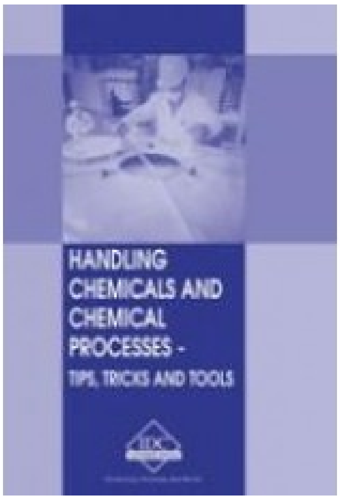
CH-E - Handling Chemicals - Tips, Tricks and Tools



Price: $139.94

Ex Tax: $127.22

Short Description

This manual will greatly assist you in communicating more effectively with your chemical engineering colleagues. If you are a non-chemical engineer this book will be invaluable in increasing your skills and knowledge in this area.

Description

This manual will greatly assist you in communicating more effectively with your chemical engineering colleagues. If you are a non-chemical engineer this book will be invaluable in increasing your skills and knowledge in this area.

Table of Contents

Download Chapter List

Table of Contents

First Chapter

1 Introduction

1.1 Introduction to chemicals

Whether we like it or not, chemicals play a vital role in our life. The human body efficiently processes and handles chemicals, and, in fact, produces a number of them.

Therefore, it is imperative to be able to handle chemicals, and in order to do so, we must understand their structure, and also be able to predict reactions when two or more chemicals come into contact with each other. The scope of this workshop is limited to handling industrial chemicals and processes.

It is impossible to state when man began actively thinking about chemicals. Even today our understanding of the ‘human reactor’ is incomplete. It has been observed that even lower living beings, like birds and animals, take ‘medicines’ to supplement deficiencies in their system. Elephants have been found to eat certain types of soil to address their calcium deficiencies. Birds eat certain types of seeds and clay when they have been deprived of nutrients. Some plants produce toxic chemicals to ward off predators and others produce substances to attract pollinators.

In history, the use of colored plant material has been found as far back as 4000 BC. This clearly suggests that early humans began experimenting with vegetable dyes (a form of chemicals). Today, chemicals are found in every aspect of our daily life. From toothpaste to shampoo to the bed time drink of water, we have incorporated chemicals into our daily lives and become accustomed to handling them.

In the industrial world however, things are a little different, and we accept the help of two basic subjects to understand chemicals and their processes. The first subject is Chemistry, a very powerful branch of science. This subject explains and helps us understand the structure of every known substance. It shows the structure of the smallest particle of matter, and can accurately predict most reactions. The other subject is Chemical Engineering. This branch of engineering deals with the standardization of chemical production processes. In this workshop we shall dwell on both these subjects.

1.2 Basics of chemical engineering and chemistry

Chemical engineering is associated with:

· Efficient and economic control of chemical processes

· Design of chemical reactors and process plants

· Development of sustainable products

· Pollution control and treatment of industrial wastes

Man has utilized chemicals for a long time, but chemical engineering was recognized as a separate field only a century ago. Even as early as 2000 BC, the Egyptians developed certain types of papers and it is believed that glass was invented close to 5000 BC. Perhaps the single most important pursuit in chemistry has been the ‘manufacture’ of gold, thanks to man's fascination with this metal. No civilization could resist the shine of this precious metal. In the middle ages, a set of ‘mad-hatters’ decided to live their dream of converting base metals to gold. This conversion became the ‘Holy Grail’ of those pursuing it. Some of the greatest discoveries in physical chemistry were made by these people, even though the ‘Grail’ still remains elusive. Today, their work is recognized as a pioneering effort and the first instance of standardization of manufacturing techniques, which ultimately led to the field of Chemical Engineering. These scientists are collectively referred to as the Alchemists.

Like all other engineering disciplines, chemical engineering was ultimately recognized as a major field of engineering only in the 19th century. Until the year 1910, the chemical industry relied largely on mechanical engineers and chemists. However, the period of the industrial revolution saw an increase in the use of chemicals in day-to-day life, thus generating a huge requirement for engineers who could design chemical reactors and plants.

Figure 1.1

Typical chemical process plant

Also, due to emerging methods and techniques, chemical processing was becoming increasingly complex, and called for some specific training. Such processing knowledge and designing skills were beyond the scope of chemists and mechanical engineers. This was the time when the chemical industry grew rapidly and needed experts to handle chemical plants and their design. Keeping all these factors in mind, the start of a new engineering discipline for chemicals was seriously considered.

