GURUNANAK INSTITUTE OF TECHNOLOGY

157/F, Nilgunj Road, Panihati

Kolkata -700114

Website: www.gnit.ac.in

Email: info.gnit@jisgroup.org

Approved by A.I.C.T.E., New Delhi

Affiliated to MAKAUT, West Bengal

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NAME OF COORDINATOR: Mr. Saikat Mazumder (GNIT)

NAME OF TEAM MEMBER: Prof. Utpal Raychaudhuri (GNIT)

MODULE I

Lecture 1. Introduction to project engineering

The general term ***plant*** design includes all engineering aspects involved in the development of either a new, modified, or expanded industrial plant. In this development, the chemical engineer will be making economic evaluations of new processes, designing individual pieces of equipment for the proposed new venture, or developing a plant layout for coordination of the overall operation. Because of these many design duties, the engineer is many times referred to here as a design ***engineer.*** On the other hand, an engineer specializing in the economic aspects of the design is often referred to as a ***cost engineer.*** In many instances, the term ***process engineering*** is used in connection with economic evaluation and general economic analyses of industrial processes, while ***process design*** refers to the actual design of the equipment and facilities necessary for carrying out the process. Similarly, the meaning of plant design is limited by some engineers to items related directly to the complete plant, such as plant layout, general service facilities, and plant location.

Although one person cannot be an expert in ***all*** the phases involved in plant design, it is necessary to be acquainted with the general problems and approach in each of the phases. The process engineer may not be connected directly with the final detailed design of the equipment, and the designer of the equipment may have little influence on a decision by management as to whether or not a given return on an investment is adequate to justify construction of a complete plant. Nevertheless, if the overall design project is to be successful, close teamwork is necessary among the various groups of engineers working on the different phases of the project. The most effective teamwork and coordination of efforts are obtained when each of the engineers in the specialized groups is aware of the many functions in the ***overall*** design project.

Lecture 2.Introduction to process design development

2.1. Introduction

In this modern age of industrial competition, a successful engineer needs more than a knowledge and understanding of the fundamental sciences and the 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. 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 industrial conditions. Development of a new plant or process from concept evaluation to profitable reality is often an enormously complex problem.

2.2. Stages of plant design project

A plant-design project move to completion through a series of stages such as is shown in the following:

1. Inception
2. Preliminary evaluation of economics and market
3. Development of data necessary for final design
4. Final economic evaluation
5. Detailed engineering design
6. Procurement
7. Erection
8. Startup and trial runs
9. Production

This brief outline suggests that the plant-design project involves a wide variety of skills. Among these are research, market analysis, design of individual pieces of equipment, cost estimation, computer programming, and plant-location surveys.

Lecture 3. Optimum economic design

If there are two or more methods for obtaining exactly equivalent final results, the preferred method would be the one involving the least total cost. This is the basis of an optimum economic *design*. One typical example of an optimum economic design is determining the pipe diameter to use when pumping a given amount of fluid from one point to another. Here the same final result (i.e., a set amount of fluid pumped between two given points) can be accomplished by using an infinite number of different pipe diameters. However, an economic balance will show that one particular pipe diameter gives the least total cost. The total cost includes the cost for pumping the liquid and the cost (i.e., fixed charges) for the installed piping system. A graphical representation showing the meaning of an optimum economic pipe diameter is presented in Fig. l-l. As shown in this figure, the pumping cost increases with decreased size of pipe diameter because of frictional effects, while the fixed charges for the pipeline become lower when smaller pipe diameters are used because of the reduced capital investment. The optimum economic diameter is located where the sum of the pumping costs and fixed costs for the pipeline becomes a minimum, since this represents the point of least total cost. In Fig. l-l, this point is represented by *E*.

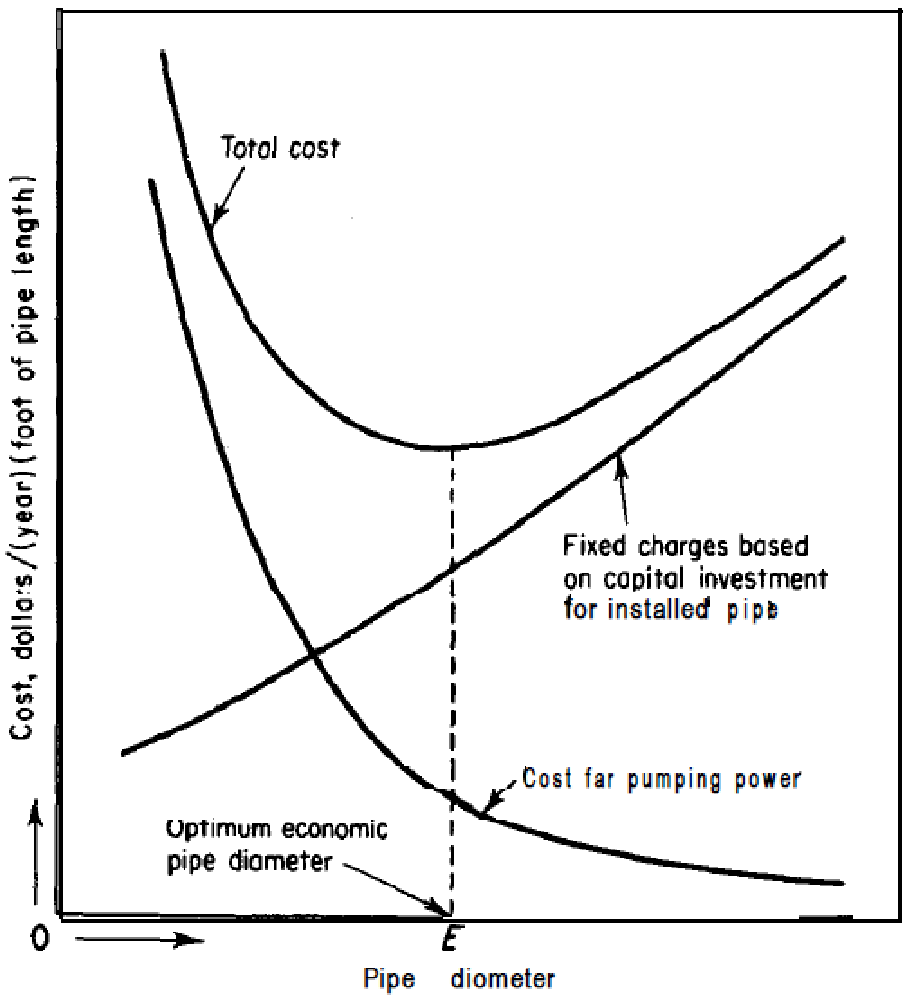


FIGURE 1-1
Determination of optimum economic pipe diameter for constant mass-throughput rate.

Lecture 4. Feasibility Survey

Before any detailed work is done on the design, the technical and economic factors of the proposed process should be examined. The various reactions and physical processes involved must be considered, along with the existing and potential market conditions for the particular product. A preliminary survey of this type gives an indication of the probable success of the project and also shows what additional information is necessary to make a complete evaluation. Following is a list of items that should be considered in making a feasibility survey:

1. Raw materials (availability, quantity, quality, cost)
2. Thermodynamics and kinetics of chemical reactions involved (equilibrium, yields, rates, optimum conditions)
3. Facilities and equipment available at present
4. Facilities and equipment which must be purchased
5. Estimation of production costs and total investment
6. Profits (probable and optimum, per pound of product and per year, return on investment)
7. Materials of construction
8. Safety considerations
9. Markets (present and future supply and demand, present uses, new uses, present buying habits, price range for products and by-products, character, location, and number of possible customers)
10. Competition (overall production statistics, comparison of various manufacturing processes, product specifications of competitors)
11. Properties of products (chemical and physical properties, specifications, impurities, effects of storage)
12. Sales and sales service (method of selling and distributing, advertising required, technical services required)
13. Shipping restrictions and containers
14. Plant location
15. Patent situation and legal restrictions

Lecture 5. Basic concepts of plant layout and design

If sufficient information is available, a preliminary design may be developed in conjunction with the preliminary feasibility survey. In developing the preliminary design the chemical engineer must first establish a workable manufacturing process for producing the desired product.

The first step in preparing the preliminary design is to establish the bases for ***design.*** In addition to the known specifications for the product and availability of raw materials, the design can be controlled by such items as the expected annual operating factor (fraction of the year that the plant will be in operation), temperature of the cooling water, available steam pressures, fuel used, value of by-products, etc. The next step consists of preparing a simplified flow diagram showing the processes that are involved and deciding upon the unit operations which will be required. A preliminary material balance at this point may very quickly eliminate some the alternative cases. Flow rates and stream conditions for the remaining cases are now evaluated by complete material balances, energy balances, and a knowledge of raw-material and product specifications, yields, reaction rates, and time cycles. The temperature, pressure, and composition of every process stream is determined. Stream enthalpies, percent vapor, liquid, and solid, heat duties, etc., are included where pertinent to the process.

Equipment specifications are generally summarized in the form of tables and included with the final design report. These tables usually include the following:

1. ***Cofumns (distillation).*** In addition to the number of plates and operating conditions it is also necessary to specify the column diameter, materials of construction, plate layout, etc.
2. Vessels. In addition to size, which is often dictated by the holdup time desired, materials of construction and any packing or baffling should be specified.
3. ***Reactors.*** Catalyst type and size, bed diameter and thickness, heat-interchange facilities, cycle and regeneration arrangements, materials of construction, etc., must be specified.
4. Heat exchangers and furnaces. Manufacturers are usually supplied with the duty, corrected log mean-temperature difference, percent vaporized, pressure drop desired, and materials of construction.
5. Pumps and compressors. Specify type, power requirement, pressure difference, gravities, viscosities, and working pressures.
6. Instruments. Designate the function and any particular requirement.
7. Special equipment. Specifications for mechanical separators, mixers, driers, etc.

Lecture 6. Basic understanding of equipment layout

6.1. Introduction

Equipment layout design refers to the arrangement of all equipment, machinery, and furnishings within a building envelope after considering the various objectives of the facility. The layout consists of production areas, support areas, and the personnel areas in the building.

The need for layout design arises both in the process of designing a new layout and in redesigning an existing layout. The need in the former case is obvious but in the latter case it is because of many developments as well as many problems with in the facility such as change in the product design, obsolescence of existing facilities, change in demand, frequent accidents, more scrap and rework, market shift, introduction of a new product etc.

6.2. Objectives

Primary objectives of a typical facility layout include

1. Overall integration and effective use of man, machine, material, and supporting services,
2. Minimization of material handling cost by suitably placing the facilities in the best possible way,
3. Better supervision and control,
4. Employee's convenience, safety, improved morale and better working environment,
5. Higher flexibility and adaptability to changing conditions and
6. Waste minimization and higher productivity.

6.3. Types of Layout

There are the following types of layouts

- Product layout
- Process layout
- Fixed position layout
- Cellular layout

Product layout

This type of layout is generally used in systems where a product has to be manufactured or assembled in large quantities. In product layout the machinery and auxiliary services are located according to the processing sequence of the product without any buffer storage within the line itself.

Process layout

In a process layout, (also referred to as a job shop layout) similar machines and services are located together. Therefore, in a process type of layout all drills are located in one area of the layout and all milling machines are located in another area. A manufacturing example of a process layout is a machine shop. Process layouts are also quite common in non-manufacturing environments. Examples include hospitals, colleges, banks, auto repair shops, and public libraries

Fixed location layout

In this type of layout, the product is kept at a fixed position and all other material; components, tools, machines, workers, etc. are brought and arranged around it. Then assembly or fabrication is carried out. The layout of the fixed material location department involves the sequencing and placement of workstations around the material or product. It is used in aircraft assembly, shipbuilding, and most construction projects.

Cellular type layout

This type of layout is based on the grouping of parts to form product / part families. Similar parts may be grouped into families based on common processing sequences, shapes, tooling requirements, and so on. The processing equipment required for a particular product family are grouped together and placed in a manufacturing cell. The cells become, in effect, miniature versions of product layouts. The cells may have movements of parts between machines via conveyors or have a flow line connected by a conveyor. This type of layout is used when various products have to be produced in medium to large quantities.

6.4. SLP

The Systematic Layout Planning (SLP) procedure as presented by Francisand White (1974) is shown in Figure-5. We see that once the appropriateinformation is gathered, a flow analysis can be combined with an activity analysisto develop the relationship diagram. Space considerations when combined withthe relationship diagram lead to the construction of the space relationshipdiagram. Based on the space relationship diagram modifying considerations andpractical limitations, a number of alternative layouts are designed and evaluated.

In general, SLP distinguishes a number of steps to determinea layout:
(1) collect information on relations between the wholeplant and its suppliers and other outside relations;
(2) collect information relating to all work centres andtheir relations;
(3) draw a schematic layout showing the flow of goodsbetween the work centres;
(4) adjust the schematic layout to take into account theavailable space;
(5) evaluate the resulting layout and associated costs offlow of goods and consider alternatives at lower costs.

The central aim of SLP is to find a layout that minimizesthe costs of transportation of goods.

Lecture7. Basic understanding of ventilation in the food plant design

7.1. Introduction

Ventilation is the supply of fresh, conditioned air to replace unwanted air. Conditioning can include alteration of moisture content, change of temperature, and filtering to remove particulates and organisms.

Within the processing area, ventilation will remove obnoxious odors, moisture, and heat and replace it with air that is free from contaminants and air that will increase the comfort level of workers. The amount of air is calculated as a replacement volume. Depending upon the production processes, the air can be replaced from 6 to 20 times per hour. It is also advisable to keep the processing area under a slight positive pressure. This will ensure that processing area air flows out when a door is opened.

Special air is required in areas where baby formula is handled or where aseptic operations take place. In these cases, air will be filtered through special filters that will remove organisms. The processing area must be under positive pressure at all times so that no organisms can enter from adjacent processing areas.

7.2. Objectives

1. To maintain an adequate oxygen supply in the work area.
2. To control hazardous concentrations of toxic materials in the air.
3. To remove any undesirable odors from a given area.
4. To control temperature and humidity.
5. To remove undesirable contaminants at their source before they enter the work place air.

7.3. Ventilation Design Parameters

1. Manufacturing process
2. Exhaust air system & local extraction
3. Climatic requirements in building design (tightness, plant aerodynamics, etc)
4. Cleanliness requirements
5. Ambient air conditions
6. Heat emissions
7. Terrain around the plant
8. Contaminant emissions
9. Regulations

7.4. Types of Industrial Ventilation Systems

The ventilation system in the plant is subdivided into the Supply System and the Exhaust System. The Purpose of the supply system is to create a comfortable environment in the plant and to replace air exhausted from the plant. The components of the supply system include air inlet section, filters, heating or cooling equipment, fans, ducts and grills for distributing the air within the working space.

The Exhaust systems serve the following purposes – An exhaust ventilation system removes the air and airborne contaminants from the work place air. The exhaust system may exhaust the entire work area, or it may be placed at the source to remove the contaminant at its source itself

There are 2 types of exhaust systems - General exhaust system and Local exhaust system. The former is used for heat control in an area by introducing large quantities of air in the area (the air may be tempered and recycled). The Local exhaust system serves the objective of removing the contaminant as it is generated at the source itself. The advantage of Local exhaust system is that is more effective and less expensive as compared to the General exhaust system.

Lecture 8. Design consideration for location of food plants

8.1. Importance of plant location for the success of the project

Plant location decisions are strategic, long term and non-repetitive in nature. Without sound and careful location planning in the beginning itself, the new plant may pose continuous operating disadvantages. Location decisions are affected by many factors, both internal and external to the organization's operations.

Internal factors include the technology used, the capacity, the financial position, and the work force required.

External factors include the economic, political and social conditions in the various localities.

Most of the fixed and some of the variable costs are determined by the location decision. The efficiency, effectiveness, productivity and profitability of the plant are also affected by the location decision. Location decisions are based on a host of factors, some subjective, qualitative and intangible while some others are objective, quantitative and tangible.

