources, development of manpower and marine technology. The department is entrusted with the responsibility for protection of marine environment on the high seas.

The budget outlay for various schemes for ocean development during 1990–91 is Rs. 35 crore under Plan and Rs. 7.02 crore under Non-Plan. The revised estimates are Rs. 43.50 crore under Plan and Rs. 12.17 crore under Non-Plan.

The objectives of 'ocean development' have been laid down by Parliament in the Ocean Policy Statement of November 1982. The domain of our concern for development of oceanic resources and its environment extends from the coastal lands and islands lapped by Brackish Water to the wide Indian Ocean. India's Costline is more than 6000 km long and its territory include 1256 islands. Its Exclusive Zone covers an area of 2.02 million-sq.km. and the continental shelf extends up to 350 nautical miles from the coast. Briefly stated, the objectives of development of the oceanic regime are:

1. To explore and assess living and non-living resources;
2. To harness and manage its resources (materials, energy and biomass) and create additional resources such as mariculture;
3. To cope with and protect its environment (weather, waves and coastal front);
4. To develop human resources (knowledge, skill and expertise); and
5. To play our rightful role in Marine Science and Technology in the International Arena.

SOLVED EXAMPLES

Example 1. *Steam at a pressure of 15 kg/cm^2 (abs) and temperature of 250°C. is expanded through a turbine to a pressure of 5 kg/cm^2 (abs.). It is then reheated at constant pressure to a temperature of 200°C after which it completes its expansion through the turbine to an exhaust pressure of 0.1 kg/cm^2(abs). Calculate theoretical efficiency.*

(*a*) *Taking reheating into account*

(*b*) *If the steam was expanded direct to exhaust pressure without reheating.*

Solution. From Mollier diagram

H_1 = Total heat of steam at 15 kg/cm^2 and 250°C = 698 Kcal/kg

H_2 = Total heat of steam at 5 kg/cm^2 = 646 Kcal/kg

Now steam is reheated to 200°C at constant pressure

H_3 = Heat in this stage = 682 Kcal/kg

This steam is expanded to 0.1 kg/cm^2

H_4 = Heat in this stage = 553 Kcal/kg

H_{w4} = Total Heat of water at 0.1 kg/cm^2 = 45.4 Kcal/kg

$$\text{Theoretical efficiency} = \frac{\{(H_1 - H_2) + (H_3 - H_4)\}}{\{H_1 + (H_3 - H_2) - H_{w4}\}}$$

$$= \frac{\{(698 - 646) + (682 - 533)\}}{\{698 + (642 - 646) - 45.4\}}$$

= **0.293 or 29.3% Ans.**

Example 2. *Determine the thermal efficiency of the basic cycle of a steam power plant (Rankine Cycle), the specific and hourly steam consumption for a 50 mW steam turbine operating at inlet conditions: pressure 90 bar and temperature 500°C. The condenser pressure is 0.40 bar.*

Solution. From Mollier diagram

H_1 = Total heat of steam at point 1 = 3386.24 kJ/kg

H_2 = Total heat of steam at point 2 = 2006.2 kJ/kg

H_{w2} = Total Heat of water at point 2 = 121.42 kJ/kg

(*a*) Thermal efficiency $= \dfrac{(H_1 - H_2)}{(H_1 - H_{w2})}$

$$= \frac{(3386.24 - 2006.2)}{(3386.24 - 121.42)} = 42.27\%$$

(*b*) Specific steam consumption is the amount of steam in kg per kW-hr.

Now 1 kW-hr = 3600 kJ

Specific steam consumption $= \dfrac{3600}{(H_1 - H_2)} = \dfrac{3600}{(3386.24 - 2006.2)}$

= 2.61 kg/kW-hr

(*c*) Hourly steam consumption = 2.61 × Kilowatts

= 2.61 × 50,000 = **1.305 Tonnes/hr Ans.**

Example 3. *A steam power plant, operating with one regenerative feed water heating is run at the initial steam conditions of 35.0 bar and 440°C with exhaust pressure of 0.040 bar. Steam is bled from the turbine for feed water heating at a pressure of 1.226 bar. Determine*

(1) Specific heat consumption

(2) Thermal efficiency of the cycle

(3) Economy percentage compared with the cycle of a simple condensing power plant.