As a result, chemical engineering emerged as a separate discipline in 1910, when professors at the Massachusetts Institute of Technology (MIT) realized that neither mechanical engineering nor chemistry offered sound approaches to a chemical plant's design. So, a new branch of engineering was started to prepare engineers to specialize in the design, operation, and construction of chemical processing plants. Subsequently, this field received universal recognition and many institutions throughout the globe started teaching this subject. Today, scores of young men and women are being trained, and thousands of chemical engineers are working around the globe.

1.3 Unit operations

The processing and manufacturing of chemicals in industries is based on many operations such as heat transfer, mass transfer, fluid flow, distillation, evaporation, absorption, drying, leaching, mixing, crystallization, adsorption and humidification.

The idea of treating these processes of the chemical industry as unit operations was also put forward by the professors of the MIT. They characterized the physical operations necessary for manufacturing chemicals as unit operations. Although originally largely descriptive, these unit operations have been the object of vigorous study and can be used now with sound mathematical procedures for plant design predictions.

In 1930, P. H. Groggins proposed a similar approach to classifying chemical operations as unit processes. Such processes include nitration, oxidation, hydrogenation, sulphonation, chlorination, and esterification. Development of a lab-scale process, designed by a chemist, into a large-scale industrial process is a difficult task and requires the knowledge of the chemicals as well as the mechanical aspects of the equipment required.

The physical operations necessary for manufacturing chemicals are called unit operations. It is a method of organizing much of the subject matter of chemical engineering. Unit operations can be called the heart of chemical engineering. The unit operations concept is based on the fact that by systematically studying the operations (such as heat transfer, mass transfer, fluid flow, drying, distillation, evaporation, absorption, extraction, and mixing) involved in the chemical industry, the treatment of all processes is unified and simplified. The unit operations are largely used to conduct the primary physical steps of preparing the reactants, separating and purifying the products, recycling unconverted reactants, and controlling the energy transfer into or out of the chemical reactors. The design of the equipment involved for these operations is also studied in unit operations.

Due to the complexity and variety of the modern chemical manufacturing processes, the need for arranging the different processes systematically has become undeniable. The chemical steps themselves are conducted by controlling the flow of material and energy to and from the reaction zone.

1.3.1 Fluid mechanics

The behavior of fluids is very important in chemical engineering since chemical engineers are constantly involved with the flow of fluids. Fluid behaviour is a major part of the unit operations principle. Industrial applications involve transport of fluids from one point to another through pipes or open ducts. This requires the determination of pressure drops in the system, the selection of a proper type of pump or compressor, power required for pumping or compression, and measurement of flow rates. All these aspects are studied in fluid flow.

The branch of engineering that investigates the behavior of fluids is called fluid mechanics. It is a part of a larger branch of engineering called continuum mechanics, which deals with the behavior of fluids as well as stressed solids. A fluid is a substance that does not permanently resist distortion. Any attempt to alter the shape of a fluid results in layers of fluids sliding over one another until a new shape is attained. During this change of shape, shear stresses exist depending upon the viscosity of the fluid and the rate of sliding. However, when the final shape is acquired all the shear stresses will disappear. Thus, a fluid in equilibrium is free from shear stresses. The design and study of measuring devices (such as flow meters, area meters, pressure gauges), transportation equipment (such as compressors and pumps), and mixing and agitation equipment (such as mixers and agitators) are considered in fluid mechanics.

Fluid mechanics can be divided into the following two branches:

- Fluid statics

- Fluid dynamics

Fluid statics deals with fluids at rest, or in equilibrium state, which have no shear stress. In the case of liquids this subject is called hydrostatics and in the case of gases it is called pneumatics. Fluid dynamics, also called fluid flow, deals with flowing fluids or with fluids wherein only a section of the fluid is in motion as compared to the other parts.

A major portion of fluid flow deals with the transportation, metering, and mixing and agitation of fluids. A thorough understanding of fluid behaviour is essential not only for accurately treating problems in the movement of fluids through pipes, compressors, pumps, and all kinds of process equipment, but also for the study of heat flow and many separation principles that depend on diffusion and mass transfer.