8.2. Factors involved in the plant location decision

- Market: It is a very important factor with respect to both phases of location studies. If product is fragile and susceptible to spoilage, proximity of the facility to the market is critical. If the product is relatively cheap and transportation cost is high, a location close to the markets is desirable.
- Raw material and supplies: The facility in general should be near to the vendors / suppliers. This will further reduce the transportation cost of incoming materials and the lead-time of the inventory replenishment.
- Transportation facilities: Transportation facilities must be available.
- Climate: Climate is another important factor to be considered for the facility location especially in industries where special constraints are needed, for example the textile industry requires a high humidity zone.
- Site size: The plot of land must be large enough to hold the facilities required by the proposed facility. Sometimes a good site may not have the required area.
- Community attitude: Community attitude is difficult to evaluate. Normally communities provide the overwhelming support to new industries, because this generates significant employment opportunities to the local people. Moreover, infrastructure development of the city or town progresses very rapidly. In some cases, when there is a fear of generation of pollution, community attitude goes in the reverse.
- Other factors that may also affect the facility location decisions are manpower availability, land cost, waste disposal, and pollution.

MODULE II

Lecture 1. Miscellaneous aspects of plant layout and design: Waste Disposal

Waste disposal is a serious problem for many chemical plants. The EPA initiative that has greatly curtailed land disposal has had a great effect on waste disposal.The disposal of waste streams that contain large amounts of water is another challenge which faces a process engineer. Deep-well injection has been used in the past, but this method has been constrained by regulatory agencies. Recently, refinery wastewater and storm water runoff has been subject to more stringent Best Available Technology (BAT) effluent controls. The agreement covers nonconventional pollutants such as phenolic compounds, ammonia sulfide, and toxic pollutants such as chromium and hexavalent chromium.

Hydrocarbon emissions is an environmental problem which is prominent in some areas of the country. In these areas, pollutant levels occasionally exceed the national ambient air quality standard.

1.1. Certain specifications related to plant layout that affect waste disposal strategies

There shall be no ponds or large standing water bodies or streams on the plantgrounds. These bodies attract birds, insects and rodents. All of these organisms areknown to carry pathogenic microorganisms. If areas of standing water exist, thenthe land will need to be graded to eliminate standing water.The outer plant layout must include provision for handling both solid and liquidwaste. These facilities should be located out of sight at the back of the plant and becompletely isolated from all aspects of the manufacturing process. Because wastewater contains high levels of organic solids, and high biological and chemicaloxygen demand (BODs and CODs), waste materials are strictly regulated by regulatory environmental agencies. On-site treatment, therefore, may be requiredbefore liquid waste can be put back into the natural water supply. Solid processwaste can also present environmental concerns and therefore there will need to beprovision to collect solid waste and dispose of it in an environmentally acceptableprocess. Waste systems, whether liquid or solid, are highly attractive to insects,rodents and birds and contain high levels of microbiological activity. They must beisolated in a way that will eliminate the waste system as a source of contamination.

Lecture 2. Miscellaneous aspects of plant layout and design: Safety arrangements

2.1. Safety considerations during equipment layout

Thought should be given to the location of equipment requiring frequentattendance by operating personnel and the relative position the control room toobtain the shortest and most direct routes for operators when on route operation.However, the control room should be in a safe area. Some importantconsiderations involved in locating a few key equipment items are listed below:

- Mixing vessels can be laid out in a straight line, in pairs or staggered.
- In evaporators using barometric leg type condensers, barometric leg should be at least 10 mm from the vessel base. This is usually situated on the ground floor. For multiple effect evaporators, place the individual effects as close as possible to minimize vapor lines. Vapor liquid separator is accommodated without increasing the distance between effects. The layout requirements for crystallizers are similar to those for evaporators.
- Furnaces should be located at least 15 m away from other equipment. Ample room need to be provided at the firing front for the operation of the burner and burner control panel.
- Where there are a large number of heat exchangers, they are often put together in one or more groups. Location should provide a layout, which is convenient to operate and maintain. Horizontal clearance of at least 1.5 m should be left between exchangers or exchangers and piping. Floating head heat exchangers require an installation length of at least 2.5 times the tube length. Air cooled exchangers are located adjacent to the plant section they serve.
- Pumps in general should be located close to the equipment from which they take suction. Changes in direction of the suction line should be at least 0.6 m from the pump. As far as possible, clearances and piping should provide free access to one side of the motor and pump. Clearances between pumps or pumps and piping should be at least 1.2 m for small pumps (18 kW) and 1.5 m to 2 m for large pumps. Pumps handling hot liquid (60 °C) should be at least 7.5 m from pumps handling volatile liquids.

2.2. Major considerations during equipment layout

- Equipment should be laid to give maximum economy of pipe work and supporting steel. Normally, they should be laid out in a sequence to suit the process flow, but exceptions to this arise from the desirability to group certain items such as tanks or pumps or perhaps to isolate hazardous operations.
- In general, high elevation should only be considered when ground space is limited or where gravity flow of materials is desired.
- Equipment items which are considered to be a source of hazard should be grouped together and wherever possible should be located separately from other areas of the plant and possible enclosed by blast walls.
- Provide sufficient clear space between critical and mechanically dangerous or high temperature equipment to allow safety of operating or maintenance personnel.
- The equipment needing frequent internal cleaning or replacement of internal parts should be laid out for ease of maintenance.
- Elevation to the underside of the pipe bridges and racks over paved areas should be at least 4 m.

Lecture 3. Miscellaneous aspects of plant layout and design: Factory floor design

Floors

Although a good floor is the starting-point for any industrial building,it is surprising both how little attention is normally paid to it,and how little is known about it by the occupiers.The different kinds of use it will receive have a direct bearing on thestrength and quality of a floor. For example, floors used for storagemust be capable of withstanding both point and area loadings, andthese often to a high level of weight. The surface must be of a goodstandard, since many handling vehicles (pallet trucks, straddle trucks)have small-diameter wheels or rollers which must be allowed toturn freely. Joints, if acceptable, must be as inconspicuous aspossible, and the surface should be free from sharp inclines, rampsor declivities. Such requirements may demand resurfacing if an oldfloor is to be used for modem storage methods, and the cost of thiscan be high. In production areas, in addition to most of the above requirements,the floor must be able to withstand without degradation the trafficimposed by the production pattern. There may be special requirementsfor surface finish brought about by the material used orhandled (oils, chemicals, food processing). Special attachment pointsmay have to be provided for machinery, or facilities for drainage. Itis not good practice to provide services (i.e. water, electricity,compressed air) from below floor level in general industry, and onlydrains or similar channels should interrupt the surface. Services arenever exactly where they are needed if floor access points are provided,and have a very limiting effect upon layout. Damage can alsooccur, and repairs are difficult and costly to effect. These commentsdo not apply to fixed-position layout, such as chemical or heavyprocessing plant, where services are normally 'built in' as construction proceeds.

Slight inclination in the general angle of the floor is sometimes maintained, especially those areas which operate with liquid raw materials. Processing areas in the industry have a general slope of not more than 6 degrees as these help in cleaning operations.

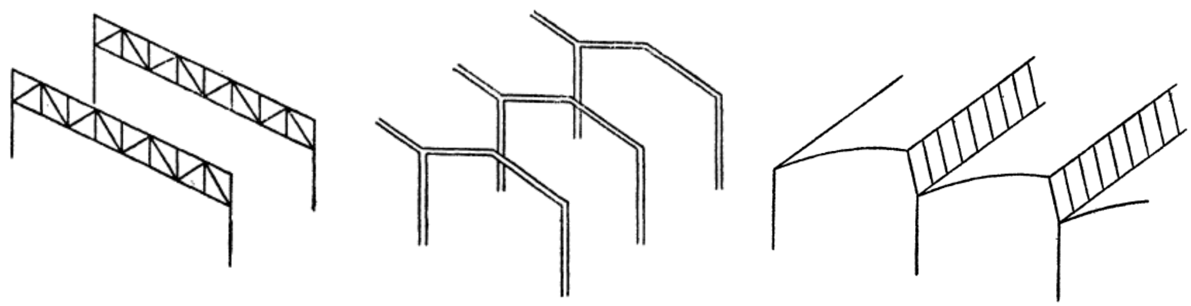
Another example can be the introduction of seamless flooring in the processing area which is a type of flooring that is devoid of sharp edges. The advantage of this is that it prevents dirt build up and also helps in cleaning.

Walls

Modern industrial buildings are usually constructed with somekind of prefabricated curtain walling to facilitate rapid construction,satisfactory insulation and protection from the weather, and to allowfor future expansion. Older buildings will have less sophisticatedsystems, and brick or breeze-block walls. It is usually only necessaryfor the layout planner to know what purpose the wall serves, if thisis not obvious. Walls, other than those forming the exterior protection,are erected for various reasons, such as division of an area,fire-breaks, protection of personnel, etc.

Lecture 4. Miscellaneous aspects of plant layout and design: Roof design

More modern buildings tend to make use of recentdesign methods, and are provided with roofs which although fullyadequate for the purpose of providing cover and lighting, do notoften allow heavy equipment to be suspended therefrom withoutendangering the safety of the structure. Such buildings may employprefabricated 'system' components, or may be cast *in situ* as a lightweightconcrete shell. In these cases the provision of any overheadlifting or moving equipment has to be accompanied by the erectionof suitable supports or framing, the vertical members of which maywell invalidate the objective of keeping the floor clear of obstructions.
So a lightweight roof may rule out the use of a medium- or heavydutyoverhead conveyor, thus dictating the handling methods on thefloor below



The matter of internal roof height is one which has received verylittle attention. In the past it was usually thought that roof height wasdependent on use, to the extent that a building used for storagepurposes normally had a higher roof than in manufacturing areas.This concept is difficult to justify today, since flexibility in use isusually regarded as more important. The cost of increasing theheight of walls to enclose a given volume is only about 15 per cent ofthe cost of lateral extension (if site cost is ignored), and with presentdays standards of insulation and air movement the heat lossesthrough the roof with increased height can be disregarded.

The optimum height of roofs for industrial buildings has longbeen a subject of controversy, but seems to be settling out in currentpractice somewhere between 6 and 8 metres (18-26 ft.). The mainfactor influencing this seems to be the convenient stacking height ofa normal fork-lift truck using palletised loads 1 to 0.5metres(3-4.5ft)in height. Stacking above this height usually calls for more specialized lifting vehicles and possibly greater driver skill. There is also a timeelement involved, since stacking speed is much lower than horizontalmovement (see Appendix). If warehousing and storage is the majoractivity in a building, then greater heights and increasing sophisticationof lifting machines are likely, but for manufacturing andgeneral-purpose buildings the heights quoted above are likely to beregarded as the norm for a long time to come.

All roof vents and fan exhausts should be adequately screened off to prevent insect entry and bird roosting/nesting. Depending on the types of products being produced in the plant, it may be necessary to add filtration to filter out specific particle sizes.

Lecture 5. The impact of factory layout on hygiene in the food industry

5.1. How hygiene is perceived in a food industry

One of the crucial elements in current food processing issafety of the products (Figee and Oortwijn, 2004; Lelieveldet al., 2003). Most consumers associate safety with productsthat are produced while taking ultimate care withrespect to hygiene. Failing to produce according to (high)hygienic standards has a direct influence on productionefficiency by loss of production, but an even greatereffect through loss of consumer confidence.

Hygiene has been approached from various angles. A substantialamount of work has been done on biology and health(Banwart, 1989). Here the main topics are the circumstancesthatfavour growth of bacteria and other micro-organisms andhow to stop growth or even remove micro-organisms fromfood products. In health sciences the influence of microorganismson people is the main subject of study. Thesestudies look at single effects and means of preventingthese effects.Another view on hygiene is offered if it is consideredfrom a legal perspective (see first three chapters in Lelieveldet al., 2003). A large number of national and Europeanrules and regulations prescribe in detail what is allowed orneeded for products to be safe and good from a hygienepoint of view. It is expected that these rules will be furthertightened, and conforming to these rules is generally seenas a minimal level of performance. However, laws hardlyprovide information on how to reach an acceptable levelof hygiene.

Chemical and food engineering provide a number ofrules and knowledge to design and run food processingplants. Most of this knowledge applies to designing agreenfield site from scratch. Within this field substantialknowledge is available with respect to equipment design,plant design (stressing all aspects of civil engineeringsuch as walls, floors, heating, piping), air control, controlof personnel, and use of materials (see Lelieveldet al.,2003, EHEDG, 2003 and the associated articles in Trendsin Food Science and Technology). However, most ofthese contributions pay attention to specific technicalaspects of hygienic design at the detailed level of machines,materials used, floors, piping, etc.

From a management point of view, hygiene isapproached as a control problem. Based on managementprinciples, Hazard Analysis Critical Control Point(HACCP) (De Smedt and Easter, 1994) and Good ManufacturingPractice (GMP) have been implemented to helpplants to maintain high levels of hygiene. Here as well,these approaches have proven their value in food processingcompanies, but give hardly any help in designing orredesigning the layout of a plant to maintain hygienic standards.Their main aim is to be able to prove that productionhas been executed according to the predetermined rules andthat critical points are sufficiently controlled.

5.1. Co-relation between hygiene and plant layout

A basic differencebetween the standard SLP approach and what is neededin our case is that SLP assumes closeness between stages,while we need to know what types of interaction mightoccur, how this interaction might influence quality andhygiene of food products, and if we need to take measuresto restrict or even prevent interaction between stages. Whereas in SLP minimizing the flow of goods is themain reason for location of one stage near another stage,it is not directly clear what the important elements infood processing are for making the above decisions oninteraction and demarcations between stages, such thathygiene of the product is best maintained.As hygiene of products is the main point of attention, wesubmit that the characteristics of the product are an importantelement. Here, we focus on those attributes of a productthat determine hygiene or can diminish hygiene. A productcannot be considered in isolation, because all types of factorsfrom the processing environment can directly influencehygiene. Factors include the flow of goods from otherstages, influences from possible interaction with issues outsidethe plant, temperature of the processing environment,and carriers of micro-organisms like air and people.In general, we can state that our method aims to restrictthe influence of environmental factors depending upon thecharacteristics of the product. Restricting those influencesmeans making a choice between two extremes: totallydemarcated process stages and totally free interactionbetween stages. Between those two extremes, severaltypes of limited interaction between processing stages arepossible.

Guiding the layout decision are the required hygienelevels at each stage of production. The required hygienelevel of a stage is defined as the level of hygiene thatprevents a product deteriorating during that stage.

Lecture 6. Material handling in the food processing plant

INTRODUCTION AND IMPORTANCE

Material handling is a necessary and significant component of any productive activity. It is something that goes on in every plant all the time. Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position and for the right cost, by using the right method. It is simply picking up, moving, and lying down of materials through manufacture. It applies to the movement of raw materials, parts in process, finished goods, packing materials, and disposal of scraps. In general, hundreds and thousands tons of materials are handled daily requiring the use of large amount of manpower while the movement of materials takes place from one processing area to another or from one department to another department of the plant. The cost of material handling contributes significantly to the total cost of manufacturing.

In the modern era of competition, this has acquired greater importance due to growing need for reducing the manufacturing cost. The importance of material handling function is greater in those industries where the ratio of handling cost to the processing cost is large. Today material handling is rightly considered as one of the most potentially lucrative areas for reduction of costs. A properly designed and integrated material handling system provides tremendous cost saving opportunities and customer services improvement potential.

DEFINITIONS

There are many ways by which material handling has been defined but one simple definition is “Material handling is the movement and storage of material at the lowest possible cost through the use of proper method and equipment”.

Other definitions are:

- “Material handling embraces all of the basic operations involved in the movement of bulk, packaged, and individual products in a semisolid or solid state by means of machinery, and within limits of a place of business”.
- “Material handling is the art and science of moving, storing, protecting, and controlling material”
- “Material handling is the preparation, placing, and positioning of materials to facilitate their movement or storage”.

