



Energy Engineering

R. P. S. Srivastav

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ENERGY ENGINEERING

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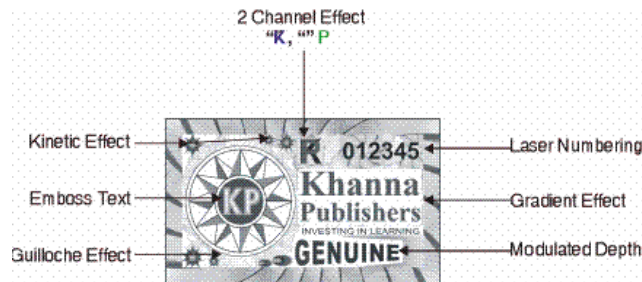
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Preface

The energy is basic requirement for the survival of universe without energy thinking of life on world environment is fruitless. This is the main reason to give more emphasis on energy. Many scientists, professors, researchers and students are engaged constantly in hunting new sources or conserving technique of energy. There are divided opinion on energy, one group concentrate only on dissipation of energy whereas other group gives more importance on propagation, saving, generation and conservation. But if some gives a close look on energy prospect, it will find that both are interested in attracting the same problems with different angles.

It is matter of pride for all the human being that in India also people have started giving importance for energy and its conservation. It is obvious from the thinking of directors of technical education boards to introduce energy as a course material at polytechnic level. Since it is new initiative there is practically no books on the subject pertaining to the requirements of polytechnic students. The author thought to enter in this venture. It is expected that it will fulfil the necessity of polytechnic students and acquaint them with the new topic on energy and its conservation.

Fundamental concept of energy and its mathematical relations are difficult to understand for an average polytechnic students. However, to help students more emphasis have been given on fundamental without bothering mathematical concept, but wherever, required simple mathematical relationship have been used. Keeping the standard and need of polytechnic students and enhancing the marketability of the book, few chapters have been added for graduate/post-graduate students as well. In nut cell it can be said that one book suits the requirement of all the technical students of aeronautical, bio-technology, chemical, mechanical and nuclear engineering and polytechnic students. The author has fully utilized his academic association with polytechnic, graduate, post-graduate of various boards and universities and has encashed them properly.

The book was started from notes preparation, discussion and delivering the materials to class rooms, correcting and recorrecting. Discussing with group of students and faculty members. In case of requirements the help of scientist, researchers and working industries were also taken.

The author is thankful to all those who have taken active part in discussion and provided suggestions for the improvement. He would be extremely thankful to the readers for their constructive suggestions, if any and healthy criticism with a view to enhance marketability of books and recommending to other students to glance through the book. I would greatly acknowledge if some misprints and errors are discovered and brought to the notice of the undersigned. It will be implemented and dually acknowledge in the next edition.

—Srivastav R.P.S.

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Introduction

1.1. BASIC CONCEPT

Requirement of “energy” is essential for the very survival of the creatures of the universe. Energy is needed for performing any work of any type. The requirement of energy has drastically increased due to enhancement of the world population, urbanization and industrialization. During last few decades, the growth of these things have increase manifolds and hence demand of energy has also increased in the same proportion. It has become challenging task to meet the ever increasing demands of energy with limited conventional and non-conventional resources. This has forced the scientists for :

- Hunting new sources of energy
- Conservation of energy.

In the first course non-conventional energy sources were successfully achieved. Due to fast depletion of conventional fuel *i.e.*, fossil fuel. It has created a tremendous gap between demands and supply. It has become essential to adopt “energy conservation” techniques in each and every fields wherever energy is required. Energy conservation not amount to “Energy Curtailment”. However, energy must be used only if it is required and in limited quantity. It should not be felt that it is available so it can be used without any control it is essential to adopt “energy conservation” techniques in almost every walk of life. The energy conservation has attended priority as it can be termed as “additional energy” or “energy saved”. The energy saved is “energy produced”.