Solution. From Mollier diagrams and steam table,

H_1 = 3314 kJ/kg

H_2 = 2560 kJ/kg

H_3 = 2100 kJ/kg

H_{w2} = 439.43 kJ/kg

H_{w3} = 121.42 kJ/kg

From the heat balance for the feed water heater

$$m(H_2 - H_{w2}) = (1 - m)(H_{w2} - H_{w3})$$

$$m(2560 - 439.43) = (1 - m)(439.43 - 121.42)$$

On solving, we get $m = 0.1304$ kg

Total work done $= 1 \times (H_1 - H_2) + (1 - m)(H_2 - H_3)$

$= (3314 - 2460) + (1 - 0.1304)(2560 - 2100)$

$= 1154$ kJ/kg

(1) Specific steam consumption $= \dfrac{3600}{1154}$ = **3.12Kg/kW-hr. Ans.**

(2) Thermal efficiency $= \dfrac{1154}{(3314 - 439.43)}$ = **40.15%. Ans.**

(3) With out regeneration feed water heating the work done will be

$H_1 - H_2 = 3314 - 2100 = 1214$ kJ/kg

Steam consumption $= \dfrac{3600}{1214} = 2.94$ kg/kW-hr

Without regeneration heating, the thermal efficiency

$$\eta = \frac{(H_1 - H_3)}{(H_1 - H_{w3})}$$

Now from the steam tables

$H_{w3} = 121.42$ kJ/kg

$$\eta = \frac{(3314 - 2100)}{(3314 - 121.42)} = 0.38$$

Increase in thermal efficiency due to regeneration feed water heating is

$= \dfrac{(0.4015 - 0.38)}{0.4015}$ = **5.5 % Ans.**

THEORETICAL QUESTIONS

1. What is the concept of Power plant?
2. Define the types of energy.
3. What are the resources for power development in India?
4. What is the present position of power in India?
5. What is the future planning for power generation?
6. Define different types of power cycle.
7. Write short notes on fuel and combustion.
8. Write short notes on steam generators.
9. Write short notes on steam condenser.
10. Briefly describe water turbine.
11. Differentiate between impulse and reaction turbine.

EXERCISES

1. A simple Rankine cycle works between pressure of 30 bar and 0.04 bar, the initial condition of steam being dry saturated, calculate the cycle efficiency work ratio and specific steam consumption. [**Ans.** 35%, 0.997, 3.84 kg/kWh]

2. A steam power plant works between 40 bar and 0.05 bar. If the steam supplied is dry saturated and the cycle of operation is Rankine. Find (*a*) cycle efficiency, and (*b*) specific steam consumption. [**Ans.** 35.5%, 3.8 kg/kWh]

3. An engine operating on ideal carnot cycle uses steam at 10 bar and 90% dryness at the end of the isothermal expansion process. The pressure during isothermal compression is 1.5bar. Find the thermal efficiency of the cycle. Also find the power developed by the engine if the engine uses 0.5 kg of steam per cycle and makes 200 cycles/min. Assume that the liquid is saturated at the beginning of isothermal expansion(evaporation). [**Ans.** 15.1%, 456 kW]

4. Steam at 28 bar and 50°C superheat is passed through a turbine and expanded to a pressure where the steam is dry and saturated. It is then reheated at constant pressure to its original temperature and then expanded to the condenser pressure of 0.2 bar. The expansion being isentropic, find

(*i*) Work done per kg of steam

(*ii*) Thermal efficiency with and without reheats. [**Ans.** 880 kJ/kg, 30.3%]

5. The steam at a pressure of 100 bar and 500°C is supplied to a steam turbine. It comes out at 0.07 bar and 0.85 dry. One stage reheating is used and reheating is carried out upto its original temperature. Determine the theoretical thermal efficiency of the plant. Also find out the pressure at which reheating is carried out. Assume expansions at both stages are isentropic. Show the processes on h-s chart. If the net output is 1400 kJ/kg of steam find out the actual efficiency of the plant. [**Ans.** 42.6%, 39.3%]