OBJECTIVES OF MATERIAL HANDLING

The primary objective of a material handling system is to reduce the unit cost of production. The other subordinate objectives are:

1. Reduce manufacturing cycle time
2. Reduce delays, and damage
3. Promote safety and improve working conditions
4. Maintain or improve product quality
5. Promote productivity
    a. Material should flow in a straight line
    b. Material should move as short a distance as possible
    c. Use gravity
    d. Move more material at one time
    e. Automate material handling
6. Promote increased use of facilities
    a. Promote the use of building cube
    b. Purchase versatile equipment
    c. Develop a preventive maintenance program
    d. Maximize the equipment utilization etc.

7. Reduce tare weight

8. Control inventory

Reduce Cost of Handling

The total cost of material handling per unit must decrease. The total cost per unit is the sum of the following:

1. Cost of material handling equipment – both fixed cost and operating cost calculated as the cost of equipment divided by the number of units of material handled over the working life of the equipment.
2. Cost of labor – both direct and indirect associated cost calculated in terms of cost per unit of material handled.
3. Cost of maintenance of equipment, damages, lost orders and expediting expenses, also calculated, in terms of cost per unit of material handled.

Reduced Manufacturing Cycle Time

The total time required to make a product from the receipt of its raw material to the finished state can be reduced using an efficient and effective material handling system. The movement of the material can be faster and handling distance could be reduced with the adoption of an appropriate material handling system.

LIMITATIONS OF AUTOMATED MATERIAL HANDLING SYSTEMS:

A good management practice is to weigh benefits against the limitations or disadvantages before contemplating any change. Material handling systems also have consequences that may be distinctly negative. These are:

1. Additional investment
2. Lack of flexibility
3. Vulnerability to downtime whenever there is breakdown
4. Additional maintenance staff and cost
5. Cost of auxiliary equipment.
6. Space and other requirements:

The above limitations or drawbacks of adopting mechanized handling equipment have been identified not to discourage the use of modern handling equipment but to emphasize that a judicious balance of the total benefits and limitations is required before an economically sound decision is made.

Lecture 7. Material of Construction for food processing equipment

7.1. Metals and Alloys

Both non-ferrous and ferrous metals and alloys are used in the construction of equipment and services for the food industry. Alloys for food contact may only contain aluminum, chromium, copper, gold, iron, magnesium, manganese, molybdenum, nickel, platinum, silicon, silver, tin, titanium, zinc, cobalt, vanadium and carbon. The machinability of these non-ferrous and ferrous materials has a large influence on the final choice for a certain construction material in a specific application.

Degradation of metals and alloys

Corrosion is a phenomenon in which, in the presence of moisture and oxygen, the metal undergoes an electro-chemical reaction with components of the surrounding medium. In the simple case of uniform corrosion, this reaction results in the formation of compounds of the metal (e.g. hydroxides) on the surface of the metal. The rate at which corrosion proceeds will depend in part on the composition of the aqueous medium: corrosion of iron in very pure water will be considerably slower than in water which contains, for example, acids or salts. The rate of corrosion depends also on the solubility of the formed compounds in the medium, and their rate of removal. Formed compounds may be rapidly removed in a flowing aqueous medium, increasing the corrosion rate. In a static medium, the rate of corrosion will be moderated as the ionic concentration of the surrounding medium increases. Corrosion products formed in the atmosphere are more or less adherent.

Iron and Steel

Although many materials have greater corrosion resistance than iron and steel,cost aspects favor the use of iron and steel. As a result, they are often used asmaterials of construction when it is known that some orrosion will occur. If thisis done, the presence of iron salts and discoloration in the product can beexpected, and periodic replacement of the equipment should be anticipated.

Stainless Steels

There are more than 100 different types of stainless steels. These materials arehigh chromium or high nickel-chromium alloys of iron containing small amountsof other essential constituents. They have excellent corrosion-resistance andheat-resistance properties. The most common stainless steels, such as type 302or type 304, contain approximately 18 percent chromium and 8 percent nickel,and are designated as 18-8 stainless steels.

Copper and its Alloys

Copper is relatively inexpensive, possesses fair mechanical strength, and can befabricated easily into a wide variety of shapes. Although it shows little tendencyto dissolve in nonoxidizing acids, it is readily susceptible to oxidation. Copper isresistant to atmospheric moisture or oxygen because a protective coating composedprimarily of copper oxide is formed on the surface. The oxide, however, issoluble in most acids, and thus copper is not a suitable material of constructionwhen it must contact any acid in the presence of oxygen or oxidizing agents.Copper exhibits good corrosion resistance to strong alkalies, with the exceptionof ammonium hydroxide. At room temperature it can handle sodium andpotassium hydroxide of all concentrations. It resists most organic solvents andaqueous solutions of organic acids.Copper alloys, such as brass, bronze, admiralty, and Muntz metals, canexhibit better corrosion resistance and better mechanical properties than purecopper. In general, high-zinc alloys should not be used with acids or alkaliesowing to the possibility of dezincification. Most of the low-zinc alloys areresistant to hot dilute alkalies.

Nickel and its Alloys

Nickel exhibits high corrosion resistance to most alkalies. Nickel-clad steel isused extensively for equipment in the production of caustic soda and alkalies.The strength and hardness of nickel is almost as great as that of carbon steel,and the metal can be fabricated easily. In general, oxidizing conditions promotethe corrosion of nickel, and reducing conditions retard it.Monel, an alloy of nickel containing 67 percent nickel and 30 percent copper, is often used in the food industries. This alloy is stronger than nickeland has better corrosion-resistance properties than either copper or nickel.

Aluminum

The lightness and relative ease of fabrication of aluminum and its alloys arefactors favoring the use of these materials. Aluminum resists attack by acidsbecause a surface film of inert hydrated aluminum oxide is formed. This filmadheres to the surface and offers good protection unless materials which canremove the oxide, such as halogen acids or alkalies, are present.

Lead

Pure lead has low creep and fatigue resistance, but its physical properties can beimproved by the addition of small amounts of silver, copper, antimony, ortellurium. Lead-clad equipment is in common use in many chemical plants. Theexcellent corrosion-resistance properties of lead are caused by the formation ofprotective surface coatings. If the coating is one of the highly insoluble leadsalts, such as sulfate, carbonate, or phosphate, good corrosion resistance isobtained. Little protection is offered, however, if the coating is a soluble salt,such as nitrate, acetate, or chloride. As a result, lead shows good resistance tosufuric acid and phosphoric acid, but it is susceptible to attack by acetic acidand nitric acid.

7.2. Plastics

Plastics are defined as shaped and hardened synthetic materials composed of long chain organic molecules called polymers, plus various additives. Additives are used to facilitate handling and processing (lubricants, mould-release agents, blowing agents, etc.), to change or improve various properties of the base polymer (heat stabilizers to cope with higher temperatures; fillers, reinforcing agents, fibers, impact modifiers to improve the durability; plasticizers to improve the flexibility; anti-statics to prevent electrical uploading; colouring agents for pigmenting; antimicrobials to prevent or retard microbiological corrosion) and to protect plastics from the effects of time and environmental conditions (flame retardants; antioxidants; UV stabilizers to absorb ultraviolet) [12].

Polytetrafluorethylene (PTFE) or Teflon, is inert (to all known chemicals), nontoxic, nonflammable, and has a working temperature range of -270 to 260 $_0$C. It has an extremely low coefficient of friction, and is applied as “non-stick” coating. It is used for machine packings, seals, gaskets, insulators, tubing, vessels for aggressive chemicals, coating in cookware, conveyor belt coating, mechanical and electrical bearings, insulation for coaxial cable, fixture and motor lead wire, industrial signal and control cable, etc.

Polyvinyl chloride (PVC) is the most widely used plastic in industry. It appears in transparent, opaque and coloured forms. It is applied as material for drains and gutters (max. 80 $_0$C), chilled and deionised water piping, rainwater pipes, tanks, guards, conveyor belt coating, electrical conduit and trunking, electrical cable sheathing, junction boxes, etc. PVC is tough, strong, with good resistance to chemicals, good low-temperature characteristics, but does not retain good mechanical perfor-mance above 80 $_0$C. In a food processing plant, where there is a significant amount of splashdown and where harsh cleaning agents are used daily to achieve sanitation standards, PVC is a better choice than PUR because it is more resistant to water and harsh cleaning chemicals. PVC is also cheaper than PUR and minimizes the risk of downtime due to cable failure.

Polyethylene (PE) is a non-polar, semi-crystalline, translucent to opaque thermoplastic with very low density, that absorbs very little water. It provides a smooth, soft and very tough surface and waxy-like feeling, but its low strength and hardness limits its use as engineering material. Polyethylene is very chemically resistant but sensitive to halogen and oxidizing acids, as well as to oxygen in the presence of heat and UV light. Polyethylene allows maximum continuous services temperatures of about 60 - 90 $_0$C, depending on the load. The lower temperature limit of use is about -50°C. A distinction is made between LDPE (low-density) and HDPE (high-density). LDPE is sensitive to grease and oil causing swelling and softening, or even stress cracking. The chemical resistance of HDPE is superior to that of LDPE, in particular towards oil and greases. Low-density polyethylene (LDPE) is applied as packaging material, plastic film, coating, pipes and fittings for drinking water and gases, domestic mouldings, electrical cable sheathing and insulation. High-density polyethylene (HDPE) is used to fabricate larger mouldings (transport and storage tanks), modular conveyor belts, sheet, tube, bearings, gears, etc. [11].

Polystyrene (PS) is an amorphous, clear transparent thermoplastic with low moisture absorption (approximately 0.05%), and available on the market in several opaque colours. In its unmodified form, polystyrene is a tough, dimensionally stable and highly resistant material but with rather poor elasticity. Polystyrene is not very useful as an engineering material because of its brittleness in unmodified forms. High-impact forms are obtained by compounding with butadiene or resins with a certain degree of elasticity, and heat-resistant forms are obtained by the use of fillers. Polystyrene also can be stabilized against ultraviolet radiation and also can be made in expanded form for thermal insulation and filler products. Polystyrene is suitable for operations at temperatures between -70 and 70 $_0$C. Polystyrene is resistant to alkalis, lyes, diluted mineral acids, alcohols, water and aqueous salt solutions, but is prone to attack by steam, many solvents and strong oxidizing materials. Polystyrene is sensitive to stress cracking, so that any residual stress within the finished product must be avoided. Applications include food packaging material, refrigerator lining, holding tank and freezing containers, thermal and electrical insulation, etc. Applications include food packaging material, refrigerator lining, holding tank and freezing containers, thermal and electrical insulation, etc. [11].

Polycarbonate (PC) is a light weight amorphous thermoplastic material commonly formed by the reaction of Bisphenol A with phosgene or diphenyl carbonate, and as such falls into the polyester family of plastics. Polycarbonate (PC) is an optical transparent or translucent high-performance plastic, also available in several grades (many colours), that remains clear over a wide temperature range (-90 up to about 130 $_0$C). It is a hard and stiff plastic with high dimensional stability that maintains its strength, rigidity and toughness up to 140 $_0$ and down to -20 $_0$C. Moisture absorption is low, being less than 0.5% after immersion in water during a long time, but gradual chemical degradation in hot water can occur, and it is also sensitive to steam. Polycarbonate has only fair resistance to chemicals, and is sensitive to mineral and organic acids, alkalines and oxidizing agents (ozone, sodium hypochlorite, peracetic acid, etc.). It is resistant to alcohols (except for methyl alcohol), various oils and fats as well as neutral and light acidic saline solutions. Some modified polycarbonates are more resistant against oxidizing and reducing agents, mineral acids and organic acids. By the use of proper additives, the weathering resistance can be increased. Stabilization of polycarbonate provides resistance against ultraviolet radiation. The durability, shatter resistance, high heat resistance and glass-like appearance of PC make it an ideal replacement for glass, and it is used in the assembly of containers, valves, housings, moulded parts, gears, glazing panels, light shields (UV stabilized), safety glass, etc. [11].

Phenolic resins have proven to be resistant to heat, fire and mechanical abrasion. Under these conditions, it maintains its form and mat or glossy surface structure very easily. Phenolic resins are used for the construction of electrical circuit boards, electrical components (plugs, switches, knobs, fittings, lighting fixtures), wiring devices, thermal insulation, mechanical parts (gears, cams), heat resistant handles, etc. The FDA Code of Federal Regulations (CFR), Title 21, section 177.2410 states that phenolic resins may be safely used for moulded articles intended for use in contact with food at the condition that migration studies have revealed that pre-set threshold values are not exceeded. Regulation EU N° 10/2011 allows the use of phenol as monomer but forbids the use of phenol as additive or polymer production aid in the production of plastics. Applications in the food contact area of food processing equipment is not at all recommended due to the free phenolic compounds (phenol, cresol and/or tertiary-butyl phenol) and formaldehyde that may be released or migrate into the food products produced [11].

Urea-formaldehyde (UF) resin is used in plywood, electrical applications, and as foam for thermal insulation. Urea-formaldehyde resins are very hard, scratch-resistant, odourless and tasteless with reasonable chemical resistance, and they have superior electrical properties. They show good resistance to all types of oils and greases but are affected by alkalis and strong acids. Urea-formaldehyde resins are less stable than melamine-formaldehyde resins. UF resins are also sensi-tive to light [11].

Poly(methyl methacrylate) (PMMA), often “Acrylic glass”, is a crystal-clear amorphous thermo-plastic with very good optical properties and quite resistant to discolouration. Besides high stiffness and strength, PMMA is also hard, brittle and scratch-resistant. Further, it has good light, ageing and weathering resistance. It is suitable for applications up to 70°C. PMMA is resistant to weak acids and alkalis, salt solutions, fats, oils and non-polar solvents, but is not resistant to concentrated acids. Further, PMMA is odourless and tasteless, and physiologically safe. The use of starting materials and production aids for PMMA is subject to the Commission Regulation (EU) No. 10/2011. Benzoyl peroxide, potassium and ammonium persulfate are not recommended as initiators in radical chain polymerization. The finished products must not test positively for peroxides. Typical areas of application are moulded parts for optical devices such as glasses, sight glasses, control knobs, light housings, transparent coverings, wash basins, etc. [11].

7.3. Elastomers

Rubber products are largely used in food processing equipment, such as for seals, gaskets, plate heat exchanger gaskets, hoses, conveyor belting, skirting, milk liners, butterfly valves, diaphragm pumps, feather pluckers, etc.

7.4. Brick and Cement Materials

Brick-lined construction can be used for many severely corrosive conditions,where high alloys would fail. Acidproof refractories can be used up to 900°C.A number of cement materials are used with brick. Standard are phenolicandfurane resins, polyesters, sulfur, silicate, and epoxy-based materials. Carbon-filled polyesters and furanes are good against nonoxidizing acids, salts, andsolvents. Silica-filled resins should not be used against hydrofluoric or fluorosilicicacids. Sulfur-based cements are limited to 95°C while resins can be used to about 175°C. The sodium silicate based cements are good against acidsto**400°C.**

7.4. Carbon and Graphite

Generally, impervious graphite is completely inert to all but the most severeoxidizing conditions. This property, combined with excellent heat transfer, hasmade impervious carbon and graphite very popular in heat exchangers, as bricklining, and in pipe and pumps. One limitation of these materials is low tensilestrength. Threshold oxidation temperatures are 350°C for carbon and 400°C forgraphite.

7.4. Wood

As it is inexpensive and durable, wood (hard marple, ash, basswood, beech, birch, butternut, cherry, oak and American black walnut) has been a traditional material for many applications in the food industry: ice cream sticks, cutting boards, vegetable and fruit boxes, pallets, etc. In the American regulations, hard maple or an equivalently hard, close-grained wood may be used for cutting boards, cutting blocks, butcher’s blocs, bakers tables and utensils such as rolling pins, chopsticks, etc. Because of the high acidity and salt content of brines in some products, which can cause severe corrosion problems even for expensive metallic construction materials such as stainless steel, fermentation tanks and storage containers in wood are still accepted in the food industry for wine, pickles and olives.