1.3.2 Heat transfer

Heat transfer is the branch of engineering that deals with the rate of heat exchange between hot and cold bodies. The driving force for heat transfer is the temperature difference per unit area or temperature gradient. In a majority of chemical processes heat is either given out or absorbed. Most of the time the fluids must be heated or cooled in a variety of equipment such as boilers, heaters, condensers, furnaces, dryers, evaporators, and reactors. Sometimes it is necessary to prevent the loss of heat from vessels or pipes. In all these cases, the fundamental problem encountered is the transfer of heat at the desired rate.

The control of flow of heat at the desired rate is one of the most important areas of chemical engineering. The principles and laws governing the rate of heat flow are studied under heat transfer. Let us consider the processes of evaporation and drying. Evaporation is the process used to concentrate a solution consisting of a non-volatile solute and volatile solvent (usually water). Drying is the removal of relatively small amounts of water or other liquid from the solid material to reduce the content of residual liquid to a low value. Although the transfer of heat is involved in every unit operation, in operations such as evaporation, and drying, the primary focus is the transfer of heat rather than the transfer of mass. Hence these operations are governed by the rate of heat transfer. Various laws and equations of heat transfer are used for designing the equipment required for these processes.

Heat transfer can take place through the following three methods:

- Conduction

- Convection

- Radiation

It is interesting to note that, most processes involve a combination of two or more modes of heat transfer.

1.3.3 Mass transfer

Mass transfer involves the transfer of a component from a region of high concentration to a region of low concentration. Mass transfer plays an important role in separating mixtures, which are in the gas, liquid, or vapor state. It results from the random velocities of molecules (molecular diffusion) or from circulating or eddy currents present in a turbulent fluid (eddy diffusion). Just as temperature gradient is the driving force for heat transfer, concentration is the driving force for mass transfer. Many unit operations such as distillation, absorption, extraction, leaching, membrane separation, dehumidification, crystallization, ion exchange, and adsorption are considered as mass transfer operations. Even though heat transfer is also involved in these operations, the rate of mass transfer governs the rate phenomena in these processes. Unlike purely mechanical separation processes, which utilize density difference and particle size, these methods make use of differences in vapor pressure, solubility, or diffusivity. Some of the commonly used mass transfer processes are briefly explained below:

Absorption

This process is used to separate a soluble vapor from an inert-gas mixture by absorbing it in a liquid. Care should be taken to see that the vapor is soluble in the liquid that is absorbing it. The solute is subsequently recovered from the liquid by distillation, and the residual liquid can either be discarded or reused.

Distillation

This process is used to separate a liquid mixture of miscible and volatile substances, into individual or groups of components, by means of vaporization.

Desorption

This process, also known as stripping, is used to transfer a solute from a solvent liquid to the gas phase.

Dehumidification

This process is used to partially remove a pure liquid from an inert or carrier gas by means of condensation. Most often the carrier gas is virtually insoluble in the liquid.

Membrane separations

This process is used to separate one component from a liquid or gaseous mixture by passing it through a membrane. Examples of this type of processes are gas separations, reverse osmosis, and ultra filtration.

Adsorption

In this process, a solute is removed from either a liquid or a gas by bringing it in contact with a solid adsorbent, the surface of which has a special affinity for the solute.

Liquid extraction

This process, also called solvent extraction, is used to separate a mixture of two components by treating it with a solvent that preferentially dissolves one or more of the components. The mixture thus treated is called the raffinate and the solvent-rich phase is called the extract. For example, in the extraction of solids, known as leaching, soluble material is dissolved from its mixture with an inert solid by means of a liquid solvent.

Crystallization

This process is used to obtain hig-purity, crystalline materials, by separating a solute from a melt or solution, leaving impurities behind.

1.3.4 Solid particulate operations

This branch of unit operations, also termed particle technology, deals with handling of solid materials and is mainly concerned with the mixing, size reduction, and mechanical separation of solids. Solids in general are more difficult to handle than fluids. In processing operations, solids appear in a variety of forms such as angular pieces, continuous sheets and finely divided powders. They may be hard and abrasive, tough and rubbery, soft or fragile, dusty, cohesive, free flowing, or sticky. Whatever their form, methods must be found to handle these solids. Following is a short description of common solid particulate operations:

Mixing

Mixing involves combining two or more separate components to obtain a uniform product. Although mixing of solids resembles the mixing of low-viscosity liquids, more power is required to mix solids. Some of the mixers and blenders used for liquids are also used for solids. The commonly used solid mixers include kneaders, dispersers, masticators, mixer-extruders, mixing rolls, pug mills, ribbon blenders, screw mixers, tumbling mixers, and impact wheel.