1.2. PRESENT AND FUTURE ENERGY SCENARIO

The energy, most critical component of an infrastructure which affects the economical growth of a country. India is 5th largest electricity producing country and 6th largest energy consumers which amounts to 34% of global energy consumer. India’s energy demand has

reached at 3.6% per capita over the last 30 years. The consumption is directly proportional to the progress of man power. With every growing population, the improvement in the living standard of the humanity and industrialization is must for the development of the countries. Very recently, the smart good technology (SGT) has attributed important role of energy scenario. SGT refer to electrical power system and enhances the good reliability and efficiently by automatically responding to the system disturbances.

1.3. CLASSIFICATION OF ENERGY

It can be classified as :

- (a) Primary
- (b) Secondary
- (c) Commercial
- (d) Non-commercial
- (e) Renewable
- (f) Non-renewable energies

1.3.1. Primary Energy (PE) and Secondary Energy (SE) Sources

PE is those which are either formed or store in nature. Common PE sources are coal, oil, natural gas (NG) and Bio-mass other PE sources are nuclear energy from radioactive substances, thermal energy stored in the earth interior and potential energy due to earth's gravity. The major primary and secondary sources are dedicated in Fig. 1.1.

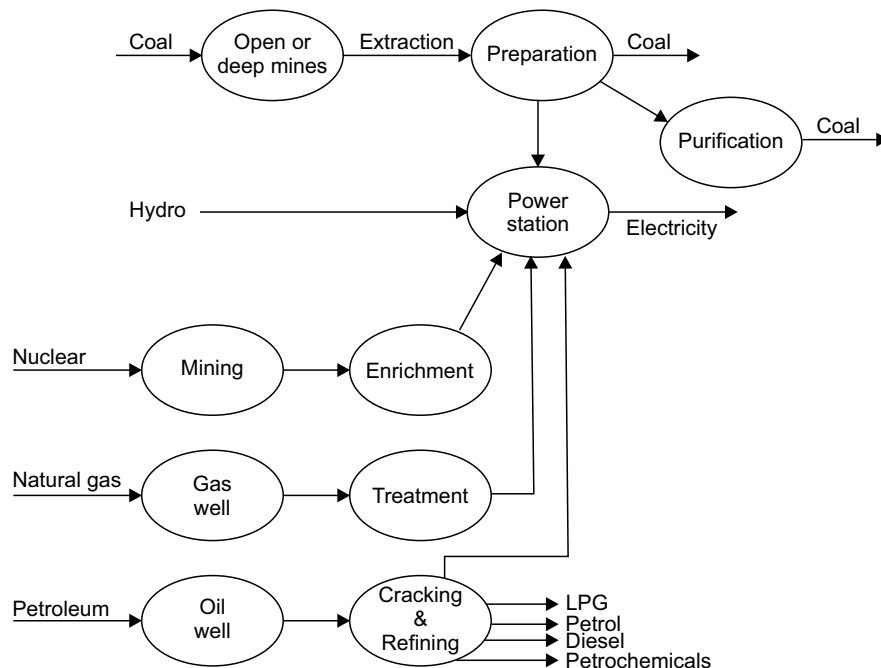


Fig. 1.1. Major and Primary and Secondary Sources.

Primary energy sources (PES) are mostly used as industrial utilities while secondary energy sources (SES) viz. coal, oil, gas are converted to steam and electricity. PES can also be used directly. Some energy sources have been termed as “Non-energy” using viz., coal, natural gas can be used as feedstock in fertilizer industries.

1.3.2. Commercial Energy (CE)

Those are available in the market for a definite price are termed as “commercial energy”. Most important form of CE is electricity, coal and refined petroleum products. The CE forms the basis for industrial, agricultural, transportation and commercial development in the modern world. In the industrialized country, commercialized fuels are predominant source not only for economic growth but also for many house hold tasks for general population.

1.3.3. Non-commercial Energy (NCE)

They are one which are not available in the commercial market with a price. It includes fuels viz. firewood, cattle dung and agricultural waste. These are traditionally gathered and does not require any price. It is mostly used in rural areas for house hold purposes. These are also termed as “Traditional Fuel”. The NCE is often ignored in energy accounting viz. fire wood-agro waste in rural areas, Solar energy for water heating, electricity generation, for drying grains, fish and fruits, animal power, for transportation, threshing, lifting water for irrigation, crushing sugar, wind energy lifting water and electricity generation.