However today, the usage of wood in the food industry remains under debate. The reason for the negative attitude towards wood seems to be caused by the food legislation and the interpretation thereof in Europe and elsewhere. Wood is out of grace because of hygienic and mechanical strength problems: risk of splinters, porosity of wood (promotes the absorption of blood, fat and moisture), difficulties to keep it smooth and free of cracks, difficulties to keep it clean and hygienic due to the lack of cleaning and/or sanitation methods, etc. Moreover, strong and oxidizing acids and diluted alkalis may attack wood. To avoid pest infestations and the growth of moulds with concomitant production of mycotoxins, wood in contact with food is also often treated with pesticides and fungicides. Control for the presence of residual levels of these fungicides and pesticides in the food in contact with the wood should be performed [16], [17].

In conclusion, the use of wood is not really recommended. On some exceptions, wood is certainly not allowed within the product contact area, and should not be exposed to the outside. It must be permanently and tightly sealed off from the product zone.

7.5.Ceramics

Properties

Ceramics are produced by the fusion and hardening of mineral substances. Fired at high temperatures, they become pressure, temperature, abrasion, high-temperature corrosion and erosion-corrosion resistant. They may reduce friction and wear; but are brittle (they rather break than bend) and weaker in tension. However, by adding small amounts of long organic polymers, less brittle and less prone to fracture, more flexible organo-ceramics can be obtained. In general, ceramic materials are also very resistant to acids and sufficiently resistant against lye.

Application

Ceramics are more and more employed in the food industries due to their resistance to extreme operating and cleaning conditions. They are used in the coating of other stable materials, in the production of ceramic membranes and in the construction of processing equipment for very sensitive products.

7.5. Glass

Glass is transparent, and may occasionally be used as a food contact surface (e.g., light and sight glasses into vessels, and in very limited extent glass piping). For such applications, glass should be nontoxic (glasses containing lead are not allowed in the food contact area), integral (homogeneous and continuous), impervious, inert (nonabsorbent, resistant to degradation, and insoluble by process or cleaning fluids), smooth (free of cracks, crevices and pits), durable (robust, heat resistant, resistant to scratching, scoring and distortion when exposed to bioprocessing fluids). Glass shall be rated for the applicable pressure and temperature range, as well as for thermal shock. Bubbles at the glass surface are not accepted. Notice however, that the surface of glass is not completely smooth. It rather has a rough surface made of peaks and pit holes that can be filled with organic and inorganic contaminants. When these impurities react chemically with the glass, the glass easily may become stained and discoloured. Glass also may become prone to hydrolytic and chemical attack by certain alkali and acid solutions, which even can make the glass surface much rougher. Resistance to water and/or acid/alkaline solutions varies from excellent to poor depending on the composition of the glass. It is important to choose the right type of glass.

In most cases, the use of glass is not recommended because it is also brittle, may break and cannot endure thermal cycling. Replacement of glass by transparent alternatives like Perspex (poly methyl methacrylate) or polycarbonate is recommended [8], [11].

Lecture 8. Specifications of processing equipments and accessories in the food industry

8.1. Pipes and Pumps

The most common means for transferring materials is bypumps and pipes. Conveyors, chutes, gates, hoists, fans, and blowers areexamples of other kinds of equipment used extensively to handle and transfervarious materials.A major factor involved in the design of pumping and piping systems is theamount of power that is required for the particular operation. Mechanicalpower must be supplied by the pump to overcome frictional resistance, changesin elevation, changes in internal energy, and other resistances set up in the flowsystem.

Friction

Frictional effects are extremely important in flow processes. In many cases,friction may be the main cause for resistance to the flow of a fluid through agiven system. Consider the common example of water passing through a pipe. Ifno frictional effects were present, pipes of very small diameters could be usedfor all flow rates.

Frictional effects due to end losses, ititings, orifices, and other installations.

If the cross-sectional area of a pipe changes gradually to anew cross-sectional area, the disturbances to the flow pattern can be so smallthat the amount of mechanical energy lost as friction due to the change in crosssection is negligible. If the change is sudden, however, an appreciable amount ofmechanical energy can be lost as friction. Similarly, the presence of bends,fittings, valves, orifices, or other installations that disturb the flow pattern cancause frictional losses.

Pipe Strength

Iron and steel pipes were originally ctassified on the basis of wall thickness asstandard, extra-strong, and double-extra-strong. Modem industrial demands formore exact specifications have made these three classifications obsolete. Pipesare now specified according to wall thickness by a standard formula.

Tubing

Copper tubing and brass tubing are used extensively in industrial operations.Other metals, such as nickel and stainless steel, are also available in the form oftubing. Although pipe specifications are based on standard nominal sizes, tubingspecifications are based on the actual outside diameter with a designated wallthickness.

8.2. Pumps

Pumps are used to transfer fluids from one location to another. The pumpaccomplishes this transfer by increasing the pressure of the fluid and, thereby,supplying the driving force necessary for flow. Power must be delivered to thepump from some outside source. Thus, electrical or steam energy may betransformed into mechanical energy which is used to drive the pump. Part ofthis mechanical energy is added to the fluid as work energy, and the rest is lostas friction due to inefficiency of the pump and drive.

8.3. Tanks, Pressure Vessels and Storage Equipment

Storage of liquid materials is commonly accomplished in industrial plants by useof cylindrical, spherical, or rectangular tanks. These tanks may be constructed ofwood, concrete, fiber reinforced plastic (FRP), or metal. Metal is the mostcommon material of construction, although use of FRP is becoming increasinglyimportant. The design of storage vessels involves consideration of details such aswall thickness, size and number of openings, shape of heads, necessary temperatureand pressure controls, and corrosive action of the contents. The same principles of design apply for other types of tanks, includingpressure vessels such as those used for chemical reactors, mixers, and distillationcolumns. Fur these cases, the shell is often designed and its cost estimatedseparately with the other components, such as tray assemblies, agitators, linings,and packing units, being handled separately.

8.4. Filters

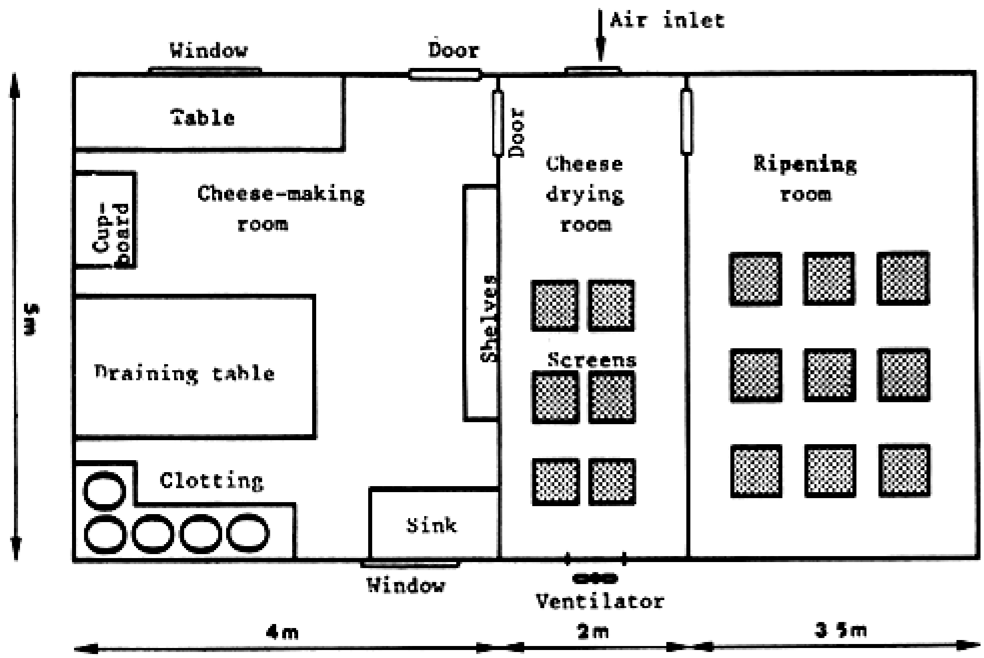
The primary factor in the design of filters is the cake resistance or cakepermeability. Because the value of the cake resistance can be determined onlyon the basis of experimental data, laboratory or pilot-plant tests are almostalways necessary to supply the information needed for a filter design. After thebasic constants for the filter cake have been determined experimentally, thetheoretical concepts of filtration can be used to establish the effects of changesin operating variables such as filtering area, slurry concentration, or pressuredifferencedriving force.In recent years, there has been considerable advance in the developmentof filtration theory, but the development has not reached the stage where anengineer can design a filter directly from basic equations as with a fractionationtower or a heat exchanger. Instead, the final design should be carried out by thetechnical personnel in filtration-equipment manufacturing concerns or by someonewho has access to the necessary testing equipment and has an extensiveunderstanding of the limitations of the design equations.

8.5. Heat Transfer Equipment

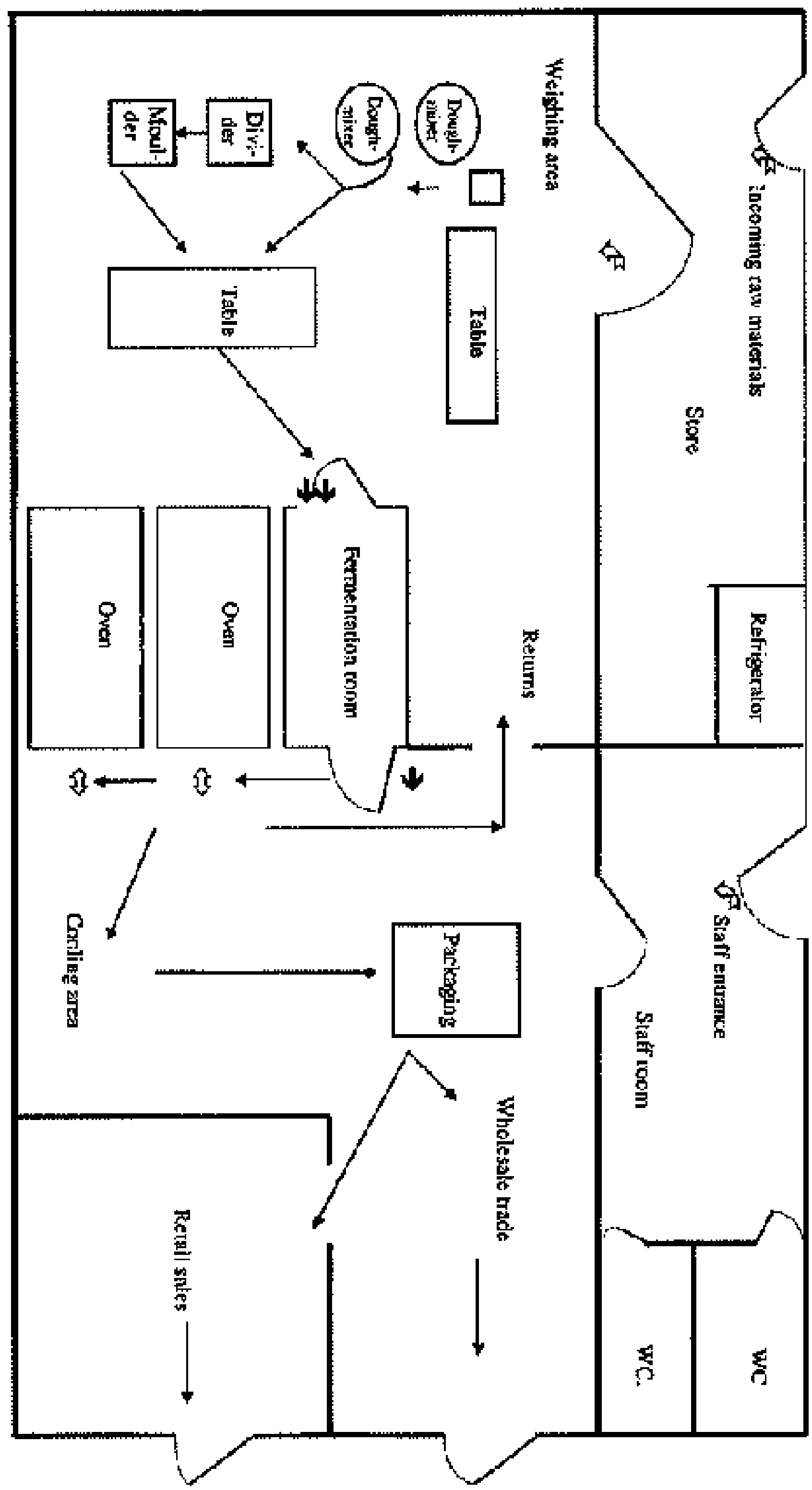
Equipment for transferring heat is used in essentially all the process industries,and the design engineer should be acquainted with the many different types ofequipment employed for this operation. Although relatively few engineers areinvolved in the manufacture of heat exchangers, many engineers are directlyconcerned with specifying and purchasing heat-transfer equipment. Intelligent selection of heat-transfer equipment requires an understandingof the basic theories of heat transfer and the methods for design calculation. Inaddition, the problems connected with mechanical design, fabrication, andoperation must not be overlooked.

MODULE III

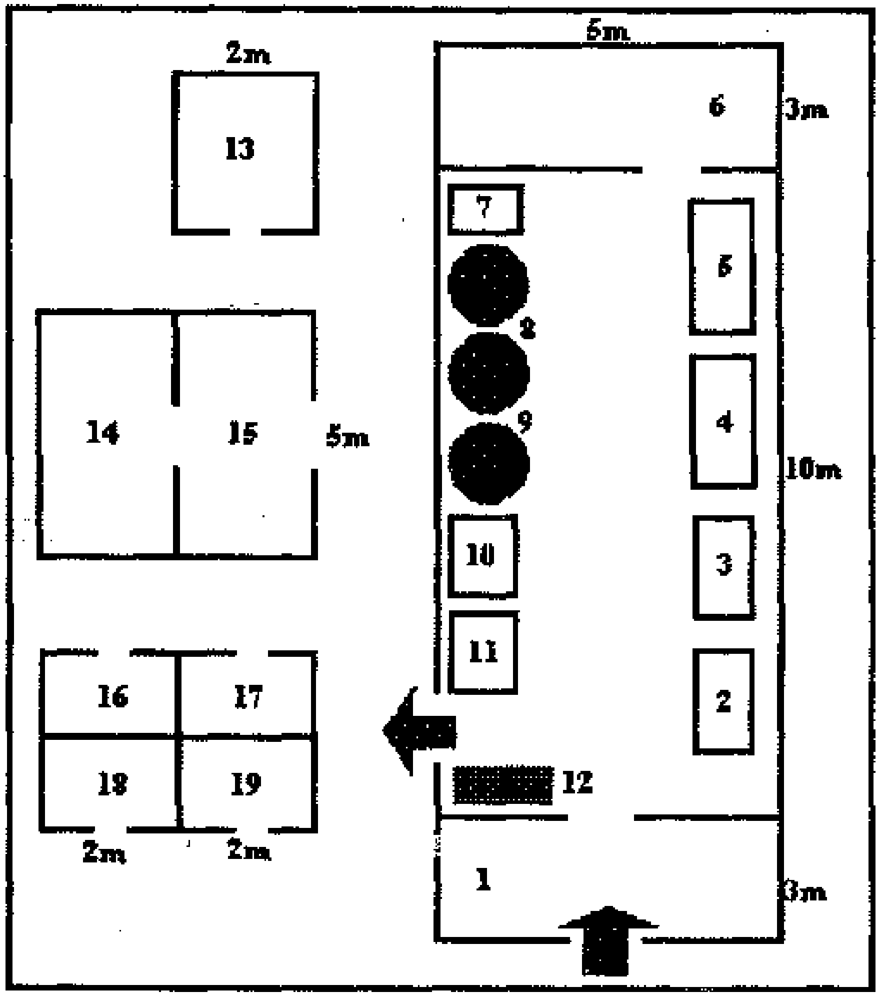
Lecture 1.Reference to design of cheese processing plant