Size reduction

Size reduction, referred to as communition, is a term applied to the methods and processes used to cut or breakdown solid particles into smaller pieces. Reduction of particle size is usually carried out in one of the following four ways:

- Compression
- Impact
- Attrition or rubbing
- Cutting

Separations

Separations can be classified into two types:

Diffusional operations

This involves the transfer of material between phases e.g. absorption, distillation, adsorption etc

Mechanical separations

It is used for heterogeneous mixtures. This consists of techniques based on physical differences, such as size, shape, or density, among particles. They are used to separate solids from gases, liquid drops from gases, solids from solids, and solids from liquids

Screening

Screening is a method of separating particles according to size alone. In industrial screening the solids are dropped or thrown against a screening surface. The undersized particles (also called fines) pass through the screen openings leaving behind oversized particles (also called tails). Industrial screens are made from woven wire, silk, plastic cloth, metal, and perforated or slotted metal plates. Stationary screens, grizzlies, gyrating screens, vibrating screens, and centrifugal sifters are examples of devices used for this purpose.

Filtration

Filtration is the separation of solid particles from a fluid by passing the fluid through a filtering medium, in which the solids are deposited. The fluid may be a liquid or a gas; the valuable stream from the filter may be fluid, solid, or both. Industrial filtrations range from simple straining to highly complex separations. Filters are divided into three main groups:

- Cake filters, which separate relatively large amounts of solids as a cake of crystals or sludge. Filter press, shell and leaf filter, belt filter, rotary drum filter and batch centrifuge filters are examples of such filters.

- Clarifying filters, which remove small amounts of solids to produce a clean gas or a sparkling clear liquid by trapping the solid particles inside the filter medium. Gravity bed filters, cartridge filters, edge filters, tank filters, pad filters, bag filters and granular bed filters are examples of such filters.

- Cross-flow filters are used for separation of very fine particles or for micro-filtration. In these filters, the feed suspension, which is under high pressure and high velocity, flows across the filter medium. Some of the liquid passes through the medium as a clear filtrate, leaving behind a more concentrated suspension. Different types of membranes are used for these filters.

Settling processes

Settling processes are used for mechanical separations, and make use of the movement of solid particles or liquid drops through a fluid.

Gravity settling processes use the principle that particles heavier than the suspended fluid can be removed in a large settling tank, in which the fluid velocity is low and the particles are allowed sufficient time to settle out.

Centrifugal settling processes are more efficient than gravity settling processes. A given particle, in a given fluid settles under gravitational force at a fixed maximum rate. To increase the settling rate, the force of gravity acting on the particle may be replaced by a much stronger centrifugal force. Centrifugal separators, to a certain extent, have replaced the gravity separators because of their smaller size and greater effectiveness with fine drops and particles. The most widely used type of centrifugal separator is the cyclone separator. Other commonly used types are centrifugal decanters, tubular centrifuges, disk centrifuge, nozzle discharge centrifuge and centrifugal classifiers.

1.4 Thermodynamics

Thermodynamics is a very useful branch of engineering science and deals with the transformation of heat energy into other forms of energy or vice versa. It is very helpful in processes such as refrigeration, flashing and the development of boilers, and steam and gas turbines.

1.5 Chemical kinetics

This branch of chemical engineering is primarily concerned with the exploitation of chemical reactions on a commercial scale. Its goal is the successful design and operation of chemical reactors. This activity, probably more than any other, sets chemical engineering apart as a distinct branch of engineering.

Design of equipment for physical treatment steps is studied in unit operations. In kinetics, the chemical treatment step of a process is studied, along with the treatment stages of a process. These are the core factors that economically make or break the process.

1.6 Chemical engineers – scope and responsibilities

Chemical engineering mainly deals with industrial processes in which raw materials are changed into useful products. A large number of chemical engineers are employed in diverse fields such as research, government and academia.

Chemical engineers:

- develop, design and engineer complete processes and the equipment used in them

- choose the proper raw material

- operate the plants efficiently, safely and economically

- ensure that the products meet the requirements set by customers

Chemical engineering is both an art and a science. Apart from the common area of petrochemical industries, chemical engineers work in numerous other areas because their background and experience are portable across genres. Products of relevance to chemical engineers range from commodity chemicals such as sulphuric acid and chlorine, to high-tech items such as lithographic support for the electronic industry (silicon chips, microprocessors) and genetically modified biochemical agents. The wide spectrum of application of chemical engineers shows that they can be trained to function in any phase of chemical manufacturing. A chemical engineer performs numerous, varied activities during his/her career ranging from plant design to successful plant operation. To have a better understanding of the work of chemical engineers, let us consider the important activities undertaken by them.