1.3.4. Renewable Energy (RE)

It is energy, which are obtained from a source which are essentially inexhaustible. Renewable sources includes wind power, solar energy, geothermal, tidal waves, and hydro electrical powers as shown in Fig. 1.2. The most important feature of RE is one which can be harnessed without releasing of harmful pollutants.

1.3.5. Non-Renewable Energy (NRE).

It is Conventional Fuels (CF) coal, oil and gas are likely to depleted with time.

1.4. GLOBAL PRIMARY ENERGY RESERVES (GPER)

(a) **Coal** – The proven GPER was estimated as 16×10^7 million litres, by the end of 2003. It is distributed like as noted below :

- USA—25.4% largest storage of global primary energy reserves,
- Russia — 15.9%,
- China — 11.6%,
- India — 8.6%,
- Other countries — 30.5%.

(b) **Oil** —It was estimated to be 18352 million litres by the end of 2003.

- USA had the largest share of reserve with atmost 27%

(c) **Natural Gas**—GPER was estimated to be 176 trillion cubic metres (TCN).

By the end of 2003. Russian federation have the largest share in natural gas which amounts to be almost 27%.

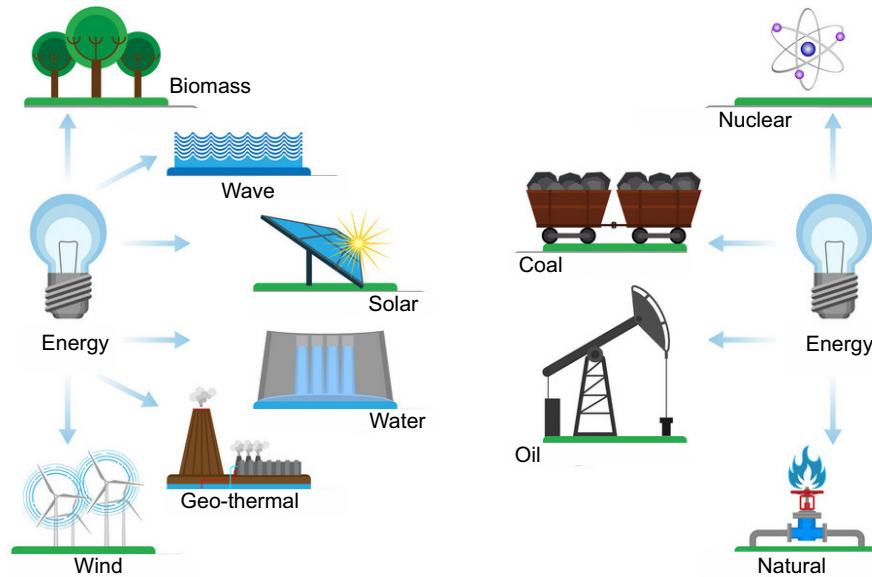


Fig. 1.2. Sources and distribution of renewable energy.

1.4.1. Global Primary Energy Consumption (GPEC)

By the end of 2003 it was equivalent to 9741 million tonnes of oil equivalent (MTOE). The energy requirements are going to increase in the future. It depends to some extent on availability of fossil fuel to meet the future energy requirement. Most commonly used terms are “Reserve” and “Resource”.

The “reserve” represents the portion of demonstrated resources which can be recovered economically with the application of extraction technology currently available.

“Resources” represents the portion of energy which are known to exist or even suspected to exist/respective of technical economical viability. Table 1.1 represents the annual consumption and availability of different non-renewable energy for the world as well as USA.

Table 1.1. Reserve of Annual Consumption of Resources Worldwide.