Lecture 2. Reference to design of bakery plant



Lecture 3. Reference to design of fruit processing plant



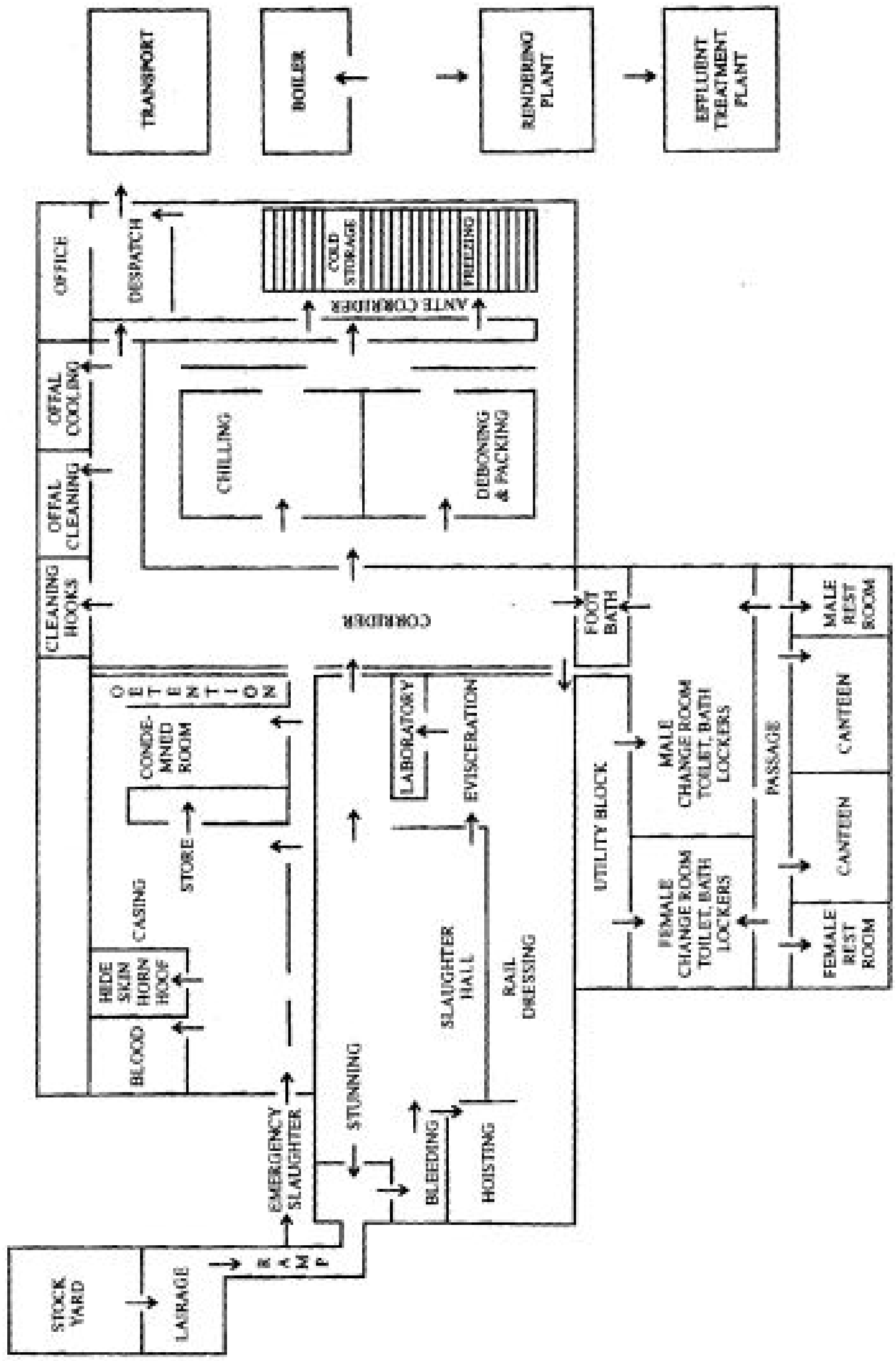
PROCESSING ROOM

(1) Reception and weighing
(2) Selection and grading
(3) Washing and disinfection
(4) Peeling and filling counter
(5) Pulp extraction
(6) QUALITY CONTROL ROOM

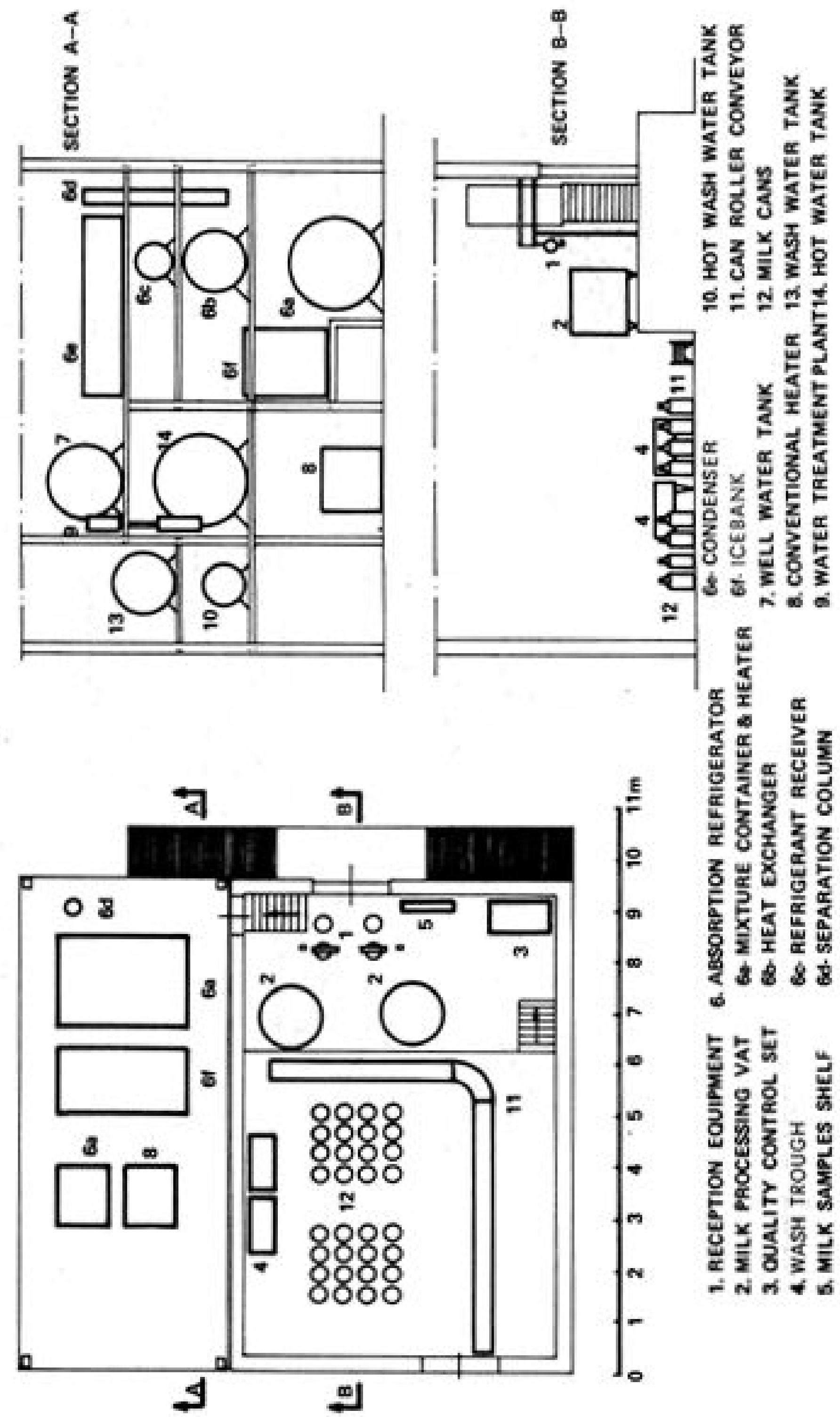
(7) Juice extraction
(8) Double-bottom kettles
(9) Autoclave

(10) Sealer-capper
(11) Packing and labelling
(12) Double dishwasher
(13) BOILER ROOM
(14) STOREROOM FOR INGREDIENTS
(15) STOREROOM FOR FINAL PRODUCTS
(16) MEN'S CHANGING ROOMS
(17) MEN'S TOILETS
(18) WOMEN'S CHANGING ROOMS
(19) WOMEN'S TOILETS

Lecture 4. Reference to design of meat processing plant



Lecture 5. Reference to design of a dairy plant



Lecture 6. ISO, HACCP requirements in food plant

HACCP

The HACCP System, as it applies to food safety management, uses the approach of controlling critical points in food handling to prevent food safety problems. Besides enhancing food safety, other benefits applying HACCP include effective use of resources and timely response to food safety problems. In addition, the application of the HACCP system can result in more focused risk management by food control regulatory authorities and can promote international trade by increasing buyer confidence in food safety.

The HACCP system identifies specific hazards and control measures to ensure the safety of food. A HACCP plan is specific to the particular food and processing application. The HACCP system is capable of accommodating changes such as advances in equipment design, new information concerning health hazards or risks, new processing procedures or technological developments.

Historical Background

The objective is to introduce the trainees to the history and background of the Hazard Analysis and Critical Control Point (HACCP) system and its importance as a food safety management system in identifying and controlling food safety hazards.

The HACCP System for managing food safety concerns grew from two major developments. The first breakthrough was associated with W.E. Deming, whose theories of quality management are widely regarded as a major factor in turning around the quality of Japanese products in the 1950's. Dr. Deming and others developed total quality management (TQM) systems which emphasised a total systems approach to manufacturing that could improve quality while lowering costs.

The second major breakthrough was the development of the HACCP concept itself. The HACCP concept was pioneered in the 1960's by the Pillsbury Company, the United States Army and the US National Aeronautics and NASA as a collaborative development for the production of safe foods for the US space programs. Pillsbury introduced and adopted HACCP as the system that could provide the greatest safety while reducing dependence on end product inspection and testing.

Recognizing the importance of HACCP to food control, the 20th session of Codex Alimentarius Commission held in Geneva Switzerland adopted Guidelines for the application of Hazard Analysis Critical Control Point (HACCP).

Advantage of HACCP

The HACCP system as it applies to food safety management uses the approach of controlling critical points in food handling to prevent food safety problems. The system which is science based and systematic identifies specific hazards and measures for their control to ensure the safety of food. HACCP is based on prevention and reduces the reliance on end product inspection and testing.

The HACCP system can be applied throughout the food chain from the primary producer to the consumer. Besides enhancing food safety, other benefits of applying HACCP include more effective use of resources, savings to the food industry and more timely response to food safety problems. HACCP enhances the responsibility and degree of control at the level of the food industry. A properly implemented HACCP system leads to greater involvement of food handlers in understanding and ensuring food safety, thus providing them with renewed motivation in their work. Implementing HACCP does not mean undoing quality assurance procedures or good manufacturing practices already established by a company, it does, however, require a revision of these procedures as part of the systematic approach and for their appropriate integration into the HACCP plan.

The application of the HACCP System can aid inspection by food control regulatory authorities and promote international trade by increasing buyer's confidence.

Any HACCP system should be capable of accommodating change, such as advances in equipment design, changes in processing procedures or technological developments.

HACCP is based on seven principles:

1. Conduct a Hazard Analysis
   This is where you evaluate your processes and identify where hazards can be introduced. Hazards can be physical (i.e. metal contamination), chemical (i.e. can a cleaning product contaminate the product, are there toxins that could contaminate the product?) or biological (at what points could bacteria or virus contaminate your product?). You will need to make sure that you have the expertise to make an accurate evaluation of the hazards. This means that if you do not have sufficient expertise in your organization you will need to identify external resources that you can use to perform the hazard analysis. The hazard identification is done in two steps, first the identification of hazards, then an evaluation of the hazard. The hazard evaluation is a determination of the degree of risk to the user from the identified hazard. Once the hazard is identified and evaluated the team must identify critical control points. These are points where the hazard must be controlled or it will present a risk to the end user.

2. Identify the Critical Control Points
   At what steps in your process can controls be applied to prevent or eliminate the hazards that have been identified? These are your critical control points. For each critical control point you will identify the preventive measure. How will you prevent the hazard?: Use of specific Temperature, ph, time, procedures?

   Establish a maximum or minimum limit for temperature, time, pH, salt level, chlorine level or other processing characteristic that will control the hazard. This is the critical limit for the CCP. If this limit is ever exceeded corrective action must be taken, and all affected product controlled.

3. Establish Critical Limits
   Your next step is to establish criteria for each critical control point. What criteria must be met to control the hazard at that point? Is it a minimum temperature? Are there regulatory limits that you must meet for this control point?
4. Establish Monitoring Procedures
   What will you measure and how will you measure it? You need to monitor the process at the critical control point and keep records to show that the critical limits have been met. Can you do continuous monitoring of the control point? If not, how often will the measurements need to be performed to show that the process is under control?
   The monitoring that takes place at the critical control points is essential to the effectiveness of the HACCP program. The monitoring program will be made up of physical measurement or observations that can be done in a timely manner, to provide the information in a time frame that allows you to take action and control product if an out of control situation occurs.
5. Establish Corrective Actions
   You will establish what actions need to be taken if a critical limit is not met. This will be identified ahead of time for each CCP. The action must make sure that no unsafe product is released. There must also be an evaluation of the process to determine the cause of the problem and an elimination of the cause.
   The action or actions taken have two purposes, to control any nonconforming product resulting from the loss of control, and to identify the cause, eliminate it and prevent the situation from reoccurring. By identifying the corrective action before an out of control situation occurs, you are prepared to take action quickly if and when it does occur.
6. Establish Verification Procedures
   The HACCP plan must be validated. Once the plan is in place, make sure it is effective in preventing the hazards identified. Test the end product, verify that the controls are working as planned. Perform ongoing verification of the system. Are measuring and monitoring equipment in control? What are corrective actions showing? Are records being maintained as required?
7. Establish Record Keeping Procedures
   You will determine what records are needed to show that the critical limits have been met, and the system is in control. Address regulatory requirements and include records from the development of the system and the operation of the system.

Developing a HACCP Plan

- *Assemble the HACCP team*
- *Describe the food and its distribution*
- *Describe the intended use and consumers of the food*
- *Develop a flow diagram which describes the process*
- *Verify the flow diagram*
- *Conduct a hazard analysis (Principle 1)*
- *Determine critical control points (CCPs) (Principle 2)*
- *Establish critical limits (Principle 3)*
- *Establish monitoring procedures (Principle 4)*
- *Establish corrective actions (Principle 5)*
- *Establish verification procedures (Principle 6)*
- *Establish record-keeping and documentation procedures (Principle 7)*

ISO

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

ISO is an independent, non-governmental international organization with a membership of 161 national standards bodies.

ISO Certification

ISO **develop** International Standards, such as ISO 9001 and ISO 14001, but are not involved in their certification, and do not issue certificates. This is performed by external certification bodies, thus a company or organization cannot be certified **by** ISO.

However ISO's Committee on Conformity Assessment (CASCO) has produced a number of standards related to the certification process, which are used by certification bodies. Read more about CASCO Standards.

ISO 22000 family - Food safety management

The ISO 22000 family of International Standards addresses food safety management.

The consequences of unsafe food can be serious and ISO's food safety management standards help organizations identify and control food safety hazards. As many of today's food products repeatedly cross national boundaries, International Standards are needed to ensure the safety of the global food supply chain.

ISO 22000:2005 sets out the requirements for a food safety management system and can be certified to. It maps out what an organization needs to do to demonstrate its ability to control food safety hazards in order to ensure that food is safe. It can be used by any organization regardless of its size or position in the food chain.

ISO 22000:2005 specifies requirements for a food safety management system where an organization in the food chain needs to demonstrate its ability to control food safety hazards in order to ensure that food is safe at the time of human consumption.