1.6.1 Process selection

The selection of a particular process is one of the most important and time-consuming activities undertaken by a chemical engineer. Selecting a process from the available options is no easy job because each process has certain advantages and disadvantages. For example, one process may be more energy efficient than the other, but the other may cause less pollution or may have readily available raw materials. To select a process, many constraints have to be considered such as time, available data, investment, and economics. Since all industries are mainly concerned with profit, economics is the chief factor in selecting a process. The reduction in plant cost per unit of production is often the major factor in selecting a process to be continuous or in batches. Today however, environmental safety is catching up with economics, in importance.

Another critical task is deciding whether a process should be completed in batches or as a continuous process. Initially, chemical processing was normally done in batches and a great deal still continues to be done in that way. Batches can be measured correctly and are more suitable for small-scale production. However, temperature and pressure control in batch processes can be pose a problem.

Furthermore, time and resources lost in attaining the required conditions such as temperature and pressure limit the use of batch processes. On the other hand, continuous processes require much smaller and far less expensive equipment. They have lesser material in process, a lower possibility of ruining large quantities, more uniform operating conditions and give more consistent products than batch processes.

Continuous processes are suitable for large-scale productions. However, these require precise control of flow-rates and conditions, which is impossible without high quality instrumentation.

1.6.2 Operation

Operation of a process plant is another important activity carried out by a chemical engineer. The smooth operation of a plant is a very difficult task and requires the close attention of the engineer at all times. Chemical processing of raw material into the desired product can only be achieved by operating the chemical plant. The quality and quantity of the product is also directly dependent on the efficient operation of a plant. Several problems like temperature and pressure control, maintenance, and safety continue to arise during the plant operation. Experience and application of engineering principles is always needed to troubleshoot these problems. Negligence of a minor issue can often lead to bigger, more complex problems, which can cause unnecessary halts in production.

In order to be able to handle plant operation smoothly, a chemical engineer should start becoming familiar with industrial equipment such as pumps, compressors, distillation columns, filter presses, and heat exchangers, early on. Almost every industry wants its engineers to be thorough with every pipe and gauge used in that particular industry. This is why all freshers are made to spend their time tracing pipelines, an activity known as line tracing. This practice familiarizes the engineers with all the pipelines, gauges, valves, and equipment available in that industry. Consequently, whenever there is a fault in any section they can identify the location and work out its solution immediately.

In fact, troubleshooting is the core of plant operation. Successful plant operation not only depends upon the original strength of the materials of construction, but also upon the effects of corrosion. Constant examination and inspection must be carried out to avoid corrosion. Mechanical failures are seldom experienced in a plant unless there has been previous corrosion or weakening due to chemical attack.

The (chemical) manufacturing process can be divided into the following steps:

- Raw materials

- Physical treatment steps

- Chemical treatment steps

- Recycling

- Products

1.6.3 Instrumentation and control

We have seen that the function of the chemical engineer is to maintain the plant in a proper working condition. Maintaining required temperature, pressure, flow-rates, and other conditions is a very difficult task. Quality instrumentation is a must for monitoring and maintaining these conditions. Hence, a chemical engineer must have proper knowledge of the instruments involved for controlling and measuring process variables. Ample ability to design control systems for processes, and to work out problems faced in controlling process operations is also essential.

Batch operation utilizes fewer instruments and requires more supervision from the workers and the chemical engineer, because the conditions and procedures differ from the beginning to the end. Programmed instruments are available, which can solve even these problems provided the expense for them can be justified. Instrument costs, once a trivial part of the total plant investment, have risen to up to 25% of the total investment.

The use of computers has reduced this cost to some extent. Earlier plants employed mechanical plant control instruments. These were replaced by pneumatic control systems, which were in turn replaced by electronic control systems. Currently, plant-control is being done by DCS (Distributed Control System) using computers. DCS incorporates the use of electronic control devices, but utilizes computers to monitor and control process conditions. Even though many industries continue to use pneumatic and electronic control systems, the global trend is moving towards DCS on account of its ability to handle plant operation more smoothly. Instrumentation has been forced into this position of eminence by the increase in use of continuous processes, increase in labor and supervision costs, the relative unreliability of human actions, and the availability of many types of instruments at a low price and high reliability.