S. No.	Energy	USA reserve	Annual consumption in USA	World resources	Annual consumption worldwide
1.	Petroleum Billion litres	5600	115.36	202,420	3200
2.	Natural gas Trillion litres	324	321	6588	124
3.	Coal Billion tonnes	260	0.73	948	828

As of 2016, the total world proved recoverable resources of coal were estimated to 948 billion tonnes (BT). Five countries as noted below have nearly 73% of the world coal reserve.

- USA — 28%
- Russia — 18%

China	— 13%
Australia	— 9% and
India	— 7%
remaining countries	— 25%

Based on the available data from oil production exporting countries (OPEC), the non-conventional oil deposits are shown in Fig. 1.3 and summarized in Table 1.2.

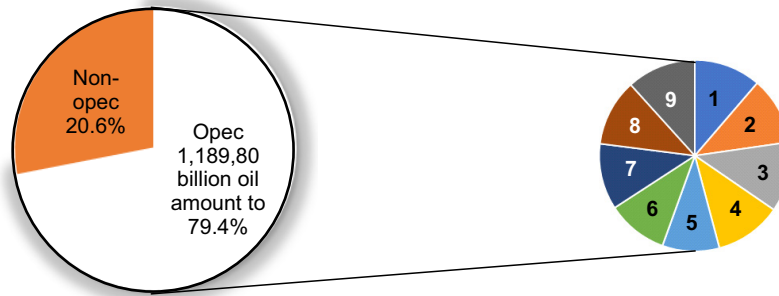


Fig. 1.3. Oil reserves in various countries.

Table 1.2. Oil availability in various countries.

S. No.	Countries	Oil Reserve in Billion Tones and %	
		Billion Tones	%
1.	Algeria	12.2	10
2.	Angola	8.16	0.7
3.	Congo	2.98	0.2
4.	Ecuador	8.27	0.7
5.	Equatorial Guinea	1.1	0.1
6.	Gabon	200	2
7.	Iran	155.6	13.1
8.	Iraq	145.02	12.2
9.	Kuwait	101.5	8.5
10.	Libiya	48.36	4.1
11.	Nigeria	139.97	3.1
12.	Saudi Arabia	267.03	22.4
13.	UAE	97.8	8.2
14.	Venezuela	302.81	25.5
	Total reserve of oil world wide	1287.8	100

Based on the data of British Petroleum (BP) Gas Reserves were dominated by Iran, Russia and Qatar which together hold nearly half the world proven reserves. According to USA, CIA the World Fact Book, the USA has largest reserves of natural gas. As per the central updates about the “Shale Gas”. It is difficult to estimate with certainty. How long these reserves deminision is difficult to predict. It depends on the “rate of consumption” (ROC). New reserves are being

hunted but the rate of energy consumption is also increasing every day. In case of energy reserve, although it is known that new reserve may be located, but quantities of reserve gas/oil finding are uncertain. However, the consumption rate can be predicted with some accuracy. Based on the past rates of consumption. It is estimated as is life times of current reserves at a constant consumption.

1.5. LIFE TIME OF CURRENT RESERVES AT CONSTANT CONSUMPTION

The current petroleum reserve can be divided by the current reserves :

- At the current rate of consumption, the approximate life time of the world petroleum, natural gas, and coal reserve is nearly 50,502.8 and 153 years respectively.
- At the current rate of consumption USA reserves for petroleum, coal, and natural gas are approximately 488,25.8 and 12.2 years respectively.

USA petroleum consumption is not coming from USA reserve as they import more than 50% of the consumption from other countries. The petroleum reserves at the current rate will last nearly 11 years. If the consumption rate increases in future, the life time will reduce. However, there are chances of adding more reserves with more exploration and discoveries. The rate of consumption may increase due to change in price index of petroleum and other alternative fuels. Likewise moving towards electricity cost and harnessing unconventional oil reserves can extend the life time of these reserves.

The reserves/production (R/P) ratio can change from year to year. The Fig. 1.4 illustrate these variation in ratio with year.