It is applicable to all organizations, regardless of size, which are involved in any aspect of the food chain and want to implement systems that consistently provide safe products. The means of meeting any requirements of ISO 22000:2005 can be accomplished through the use of internal and/or external resources.

ISO 22000:2005 specifies requirements to enable an organization

- to plan, implement, operate, maintain and update a food safety management system aimed at providing products that, according to their intended use, are safe for the consumer,
- to demonstrate compliance with applicable statutory and regulatory food safety requirements,
- to evaluate and assess customer requirements and demonstrate conformity with those mutually agreed customer requirements that relate to food safety, in order to enhance customer satisfaction,
- to effectively communicate food safety issues to their suppliers, customers and relevant interested parties in the food chain,
- to ensure that the organization conforms to its stated food safety policy,
- to demonstrate such conformity to relevant interested parties, and
- to seek certification or registration of its food safety management system by an external organization, or make a self-assessment or self-declaration of conformity to ISO 22000:2005.

ISO 22004:2014 provides generic advice on the application of ISO 22000.

ISO 22004:2014 does not create, alter or replace any of the requirements in ISO 22000. As individual organizations are free to choose the necessary methods and approaches to fulfill the requirements of ISO 22000, the guidance provided by this ISO 22004:2014, are under no circumstances, to be considered a requirement.

ISO 22003:2007 defines the rules applicable for the audit and certification of a food safety management system (FSMS) complying with the requirements given in ISO 22000:2005 (or other sets of specified FSMS requirements), and provides the necessary information and confidence to customers about the way certification of their suppliers has been granted.

ISO 22005:2007 gives the principles and specifies the basic requirements for the design and implementation of a feed and food traceability system. It can be applied by an organization operating at any step in the feed and food chain.

ISO 9000 to 22000

While similar in philosophy to ISO 9001 and ISO 14001, ISO 22000 contains clauses that are specific to the food industry, including:

• The establishment of prerequisite programs (PRPs), which define the basic conditions and activities needed to maintain a hygienic environment, both within the organization and throughout the food chain

• The identification and control of food safety hazards, and the determination of an acceptable level of risk

• The establishment of a HACCP plan, including the identification and monitoring of critical control points: process steps at which controls can be applied to prevent or eliminate a food safety hazard, or reduce it to an acceptable level

• The handling of potentially unsafe food products to ensure that they do not enter the food chain

• The establishment of a food safety team responsible for tasks such as hazard analysis, selection of control measures, establishment of PRPs, and planning of internal audits

• The information and characteristics needed for both raw materials and end products to ensure that a proper hazard analysis can be conducted

• The establishment of a communications plan with external parties – such as suppliers, customers, and regulatory authorities – to ensure that food safety information is available to all.

Lecture 7. Hygienic Design of Food Plants

Introduction

One of the most critical components of producing safe food products starts at thevery beginning of the plant construction design: the plant layout. A poorly laid outplant will undermine product safety and productivity creating the potential forproduct contamination and long term product safety issues. A well laid out plantwill minimize contamination from rodents, insects and birds, microorganisms andindividuals that want to deliberately contaminate food products for criminalreasons. A well laid out plant facilitates the movement of materials through theplant in the most hygienic way, and typically results in less operator frustration.This leads to a feeling of well being and ultimately greater productivity andquality.

Layout of plant grounds and outer perimeter

The outer perimeter of the plant should be planned to have a system of barriers(i.e. fences) to control physical access around the entire perimeter of the property(see Fig. 12.1). In addition, this system of physical perimeter control will be usedto set up an outer perimeter of rodent control. The outer perimeter barrier shouldbe designed in a way to funnel traffi c and visitors into a single monitored entrancepoint for security reasons.

Ground areas that are not paved should consist of grass that is mowed and keptshort (not more than 76.2 mm or 3.0 inches) to reduce insect, rodent and birdharborage potentials. Roadways leading into and out of the plant, parking lots andtruck dock areas must be paved to reduce dust and mud. In addition, they need tobe sloped to drain to provide adequate storm drainage to reduce standing waterissues. Large trees and bushes must be removed from the property to eliminateinsect, rodent and bird harborage

Dumpster/refuse/recycle areas must be paved and they need to be sloped todrain to provide adequate drainage. Dumpster/refuse/recycle areas should have awater source for periodic cleaning as part of the master sanitation schedule. Sincethe dumpster/refuse/recycle area is one of the most vulnerable areas of the plantrelative to insect, rodent and bird infestation, it is critical that the area is properlyconstructed to be unattractive to insects, rodents and birds and to physically keeporganisms out.

Another vulnerable area for rodent harborage and access is the ground levelsegment of roof rainwater drainage pipes. Rainwater pipes need to be designed tocontain back-inlet gully fittings.

General interior building layout requirements

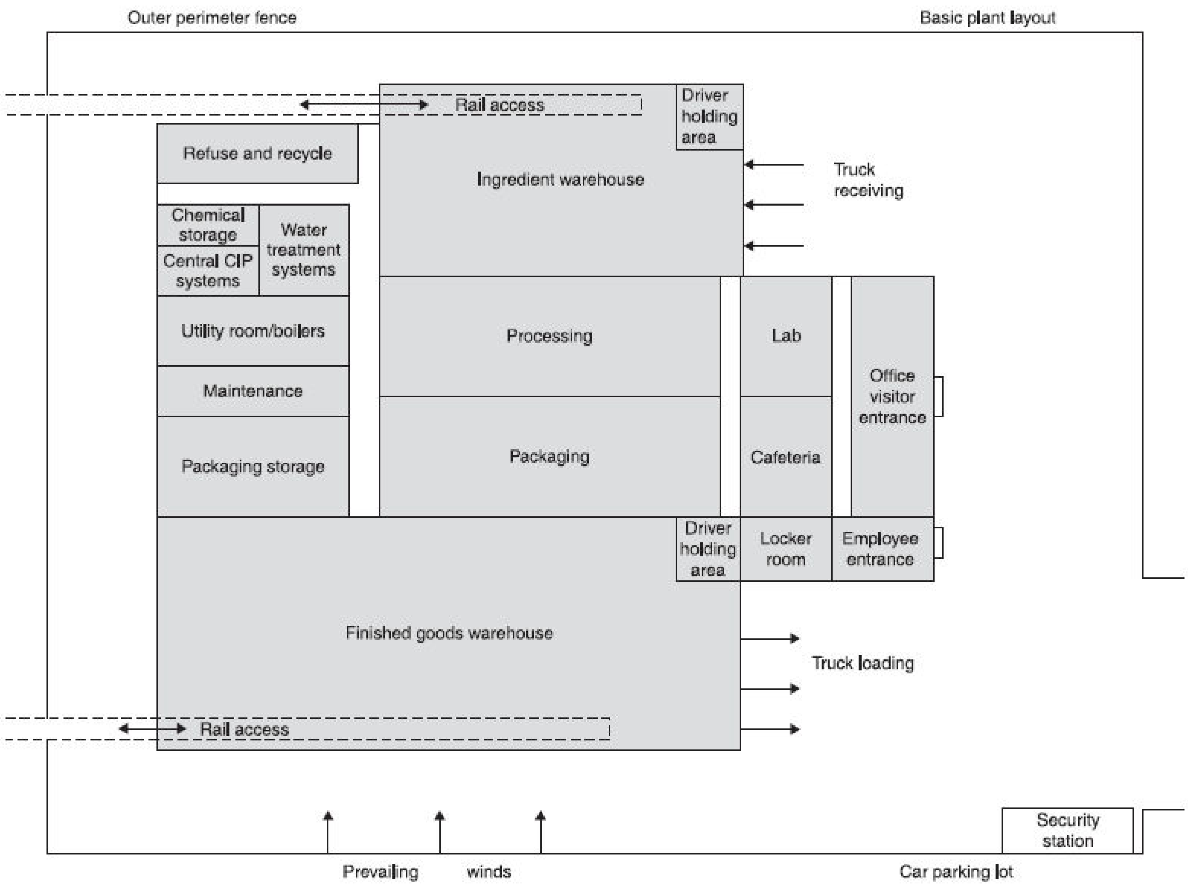
Plant and buildings shall be of adequate size and construction to facilitateall equipment and maintenance and sanitation operations associated with foodprocessing equipment and operations. When considering space needed for equipmentit is critical to consider adequate space for maintenance operations, cleaningoperations, the operator and for materials and supplies (see Fig. 12.1). Layout anddesign of the plant shall be such that raw materials are environmentally isolatedfrom the blending and processing and finished product storage environments. This isespecially critical where raw materials are known to present a risk from amicrobiological contamination standpoint. In this case microbiological crosscontamination opportunities must be minimized (see Fig. 12.1).Blending, processing and filling areas shall be separated from each other tominimize microbiological cross contamination potentials and to allow for theseareas of product exposure to be made secure by restricting access to these areas byauthorized personnel only.

Cleaning-in-place (CIP) cleaning systems need to be isolated from blending,processing and packaging areas (see Fig. 12.1). To help reduce the possibility ofchemical contamination of open product areas, it is recommended that hazardouschemicals storage be provided in a separate, locked and secured room. This roomshould be used for the secure storage and handling of CIP chemicals, watertreatment chemicals and pesticides (see Fig. 12.1).

Employee entrance areas will be separated from visitor entry areas andshould require pass key or pass card access to the plant. Some manufacturershave adopted fi nger print or palm print access for employee identification andauthorization. Employees shall have adequate locker room, rest room, shower andcafeteria facilities. These areas shall be separated from raw material handling,blending, processing and fi lling/packaging areas (see Fig. 12.1). In addition, theplant layout needs to allow for a separate secure truck/train operator waiting area.Truck and train operators should not have free access to the plant (see Fig. 12.1).Warehouse areas need to be designed and laid out to allow for a 0.50 meter(18 inch) free zone between product storage and the outer wall of the building to allow for rodent control device placement, inspection and cleaning.Materials chosen to construct the plant building shall be recognized as beingimpervious to insects and rodents.

For doors that see frequent use and are constantly opened, the use of automatic

roll up doors should be planned or the installation of air curtains. Critical factorsto consider with air curtains are that the air flow covers the entire floor opening,that the air column be at least 75 mm thick with a minimum velocity of 488 m perminute.



This suggested layout not only allows for smooth flow of materials from raw material receiving through finished goods shipping, it allowsfor the separation of critical storage, process and packaging areas from areas that handle potential contaminants. This basic layout facilitates themanufacturing process, while providing for needed safety isolation of high contamination areas.

Lecture 8. Role of FSSAI in the food industry

FSSAI

The Food Safety and Standards Authority of India (FSSAI) has been established under Food Safety and Standards , 2006 which consolidates various acts & orders that have hitherto handled food related issues in various Ministries and Departments. FSSAI has been created for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption.

Highlights of the Food Safety and Standard Act, 2006

Various central Acts like Prevention of Food Adulteration Act,1954, Fruit Products Order , 1955, Meat Food Products Order,1973, Vegetable Oil Products (Control) Order, 1947,Edible Oils Packaging (Regulation)Order 1988, Solvent Extracted Oil, De- Oiled Meal and Edible Flour (Control) Order, 1967, Milk and Milk Products Order, 1992 etc. was repealed after commencement of FSS Act, 2006.

Function of FASSAI

- Framing of Regulations to lay down the Standards and guidelines in relation to articles of food and specifying appropriate system of enforcing various standards thus notified.
- Laying down mechanisms and guidelines for accreditation of certification bodies engaged in certification of food safety management system for food businesses.
- Laying down procedure and guidelines for accreditation of laboratories and notification of the accredited laboratories.
- To provide scientific advice and technical support to Central Government and State Governments in the matters of framing the policy and rules in areas which have a direct or indirect bearing of food safety and nutrition.
- Collect and collate data regarding food consumption, incidence and prevalence of biological risk, contaminants in food, residues of various, contaminants in foods products, identification of emerging risks and introduction of rapid alert system.
- Creating an information network across the country so that the public, consumers, Panchayatsetc receive rapid, reliable and objective information about food safety and issues of concern.
- Provide training programmes for persons who are involved or intend to get involved in food businesses.
- Contribute to the development of international technical standards for food, sanitary and phyto-sanitary standards.
- Promote general awareness about food safety and food standards.

MODULE IV

Lecture 1.Introduction to block flow diagram and piping and instrumentation diagram.

Flow Process Charting

This method of recording is essentially **sequential** in character, andwhile it can also give limited spatial and relational information,these aspects are secondary to its main purpose, which is to set downon paper the series of related events which make up an activity, sothat they can be seen and examined for purpose and validity.There are five basic symbols, each of which stands for a class ofactivity:

○ **Operation, activity, process.**
□ **Inspection, examination, check.**
⇦ **Transportation or movement of any kind.**
D **Delay which does not further the activity.**
▽ **Storage, bulk supply, stock.**

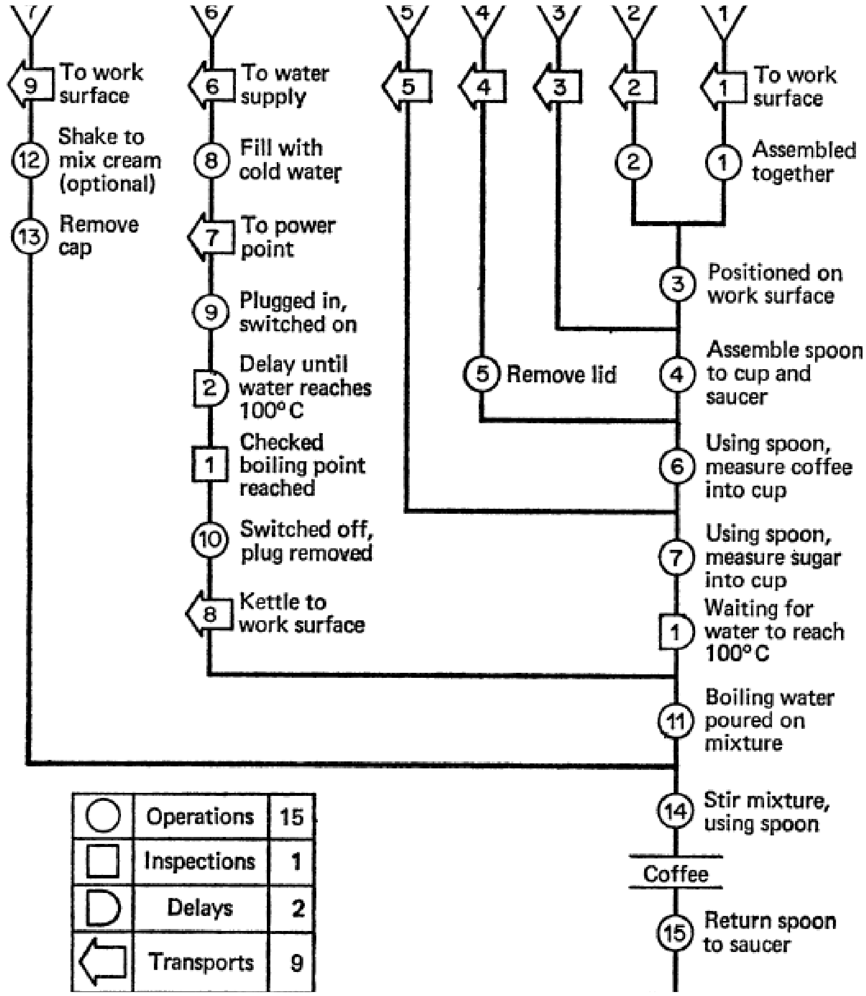
Using these five symbols, with an appropriate legend alongside,makes it possible to break down any activity into its constituentparts or elements.There are several types of flow process chart (FPC) which areused for particular aspects of recording:

Material charts, where the events occurring to a particular materialare being followed.

Man charts, where the activities of persons are being examined.

Machine charts, where the sequence of operations of a machine,e.g. a fork-lift truck, are being followed.

Outline charts, using only O and ▭symbols, often used to givea quick outline of a whole series of processes.