1.6.4 Chemical process economics

Economics is a vital part of an engineer’s work. Engineers are distinguished from scientists by their consciousness of costs and profits. As discussed earlier, economics plays a vital role in the operation, design, and maintenance of every chemical plant. A good chemical engineer always gives economics top priority, and must keep up with the economic changes that may affect their products.

The primary objective of an engineer's efforts must be to safely deliver the best product, or provide the most efficient services at the lowest cost to the employer and the consumer. Since change is an inherent characteristic of chemical procedures, potential alteration of a process and its economic implications are of importance not only when the plant is being designed but throughout its lifetime.

1.6.5 Marketing

Whenever a new product is under assessment, market evaluation for that product becomes essential. The job of a chemical engineer will then include the market estimation of that product. The factors generally considered in the market evaluation are present and future supply and demand, present and future uses, present buying habits, price range for products and by-products, character, location, and number of possible customers.

The marketing of a product not only depends upon its advertisement, but also on the quality, physical condition, and packing. Proper instrumentation, uniform plant conditions, good operators and careful supervision lead to quality production. The physical appearance of a product, such as crystal structure, particle size and shape, colors, and moisture content, has a very strong impact on its marketability.

Packaging also plays an important role in the marketing of a product, especially consumer products. Packaging is often expensive, and the most economical containers are refillable bulk ones such as tanks, tank-ships, and tank-cars. However, these cannot be used for consumer products since packaging is very important to customers. For consumer products, quality packing with attractive colors, designs and materials has to be used.

The price of a product is the real concern for a customer. To enhance the marketing of a product, an engineer should listen to the suggestions and information brought to him by the salesperson, who is the link between the company and the customer.

1.6.6 Safety

The chemical engineer also plays an important role in plant safety. One of the biggest threats to a plant is fire, and precautions must be taken to prevent and extinguish fires. Employee safety is also imperative, and care should be taken to protect employees from toxic chemicals. Safety measures not only keep the employees out of danger but also save money and time by reducing accidents and any unnecessary halts in the production. Well-run plants have safety devices and also put into practice continuing programs for alerting those working with a given process, to its hazards. Adequate safety and fire protection measures require expert guidance. There is considerable difference of opinion in rating certain chemicals as hazardous and their degree of toxicity resulting in different standards for many toxic and harmful substances. However currently the governments decide these standards and are very strict in their implementation.

1.6.7 Construction of a plant

The construction (erection) of a plant is another activity carried out by a chemical engineer. The chemical engineer's role in plant construction is to essentially implement the design standards and interpret technical and design data whenever needed.

During plant construction, the chemical engineer should visit the plant site to assist in the interpretation of plans and learn methods for improving future designs. The engineer should also be available during the initial start-up of the plant and early phases of operation. During the erection of a plant, the engineer becomes intimately connected with the plant and thus learns its internal structure. The chemical engineer becomes involved with the installation of every pipe and gauge of the plant and this helps greatly while running the plant and eliminating problems faced during operation.

1.6.8 Research and development

Sustained and skilled research accompanied by patent protection is required for future profits. The chemical process industry witnesses rapidly changing procedures, new processes, new raw materials and new markets, and research creates or utilizes these changes. Without advanced investigation or research a company would lag behind in the competitive progress of its industry. Development is the adaptation of research ideas to the realities of production and industry. The progress of industry opens up new markets for even the most fundamental, established products.

1.6.9 Management

Due to the dramatic rise in productivity supplemented by recent technological advances in the chemical process industries, management has become very complex. This complexity has made it very difficult for business administration graduates, who do not have any knowledge of chemicals and equipments, to handle things. Currently chemical companies prefer to employ chemical engineers as managers.

Human management is a very important aspect of plant operation. Handling personnel is a challenging job. The job of a chemical engineer is to effectively and efficiently control and run machines, and there is no machine better or more complex than the human being. Controlling this machine is perhaps the most difficult task a man has to perform. But as an engineer is in constant interaction with his workers and personnel, he has to perform this task effectively. Hence, a good engineer must be a good manager and has to listen to his workers' opinions and understand their attitude. Keeping the personnel in high spirits and motivating them is very important.