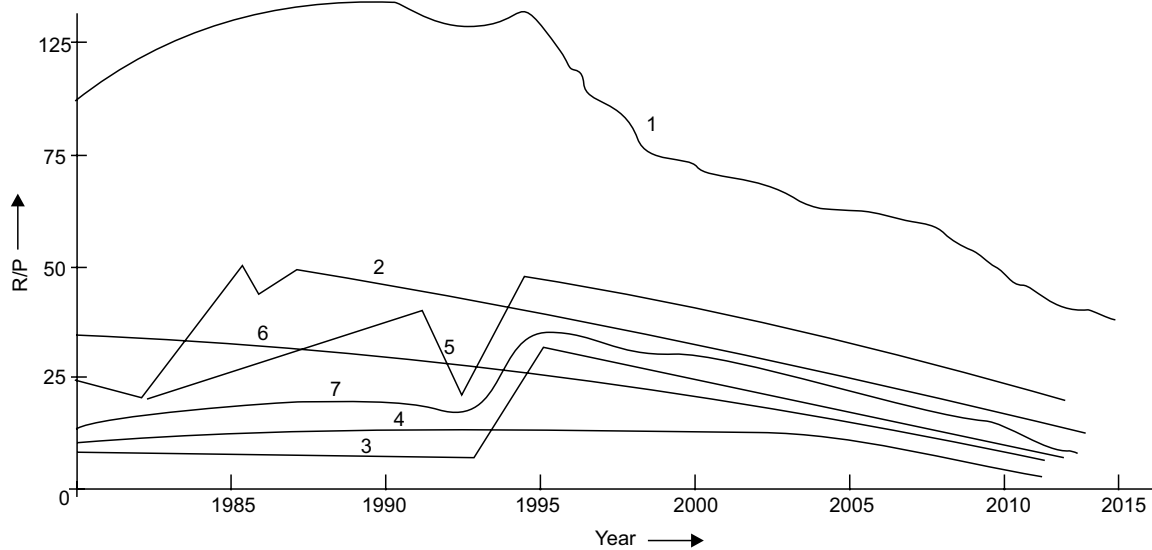


Fig. 1.4. Variation of R/P ratio overtime for oil.

1. World	— 52.53
2. North America	— 30.42
3. South of Central America	— 118.85
4. Europe and EU Russia	— 24.65

5. Middle East — 77.78
 6. Africa — 42.84 and
 7. Asia Pacific — 14.06

In tabular form it can be reproduced as shown in Table 1.3.

Table 1.3. Country Wise Variation of R/P Ratio

<i>S. No.</i>	<i>Country</i>	<i>R/P Ratio</i>
1.	World	52.53
2.	North America	30.42
3.	South of Central America	118.85
4.	Europe and EU Russia	24.65
5.	Middle East	77.78
6.	Africa	42.84
7.	Asia Pacific	14.06

1.6. INDIAN SCENARIO OF ENERGY

India is 4th largest lignite (coal) producing country in the world. The production of coal is concentrated in states of Andhra Pradesh (Undivided), Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Orissa and West Bengal the other fossil fuel reserves in India are:

- **Oil Supply :** Oil accounts for about 36% of India total energy consumption (TEC). India is one of the top oil guzzling nation in the world and may take over Korea soon, which is 3rd largest oil consuming country. In Asia and China the oil production is peaked up about 32 million tonnes (MT) as against the current peak demand of about 110 million tonnes. The oil consumption by end of 2007 was 136 MT and the domestic production was 34 MT. India pays Rs. 4800 billion in oil import. India imports 70% of its crude need from Gulf Nations. In India, oil is located in Bombay High, Upper Assam, Cambay, Krishna-Godavari Sector. The sector wise petroleum product consumption (PPC), accounts 42.1 in transports, domestic 24% and industries 24%. India spent more than Rs. 11×10^4 crore on oil import by 2004.
- **Natural Gas :** It accounts for about 89% of energy consumption in India. The current demand of natural gas is 96 million cubic metres/day (MCMD) against availability of 62 MCMD by the year 2007 the demand is expected to be around 220 MCMD. The natural gas reserves are estimated at 660 billion cubic metres (BCM).
- **Electrical Energy Sources :** The installed capacity of electrical energy production sector (EEPS) was 10^5 MW as on 2004. It consists of 28860 MW hydro, 77931 thermal, 2720 nuclear and 1889 wind. The gross generation of power in 2002–2003 stood at 531 billion kilowatt (BkW) units.
- **Hydro-Power Supply (HPS) :** India is endowed with vast and viable hydro potential for power generation. Out of which only 15% has been harnessed so far. The share of

HPS in the country total generated units has steadily decreased and presently stands at 25% as of 2004. It is assessed that exploitable potential is at 60% with load factor of 84,000 MW.