MATERIAL-TYPE FLOW PROCESS CHART

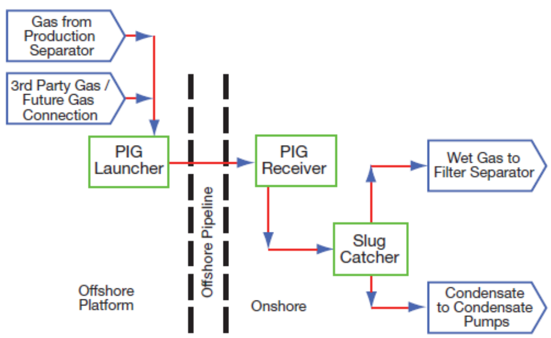
Lecture 2. Preparation of flow sheets for material movement and utility consumption in food plants

The terms *flowsheet*and *flow diagram* are often used in thecontextofengineeringanddesignapplications.Althoughthis terminology is not the most accurate way to describe P&IDs,itissufficienttodescribetheoverallfamilyofprocess-baseddiagramstowhichP&IDsbelong.

The *block flow diagram* (BFD) (Figure 1) is a very simple diagram that can condense an entire processontoaslittleasasinglesheet.Moredetailed information can be found in the *process flow diagram* (PFD), which is considered the precursor to the P&ID. Typically, the PFD is used by plant designers to conduct initial layout studies of a plant's process systems and major pipework. Since PFDs use many of the same symbols as P&IDs, theyallowviewerstomoreeasilyidentifyitemsand processesbysight.ThisisincontrasttotheBFD's standardblockandlinediagram,whichemphasizes the descriptions contained in thoseblocks.P & IDs provide the most detail of the three types ofdiagrams,usingstandardnomenclatureandsymbolstofullydescribetheprocess.Someregulatoryagencies mandatetheiruseduringdesignandconstruction,aswellas throughoutongoingoperationsanddecommissioning.

Block flowdiagrams

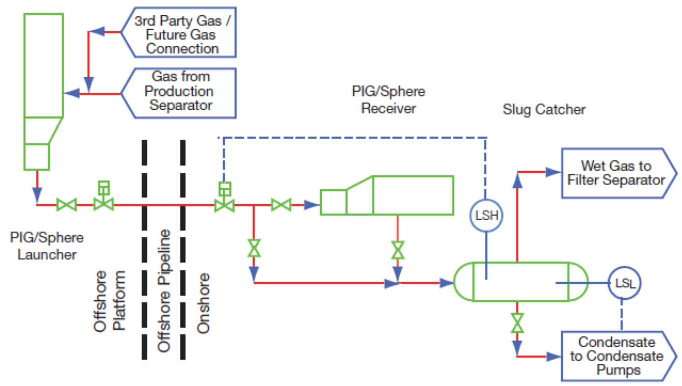
Thebeauty(andadvantage)ofaBFDisitsabilitytoout- line the complete process on little more than a single sheet. These diagrams usually resemble an organizational chart, containing mainly text enclosed by boxes, interconnecting linesandtheprocesscommoditiestheytransport,andflow arrows to indicate process flow directions.



▲ **Figure 1.** A block flow diagram can illustrate an entire process on one sheet.

Process flow diagrams

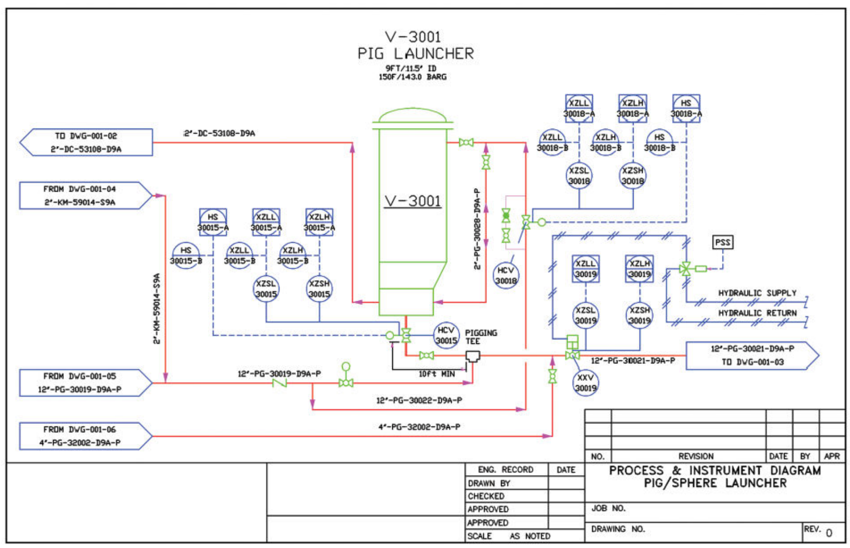
Process flow diagrams (Figure 2) carry more information than the block flow diagrams from which they are derived. They show more detail about major equipment and subsystems and the flow of product between them.PFDs include information on the pressuresandtemperaturesoffeedandproductlinestoand fromallmajorpiecesofequipment,suchasvessels,tanks, heatexchangers,pumps,etc.Alsoindicatedaremain headers and points of pressure, temperature and flow control, plusthemainshutdownpointsinthesystem.



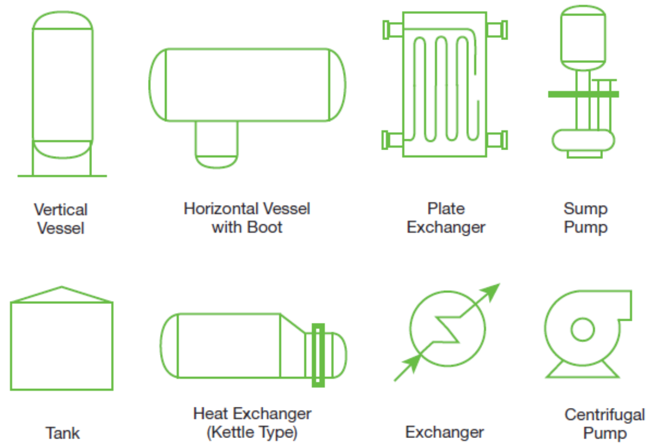
▲ **Figure 2.** Process flow diagrams illustrate major equipment and subsystems and the product flow between them.

Piping and instrumentation diagrams

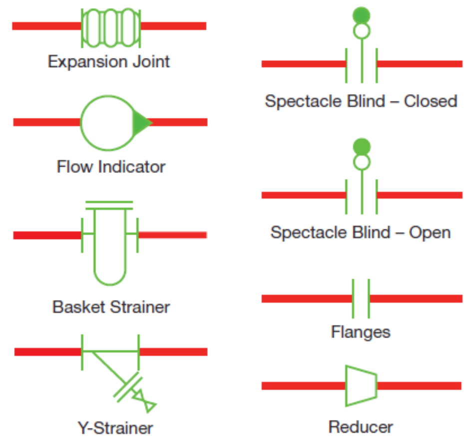
AP&ID(Figure3)carriesawealthofinformationthat spans engineering disciplines to define a process. It is the bestwayofaccuratelydocumentingtheoperationofa process,anditistrulyacoordinatingdocument.

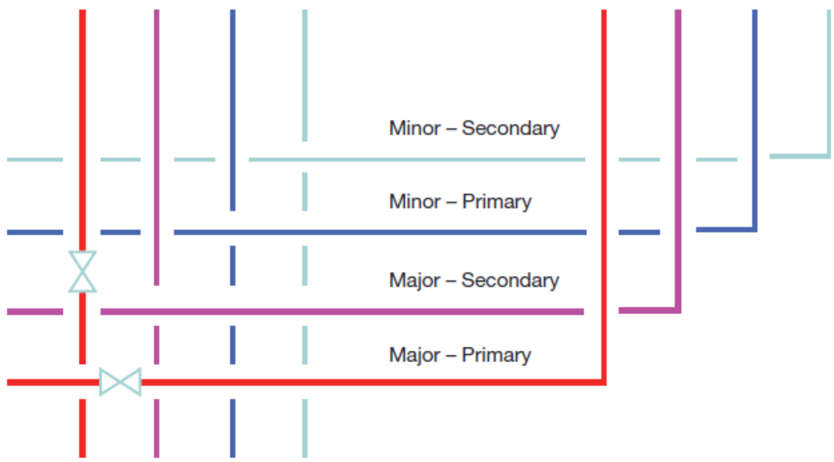


▲ **Figure 3.** A piping and instrumentation diagram serves as an important reference that is useful at any stage of the process lifecycle.



▲ **Figure 4.** So that flowsheets can be universally understood, typical equipment configurations have both standardized equipment symbols and numeric means of identification.





WHEN PROCESS AND INSTRUMENT LINES CROSS THEY ARE BROKEN BASED ON THEIR HIERARCHY

Standards and rules

P&IDs are prepared according to a set of rules established to maximize the documents' usefulness. Standard symbols that are easily recognized must be used to represent the items on a P&ID. Each line, instrument, piece of equipment,etc.(Figures4-6),mustbelabeledusingspecific conventionsofnomenclature.

Lecture 3. Application of Program Evaluation and Review Technique (PERT)

PERT was developed in the late 1950s by the Navy Special Projects Office in cooperation with the management consulting firm of Booz, Allen, and Hamilton. The techniquereceived substantial favorable publicity for its use in the engineering and development program of the Polaris missile, a complicated project that had 250 prime contractors and over9,000 subcontractors. Since that time, it has been widely adopted in other branches of government and in industry and has been applied to such diverse projects as construction offactories, buildings, and highways, research management, product development, the installation of new computer systems, and so on. Today, many firms and government agenciesrequire all contractors to use PERT.

Program Evaluation & Review Technique (PERT):

Developed to manage the Polaris missile project

Many tasks pushed the boundaries of science & engineering (tasks' duration = probabilistic)

Lecture 4. Application of Critical Path Method (CPM)

Critical Path Method (CPM):

Developed to coordinate maintenance projects in the chemical industry

A complex undertaking, but individual tasks are routine (tasks' duration = deterministic)

Project management can be understood as a systematic way of planning, scheduling, executing, monitoring, controlling the different aspects of the project, so as to attain the goal made at the time of project formulation. PERT and CPM are the two network based project management techniques, which exhibit the flow and sequence of the activities and events. **Program (Project) Management and Review Technique (PERT)**is appropriate for the projects where time needed to complete different activities are not known.

On the other hand, **Critical Path Method** or**CPM**, is apt for the projects which are recurring in nature.

The two scheduling methods, uses common approach for designing the network and for ascertaining its critical path. They are used in the successful completion of a project and hence used in conjunction with each other. Nevertheless, the truth is that CPM is different from PERT in a way that the former concentrates on time while the latter stresses on time-cost trade-off. In the same manner, there are many differences between PERT and CPM, which we are going to discuss in this article.

Key Differences Between PERT and CPM

The most important differences between PERT and CPM are provided below:

1. PERT is a project management technique, whereby planning, scheduling, organising, coordinating and controlling of uncertain activities is done. CPM is a statistical technique of project management in which planning, scheduling, organising, coordination and control of well-defined activities takes place.
2. PERT is a technique of planning and control of time. Unlike CPM, which is a method to control costs and time.
3. While PERT is evolved as research and development project, CPM evolved as construction project.
4. PERT is set according to events while CPM is aligned towards activities.
5. A deterministic model is used in CPM. Conversely, PERT uses probabilistic model.
6. There are three times estimates in PERT i.e. optimistic time (to), most likely time ™, pessimistic time (tp). On the other hand, there is only one estimate in CPM.
7. PERT technique is best suited for a high precision time estimate, whereas CPM is appropriate for a reasonable time estimate.
8. PERT deals with unpredictable activities, but CPM deals with predictable activities.
9. PERT is used where the nature of the job is non-repetitive. In contrast to, CPM involves the job of repetitive nature.

10. There is a demarcation between critical and non-critical activities in CPM, which is not in the case of PERT.
11. PERT is best for research and development projects, but CPM is for non-research projects like construction projects.
12. Crashing is a compression technique applied to CPM, to shorten the project duration, along with least additional cost. The crashing concept is not applicable to PERT.

Lecture 5. Problems on networking and finding critical pathway

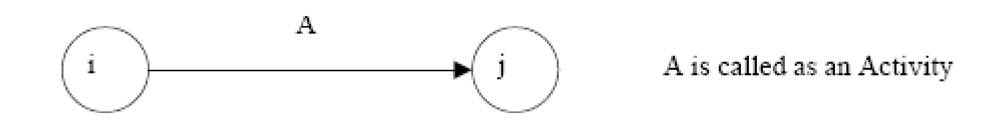
COMPONENTS of PERT/CPM NETWORK

PERT / CPM networks contain two major components

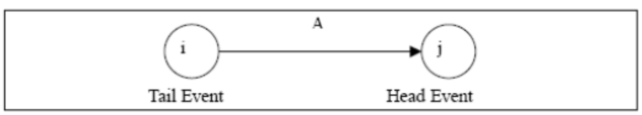
i. Activities, and

ii. Events

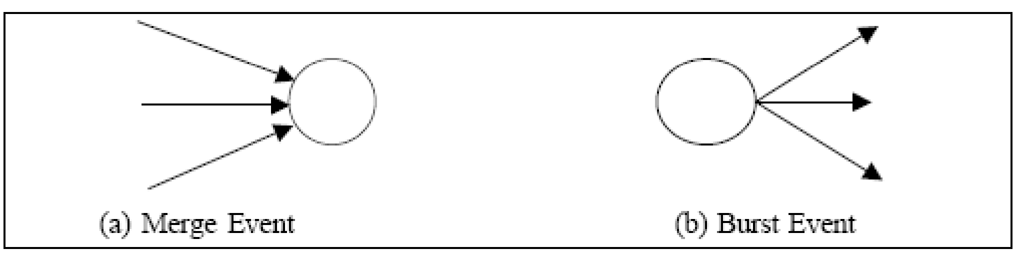
Activity: An activity represents an action and consumption ofresources (time, money, energy) required to complete a portion of aproject. Activity is represented by an arrow.



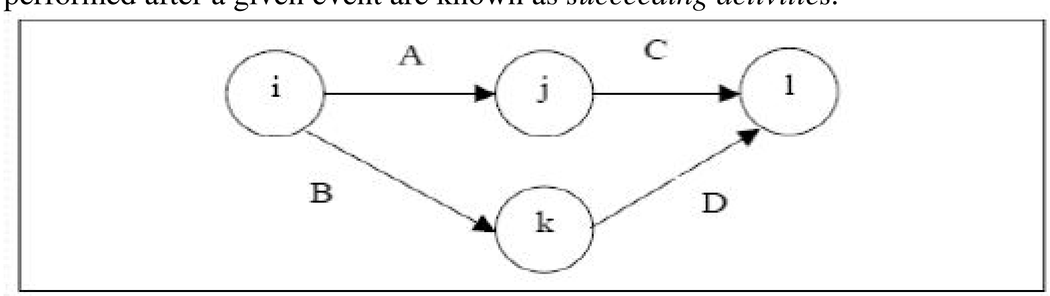
Event: An event (or node) will always occur at the beginning and end of anactivity. The event has no resources and is represented by a circle. The ith eventand jth event are the tail event and head event respectively.



Merge and Burst Events
One or more activities can start and end simultaneously at an event.

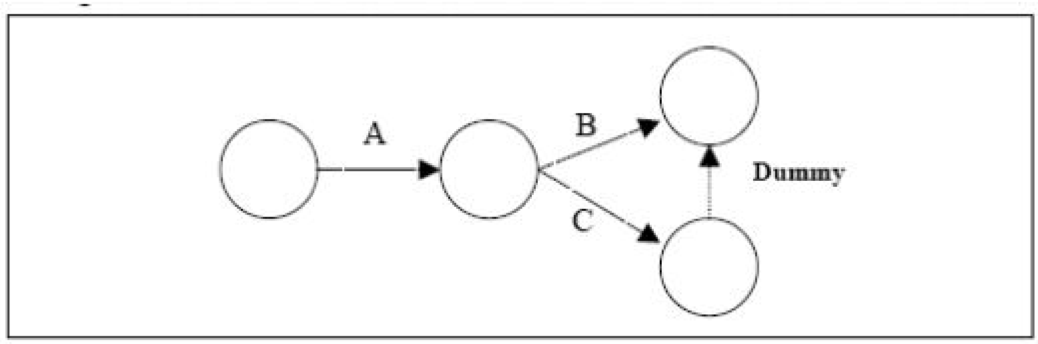


Preceding and Succeeding Activities
Activities performed before given events are known as *preceding activities* and activities performed after a given event are known as *succeeding activities.*



Activities A and B precede activities C and D respectively.