1.6.10 Process system engineering

It is becoming increasingly evident that each separate unit of a plant influences all others in subtle ways. Engineers are realizing that they can no longer think of a process plant as a collection of disjointed operations and processes. It is also true that the plant is a part of an ecological system extending well beyond its boundaries. The general availability of computers has made it possible to study the dynamic behavior of plants together with their static or steady state behavior. Such intense studies have shown new possibilities for plant operation, not previously conceived. The next generation of engineers will be studying, analyzing and optimizing such interrelated and complex systems. This is a major improvement over envisioning design, which involves simple, non-interacting, static systems that use only operations and unit processes.

1.6.11 Environment

The role of a chemical engineer in controlling pollution and waste generation can hardly be overemphasized. Chemical engineers are concentrating on the area of environmental engineering to develop new methods and techniques to minimize waste generation, treat wastes generated by process industries, and develop renewable sources of material and energy.

These engineers are working towards developing sustainable and renewable technologies. Their role in the preliminary design phases of process industries has now led to new, practically fumeless, chemical plants.

1.6.12 Design

The design of a chemical process plant is the one activity, which is unique to chemical engineering and is the strongest reason that justifies the existence of chemical engineering as a distinct branch of engineering. Designing is one of the most creative, satisfying and rewarding activities undertaken by a chemical engineer. It is the synthesis, the collaboration of ideas to achieve a desired purpose. It is perhaps the most important task undertaken by a chemical engineer. The design does not exist at the commencement of a project. The designer starts with a specific objective in mind and develops and evaluates possible designs, to arrive at the best way of achieving that objective.

As mentioned before, one of the principle responsibilities of the chemical engineer is the design, construction, and operation of chemical plants. In this modern age of industrial competition, a successful chemical engineer needs more than just the knowledge and understanding of fundamental sciences and related engineering subjects such as thermodynamics, reaction kinetics and computer technology. The engineer must also have the ability to apply this knowledge to practical situations for the purpose of accomplishing something that will be beneficial to society. However, in making these applications, the chemical engineer must recognize the economic implications which are involved and proceed accordingly.

Plant design includes all engineering aspects involved in the development of either a new, modified or expanded industrial plant. During this development, the chemical engineer makes economic evaluations of new processes, designs individual pieces of equipment for the proposed new venture, or develops a plant layout for coordination of the overall operation. Because of these design duties, the chemical engineer is often referred to as a design engineer. On the other hand, a chemical engineer specializing in the economic aspects of design is often referred to as a cost engineer. The chemical engineering design of new chemical plants and the expansion or revision of existing ones require the use of engineering principles and theories combined with a practical realization of the limits imposed by individual conditions.

1.7 The ten ‘greatest achievements’ of chemical engineering

1.7.1 The atom

Biology, medicine, metallurgy, and power generation have all been transformed by the capability to split the atom and isolate isotopes. Chemical engineers played a significant role in achieving both these results. Early on, chemical facilities were used in warfare, which ultimately resulted in the production of the atomic bomb. Today, this technology has found uses in more peaceful applications. Doctors now use isotopes to monitor bodily functions, and quickly identify clogged arteries and veins. Similarly, this technology helps biologists gain invaluable insight into the basic mechanisms of life and assists archaeologists in accurately dating their historical findings.

1.7.2 The plastic age

The start of the 19th Century witnessed tremendous achievements in polymer chemistry. However, it required the vision of chemical engineers during the 20th century to make bulk produced polymers a viable economic reality. When a plastic called Bakelite was introduced in 1908, it heralded the dawn of the ‘Plastic Age’ and quickly found uses in electric insulation, plugs and sockets, clock bases, iron cooking handles and fashionable jewelry. Now, plastic has become so ubiquitous that we hardly notice its existence. Yet, nearly all aspects of modern life are positively and deeply impacted by plastic.

1.7.3 The human reactor

Chemical engineers have been engaged in the detailed study of complex chemical processes by breaking them up into smaller processes called ‘unit operations’. Such operations might comprise heat exchangers, filters, chemical reactors and the like. Subsequently, this concept has also been applied to the human body. The implications of such analysis have helped to improve clinical care, suggest improvements in diagnostic and therapeutic devices and have led to mechanical wonders such as artificial organs. Doctors and chemical engineers continue to work in tandem to help us live longer, fuller lives.