- **Final Consumption** : The final electricity consumption (FEC) is “actual energy demand (AED) at the user end”. It is difference between PEC and the losses which take place in transport, transmission, distribution and refinement. The energy for final consumption is depicted in Table 1.4.

Table 1.4. Demand of Commercial Energy for Final Consumption.

S. No.	Source	Units	1994–95	2001–02	2006–07	2011–12
1.	Electricity	Billion units	289.36	480.08	712.67	1067.88
2.	Coal	Million tonnes	76.67	109.01	134.99	173.47
3.	Lignite	—do—	4.85	11.69	16.02	19.70
4.	Natural Gas	Million cubic metre	9,880	15,730	18,291	20,873
5.	Oil Products	Million cubic tonnes	63.55	99.89	139.95	196.47

The primary energy consumption (PEC) for few of the developed and developing countries are presented in Table 1.5.

Table 1.5. PEC of Fuel as off 2003 in MTOE.

S. No.	Country	Oil	N. Gas	Coal	N.E.	Hydro	Total
1.	USA	914.3	566.8	573.9	181.9	60.9	2297.8
2.	Canada	96.4	78.7	31.0	16.8	68.6	291.4
3.	Russia	124.7	365.2	111.3	34.0	35.6	670.8
4.	France	94.2	39.7	312.3	99.8	14.8	560.9
5.	UK	76.8	85.7	39.1	20.1	1.3	223.0
6.	China	275.2	29.5	799.7	9.8	64.0	1178.3
7.	India	113.3	27.1	185.3	4.1	15.6	345.3
8.	Japan	248.7	68.9	112.2	52.2	22.6	504.8
9.	Malasia	23.9	35.6	3.2	—	1.7	54.4
10.	Pakistan	17.0	19.0	2.7	0.4	5.6	44.8
11.	Singapore	34.1	4.8	—	—	—	38.9
	Total	3631.9	2331.9	2578.4	598.8	595.4	9741.1

1.7. ENERGY DISTRIBUTION (ED) BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

Although 80% of the world population lies in the developing countries whose population has increased four fold in the last 25 years. Their energy consumption amounts to only 40% of total world energy consumption. The rapid population growth in this region has kept the per capita energy consumption low compared to the highly industrialized countries. The world energy consumption/person is equivalent to 2.2 tonnes of coal. The industrialized countries

(IC), people uses four to five times more. It is the world average and nine times more than the average of developed countries. An American uses 32 times more commercial energy than India.

1.7.1. Indian Energy Consumption Pattern

Coal dominates the energy mix in India contributing of 55% of total primary energy production. Indian consumption pattern in summarised in Table 1.6.

Table 1.6. Energy Consumption Pattern in India

S. No.	Primary Energy	Percent consumption
1.	Coal	55
2.	Natural Gas	10 in 1944, 13 in 1999, 17 in 2005, 20 in 2010 and 25 in 2019
3.	Oil	20 in 1944 and 17 in 2019. There is declined trend in oil production.

• **Coal Supply** : Coal reserve in India is 84,396 million tonnes. It amounts to 8.6% of the world reserve and it may last till 2233 at the current rate of R/P ratio in contrast, the world proven coal reserve are expected to last till 2295 at the current R/P ratio.

R/P is “the remaining reserve at the end of year divided by the production in the year”. It predicts the length of time the remaining reserve would last if the production were continued at the same rate.