Dummy Activity
An imaginary activity which does not consume any resource and time is called a***dummy activity. Dummy activities are simply used to represent a connectionbetween events in*** order to maintain a logic in the network. It is represented by adotted line in a network.



RULES IN CONSTRUCTING A NETWORK
1. No single activity can be represented more than once in a network.The length of an arrow has no significance.
2. The event numbered 1 is the start event and an event with highestnumber is the end event. Before an activity can be undertaken, allactivities preceding it must be completed. That is, the activities mustfollow a logical sequence (or – interrelationship) between activities.
3. In assigning numbers to events, there should not be any duplication ofevent numbers in a network.
4. Dummy activities must be used only if it is necessary to reduce thecomplexity of a network.
5. A network should have only one start event and one end event.

CRITICAL PATH ANALYSIS
The critical path for any network is the longest path through the entire network.Since all activities must be completed to complete the entire project, the lengthof the critical path is also the shortest time allowable for completion of theproject.
Thus if the project is to be completed in that shortest time, all activities on thecritical path must be started as soon as possible.These activities are called **critical activities.**
If the project has to be completed ahead of the schedule, then the time requiredfor at least one of the critical activitymust be reduced.Further, any delay in completing the critical activities will increase the projectduration.The activity, which does not lie on the critical path, is called non-criticalactivity.These non-critical activities may have some slack time.The slack is the amount of time by which the start of an activity may bedelayed without affecting the overall completion timeof the project.But a critical activity has no slack.To reduce the overall project time, it would require more resources (atextra cost) to reduce the time taken by the critical activities to complete.

Lecture 6. Cost estimation for a Food Plant

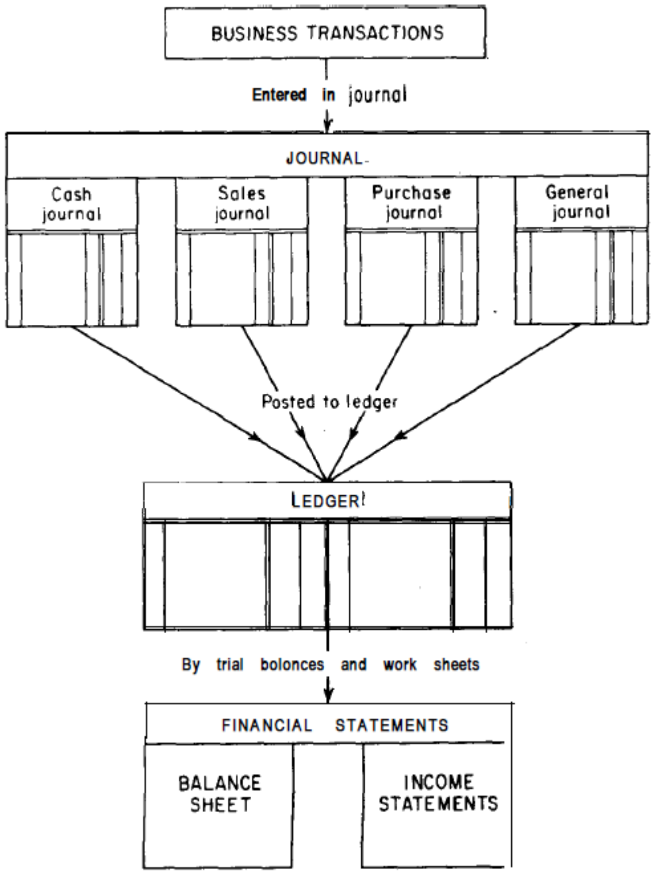


DIAGRAM OF ACCOUNTING PROCEDURE.

An acceptable plant design must present a process that is capable of operatingunder conditions which will yield a profit. Since net profit equals total incomeminus all expenses, it is essential that the chemical engineer be aware of themany different types of costs involved in manufacturing processes. Capital mustbe allocated for direct plant expenses, such as those for raw materials, labor,and equipment. Besides direct expenses, many other indirect expenses areincurred, and these must be included if a complete analysis of the total cost is to be obtained. Some examples of these indirect expenses are administrativesalaries, product-distribution costs, and costs for interplant communications.A capital investment is required for any industrial process, and determinationof the necessary investment is an important part of a plant-design project.The total investment for any process consists of fixed-capital investment forphysical equipment and facilities in the plant plus working capital which mustbe available to pay salaries, keep raw materials and products on hand, andhandle other special items requiring a direct cash outlay. Thus, in an analysis ofcosts in industrial processes, capital-investment costs, manufacturing costs, andgeneral expenses including income taxes must be taken into consideration.

CASH FLOW FOR INDUSTRIAL OPERATIONS

Figure 6-1 shows the concept of cash flow for an overall industrial operationbased on a support system serving as the source of capital or the sink for capital*receipts. Input to the capital sink can be in the form of loans, stock issues, bondreleases, and other funding sources including the net cash flow returned to thecapital sink from each project. Output from the capital source is in the form oftotal capital investments for each of the company's industrial operations,dividends to stockholders, repayment of debts, and other investments.

Operating Time and Rate of Production

One of the factors that has an important effect on the costs is the fraction of thetotal available time during which the process is in operation. When equipmentstands idle for an extended period of time, the labor costs are usually low;however, other costs, such as those for maintenance, protection, and depreciation,continue even though the equipment is not in active use.Operating time, rate of production, and sales demand are closely interrelated.The ideal plant should operate under a time schedule which gives themaximum production rate while maintaining economic operating methods. Inthis way, the total cost per unit of production is kept near a minimum becausethe fixed costs are utilized to the fullest extent. This ideal method of operationis based on the assumption that the sales demand is sufficient to absorb all thematerial produced. If the production capacity of the process is greater than thesales demand, the operation can be carried on at reduced capacity or periodicallyat full capacity.

Lecture 7. Scale-up challenges in a food industry

When accurate data are not available in the literature or when past experiencedoes not give an adequate design basis, pilot-plant tests may be necessary inorder to design effective plant equipment. The results of these tests must bescaled up to the plant capacity. A chemical engineer, therefore, should beacquainted with the limitations of scale-up methods and should know how toselect the essential design variables.Pilot-plant data are almost always required for the design of filters unlessspecific information is already available for the type of materials and conditionsinvolved. Heat exchangers, distillation columns, pumps, and many other types ofconventional equipment can usually be designed adequately without usingpilot-plant data.

For scale up the following 3 types of hydraulic similarities are important from the subject point of view.
1. Geometric Similarity
2. Kinematic Similarity
3. Dynamic Similarity

Geometric Similarity

Geometric similarity is said to exist between the model and the proto type. It differs only in size or in other words , the Geometric similarity is said to exist within the model and the prototype if ratios of all the corresponding linear dimensions are equal. Let 'L' = Length of the prototype and 'B' = Breadth of the prototype and 'D'= Depth of the prototype and 'l','b','d' = corresponding values of the model. Now, if geometric similarity exists between the prototype and the model then the linear ratio of the prototype and the model (also called scale – ratio) will be

$L_r = (L/l) = (D/d) = (B/b)$

Similarly area ratio of the prototype and the model will be

$A_r = (L/l)^2 = (D/d)^2 = (B/b)^2$

The volume ration of the prototype and the model will be

$V_r = (L/l)^3 = (D/d)^3 = (B/b)^3$

Kinematic Similarity

The kinematic similarity is said to exist between the model and the prototype is both of them have identical motions and velocities or in other words, the kinematic similarity is said to exist between the model and the proto-type is the ratio of the corresponding velocities at corresponding points are equal.

Let, V_i= velocity of liquid in proto-type at point 1
V_{ii} = velocity of liquid in proto-type at point 2
v_i and v_{ii} = corresponding values of the model.

Then the velocity ratio of the proto-type to the model, if the kinematic similarity exists is,

$\gamma_r = V_i / v_i = V_{ii} / v_{ii}$

Dynamic Similarity

The dynamic similarity is said to exist between the model and the prototype if both of them have identical forces. In other words, the dynamic similarity is said to exist between the model and the prototype, if the ratio of the corresponding forces acting at the corresponding points are equal.

Let,
F_1 = Force acting in the prototype at point 1
F_2 = Force acting in the prototype at point 2
f_i and f_{ii} = corresponding values of the model.

Then the forces may be represented by a ratio,

$F_r = F_1 / f_i = F_2 / f_{ii}$

Lecture 8. Problems on scale up in a food processing plant

1.

After a batch fermentation, the system is dismantled and approximately 75% of the cell mass is suspended in the liquid phase (2 l), while 25% is attached to the reactor walls and internals in a thick film (ca. 0.3 cm). Work with radioactive tracers shows that 50% of the target product (intracellular) is associated with each cell fraction. The productivity of this reactor is 2 g product/l at the 2 l scale. What would be the productivity at 20,000 l scale if both reactors had a height-to-diameter ratio of 2 to 1?

2.

Consider the scale-up of a fermentation from a 10 l to 10,000 l vessel. The small fermenter has a height-to-diameter ratio of 3. The impeller diameter is 30% of the tank diameter. Agitator speed is 500 rpm and three Rushton impellers are used. Determine the dimensions of the large fermenter and agitator speed for:

a. Constant *P/V*

b. Constant impeller tip speed

c. Constant Reynolds number

SAMPLE QUESTIONS

GROUP A

1 Multiple Choice Question (MCQ) (Answer any ten) 10X1=10

i).Project Engineering Bridges the boundaries between engineering and

a) Project Management b) Project Architecture c) Project Manager d) Construction Engineer

ii) The location of the plant can have a crucial effect on

a) Profitability of the project b) Cost of the project c) Loss of the project d) Convenience of the project

iii) Equipment that needs to have frequent operation should be located convenient to the

a) Control room b) Instrumentation room c) Store room d) Operator's room

iv) Compressors and large pumps should be placed under

a) Cover b) Convenient position c) Convenient height d) none of the above

v) Blast walls may be needed to isolate potentially

a)Explosive equipment b)Hazardous equipment c) Processing equipment d) All of the above

vi) Approved means approval by the

a) Local authority b) Municipal authority c) Government authority d) All of the above

vii) Building layout of a food processing plant should include

a) Flexibility of operation b) employee facilities c) Study of chemical & physical nature of material being used d) all of these,

viii) Sufficient working space and headroom must be provided to allow easy access to

a) Equipment b) Instruments c) Packaging d) Quality control Lab

ix) The equipment should be of an approved type and based on

a) 3A standards b) Drainage regulations Act c) Public health Act d) None of these

x) All doors are to have a smooth, hard, non absorbent finish suitable for cleaning and exterior doors should be a)Self – closingb)Double doorc)Sliding doord)None of these

xi) Floors of a food processing industry should_

(a) have a gentle slope
(b) should not be slippery
(c) should have rounded joints for wall-floor junction
(d) all of these

xii) Which of the following material is ideal for constructing food equipment ?

(a) Stainless Steel

(b) Glass

(c) Wood

(d) Nickel and Nickel Alloy

xiii) How does streamlining of a process helps to make a plant design economically feasible?

(a) It reduces possibility of repetition of work

(b) It reduces the labour cost

(c) None of the above

(d) All of the above

xiv) What is the full form of FSSAI?

(a) Food Security and Standards Authority of India

(b) Food Safety and Standards Administrator of India

(c) Food Safety and Standards Authority of India

(d) Food Standard and Safety Authority of India

xv) Which of the following material would you choose while constructing a heat exchanger for a food processing industry?

(a) Aluminum

(b) Copper and Copper Alloys

(c) Titanium

(d) None of these

GROUP B

Short Question (SQ) **(answer any three)** **5 X3=15**

2. What are the considerations for choosing materials in project? What is Project Engineering? (2.5 + 2.5=5)

3. What are the different site and plant approvals mandatory before establishing food process industries? How equipment specifications are divided into different sections? (2.5 + 2.5)

4. What are the constructional requirements before establishing food process industries? (5)

5. What are the daily operations of Project Engineer in construction Industries? (5)

6. What are the crucial factors considered before selecting suitable plant site (5)

7. What are the basic requirements of Fruit products Order?What are the safety arrangements of a plant? (2.5 + 2.5=5)

8. Give the process flow steps for freezing of fruit based product and hard dough biscuits.(3+2=5)

(2+3)

9. Describe the ventilation and lighting requirements in a food processing industry.

(3+2=5)

10. Write the different stages mentioning the critical control point in each stage in bread making. Describe the design of utility system in food processing industry. (2.5 + 2.5=5)

11. What are the factors must be considered when selecting a suitable plant site? Draw a suitable site layout pointing the various facilities in it? (2.5 + 2.5=5)

12.What are the properties of food contact surfaces? Among the principle factors effecting plant layout which factor do you consider the most important and why?

(2.5 + 2.5=5)

13. What are the different document packages? What are the general requirements of shipping? (2.5+2.5=5)

14. Write short note on: (any two) (2 ½ x 2 = 5)

i) Pilot plant

ii) Program Evaluation and review Technique

iii) Network Diagrams

iv) Modular Construction

15. Explain the concept of Optimum Economic Design with a suitable example.

16. What are the different characteristics of a suitable construction material?

17. What are the major differences between the design of a food related plant and any other plant?

18. What are the different characteristics of a suitable construction material?

19. What is the major advantage and disadvantage of choosing Aluminum and Aluminum Alloys as a material of construction?

20. What are the basic stages through which a design project moves to completion?

21. What are the different considerations that are to be made while choosing a plant location for a food industry?

GROUP C

Long Question (SQ) (answer any three) 15 X3=45

1. Draw a layout and explain the designing aspects of pilot and semi commercial food processing plants. Explain the application of programme evaluation of review technique and critical path method in Project planning and monitoring. (3+2.5+2.5+3.5+3.5=15)
2. Discuss the principal factors to be taken in consideration while selecting the location for food plants. What are the requirements in designing the floor space and ceiling of a food processing plant? Discuss the importance of a proper equipment layout and design and describe the installation of equipments and pipe works in the plant. (7.5+4+3.5=15)
3. Discuss the practical application with the special reference to food process industries

a) ISO, b) FPO c) MPO (5+5+5=15)

4. Enlist all the machinery and equipments and describe the process of manufacturing biscuits. Draw the layout for arrangement of machines and equipments. (7.5+7.5=15)
5. What are the precautions to be considered in manufacturing the food contact surfaces of equipments? Give details of materials used for construction explaining their advantages and disadvantages. Describe the storage design of raw materials and finished products in a food processing industry. (3+6+6=15)
6. What is ISO? What are the different ISO standards related to food Industry? What are the agencies involved in making regulatory standards and methods of their measurement and interpretation? A reaction in a beaker can be vastly different at production scale justify the statement. (3+5+5+2=15)
7. What are the methods for carrying out a design project? How should a feasibility study be performed for the successful implementation of a food plant design? What are the guiding factors for a successful plant layout? (3+7+5=15)
8. What do you mean by HACCP? What are the benefits of HACCP? What are the principle steps that are to be followed to apply HACCP? (2+5+8 = 15)

9. Write a short note on Hygienic design of equipment for food industry. Discuss the important points that are to be considered while establishing processing equipment for a plant. Give example of a few plastic materials that are used constructing food equipment. (5 + 7 + 3 = 15)
10. Draw the layout of a Cheese processing plant and label its various parts. Give a short note on the Milk and Milk Product Order. (10+5 = 15)