1.7.4 Wonder drugs for the masses

Chemical engineers have been adept at taking small quantities of antibiotics developed by distinguished researchers, such as Sir Arthur Fleming (who discovered penicillin in 1929), and increasing their yields several thousand times through mutation and special brewing techniques. Today’s low price, high volume drugs owe their existence to the work of chemical engineers. This ability to bring once scarce materials to all members of society through industrial creativity is a defining characteristic of chemical engineering.

1.7.5 Synthetic fibers

From blankets and clothes to beds and pillows, synthetic fibers keep us warm, cozy and provide a good night’s rest. Synthetic fibers also help reduce the strain on natural sources of cotton and wool, and can be tailored to specific applications.

1.7.6 Liquefied air

When ambient air is cooled to very low temperatures, (about 320ºF below zero) it condenses into a liquid. Chemical engineers are then able to separate the different components of air. Purified nitrogen can be used to recover petroleum, freeze food, produce semiconductors or prevent unwanted reactions. Likewise, oxygen is used to make steel, smelt copper, weld metals together and provide life-support for patients.

1.7.7 The environment

Chemical engineers furnish economical solutions to clean up yesterday’s waste and prevent tomorrow's pollution. Catalytic converters, reformulated gasoline and smoke stack scrubbers all help keep the world clean. Additionally, chemical engineers help reduce the strain on natural materials by means of synthetic replacements, more efficient processing and new recycling technologies.

1.7.8 Food

Plants require large quantities of nitrogen, potassium and phosphorus to grow in profusion, and provide us with a bountiful and balanced diet. Chemical fertilizers can help provide these nutrients to crops. Fertilizers are especially important in certain regions, where food can sometimes be scarce. Advances in biotechnology also offer the potential to further increase worldwide food production. As in other fields, chemical engineers are at the forefront of food processing and help create better tasting and most nutritious food.

1.7.9 Petrochemicals

Chemical engineers have assisted in the development of processes like catalytic cracking, which is used to break down the complex organic molecules found in crude oil into much simpler components. The base components thus generated are separated, and recombined to form many useful products including: gasoline, lubricating oils, plastics, synthetic rubber and synthetic fibers. Petroleum processing is therefore recognized as an enabling technology, without which, much of modern life would cease to function.

1.7.10 Synthetic rubber

Whether you drive, bike, roller-blade, or run, odds are you are running on rubber. During World War II, increasing use of rubber to make tires, gaskets, hoses, conveyor belts, and even running shoes, made synthetic rubber capacity very significant. Chemical engineers played a prominent role in developing today’s synthetic rubber industry.

1.8 Chemical engineering: ‘Today and Tomorrow’

The ‘Big Four’ of engineering fields comprise civil, mechanical, electrical, and chemical engineers. Of these, chemical engineers are numerically the smallest group. However, this relatively small group holds a very important position in many industries and chemical engineers are, on an average, the highest paid of the ‘Big Four’. Also, numerous chemical engineers have found their way into the upper management.

Chemical Engineering offers a career which enables professionals to contribute in a meaningful way to society. Many young engineers are assigned projects which involve environmental, health, and safety issues associated with chemical processing. The chemical processing industry is committed to producing high value products, which benefit society, and have minimal environmental, health and safety consequences.

1.9 Summary

Since the dawn of time, chemicals have been used to improve the quality of life. The human body in itself is the best and most complex chemical process system that exists.

In the Middle Ages, a band of researchers collectively called Alchemists recorded their research in turning base metals into gold. This was the first step towards understanding the nature of chemicals.

The term ‘Chemical Engineering’ is attributed to Professor J. Beckman of the Gottingen University. In 1910, the Massachusetts Institute of Technology introduced a separate branch of engineering and the first course on Chemical Engineering was taught. Since then, scores of other universities, the world over, have followed suit and offer a course on Chemical Engineering.

Until the late 1980s, when the field of electronics and computers really took off, chemical engineers were the highest paid individuals compared to graduates from other domains of engineering. Even the field of electronics has its roots deeply embedded in chemical engineering research.

The ten greatest achievements in the field of chemical engineering are:

- Understanding the structure of atoms

- Development of plastics

- Understanding the human reactor

- Production of wonder drugs for the masses

- Production of synthetic fibers

- Liquefied air
- Saving the environment (harnessing the power of nature)
- Food processing
- Petrochemicals
- Production of synthetic rubber

Quick quiz

Who are Alchemists?

Why is their work of importance?

What was the first parameter used to measure the industrial strength of a country?

How does Chemical Engineering differ from any other branch of engineering?

What was the first naturally occurring substance used in the development of plastics?