1.8. FORMS OF ENERGY

Depending upon the uses the energy is called by various name *viz.* thermal, electrical, electromagnetic, chemical energy. In the industrial sector one come across thermal or heat energy. It is a source to enhance/decrease the temperature of the system. The heat is mostly used in the industrial sector. It is used either in the form of “Electricity” or “Steam”. The electricity is commonly used in house hold for lighting, refrigerator, air conditioners, and/or TV, washing machines etc.

Heat is dissipated in different forms and compares of great many fascinating area, *viz.*

- (i) Design of steam generators, heat exchangers, boilers, condensers, evaporators and many other energy/heat associated equipments.
- (ii) Transforming the solar, wind, bio-gas for space heating/cooling and for power generation.
- (iii) Design of refrigerators, internal combustion engines (ICE), air conditioners (AC) and many cooling/heating devices.
- (iv) Heat treatment of metals, metals casting and steel carburization.
- (v) Discharge of huge amount of waste energy from industrial environment.
- (vi) Control of thermal pollution.
- (vii) Use for conversion of industrial exhaust gases ladent with various gaseous pollutants such as NO_{2x} , Co_x , SO_{2x} etc. with varying concentration. By heat treatment these pollutants diffuse downwards due to lowering of their concentration.
- (viii) Equipments design associated with simultaneous heat of mass transfer.

- (ix) Energy is required in forging industries where steel components are exposed to carburizing atmosphere.
- (x) It is essential in the case of walls of centrally heated building, steam pipes and in the steam power plants.
- (xi) The knowledge of energy conservation is very much desirable with minimum possible area for energy transmission.

1.9. TYPES OF ENERGY

The different forms of energy are :

- (a) Kinetic
- (b) Potential
- (c) Pressure
- (d) Internal also known as vibration energy
- (e) External energy.

1.9.1. Kinetic Energy

All the molecules are interlinked by the force of mutual attraction. Energy of molecular motion is caused by the kinetic energy.

1.9.2. Potential Energy

The energy of Mutual attraction of energy is termed as potential energy. It is produced due to gravity.

1.9.3. Pressure Energy

Energy associated with the pressure of the object is known as pressure energy.

1.9.4. Vibration Energy

Energy caused by the vibration of the object designated as vibration energy.

1.9.5. External Energy

“The energy obtained by external pressure exerted on a object is external energy”.

In the industrial environment, one come across thermal or heat which is also called thermal energy. It is a source to enhance/decrease the temperature of the system. Therefore, the temperature is measure of hotness/coldness of the system, temperature gradient is inherent property of “thermodynamic system” such as chemical, bio-chemical. Aero dynamic, propulsion and transportation. If two systems are at two different temperature ($T_A > T_B$) (say) and brought in contact with each other, then energy transfer will take place from T_A (the hotter spices) to T_B (colder spices) till both of them reach to the same temperature. This situation is termed as “energy equilibrium”. the energy flow due to temperature difference is known as thermal energy of heat. A study of energy transfer refers with rate at which the energy is transferred, hence, heat energy is transit between system which occures due to temperature difference. The quantity of energy received/rejected by a system is governed by :

$$Q = mC_p (T_B - T_A) \quad \dots(1.1)$$

Energy Engineering

About the Book

Energy Engineering or Energy Systems Engineering is broad field of engineering dealing with energy efficiency, energy services, facility management, plant engineering, environmental compliance, sustainable energy and renewable energy technologies. This book also helpful to mathematical relations are difficult to understand for an average polytechnic students. However, to help students more emphasis have been given on fundamental without bothering mathematical concept, but wherever, required simple mathematical relationships have been used. Few chapters have been added for undergraduate/postgraduate students as well. This book suits the requirement of all the technical students of aeronautical, biotechnology, chemical, mechanical and nuclear engineering and polytechnic student.

Contents

- Introduction
- Aspects of Energy Conservation
- Energy Conservation in Electric Utility and Industries
- Heating, Ventilation, Air-Conditioning (HVAC)
- Electric Lighting
- Prime Movers for Power Generation
- Co-generation Technology
- Waste Heat Recovery and Treatment
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