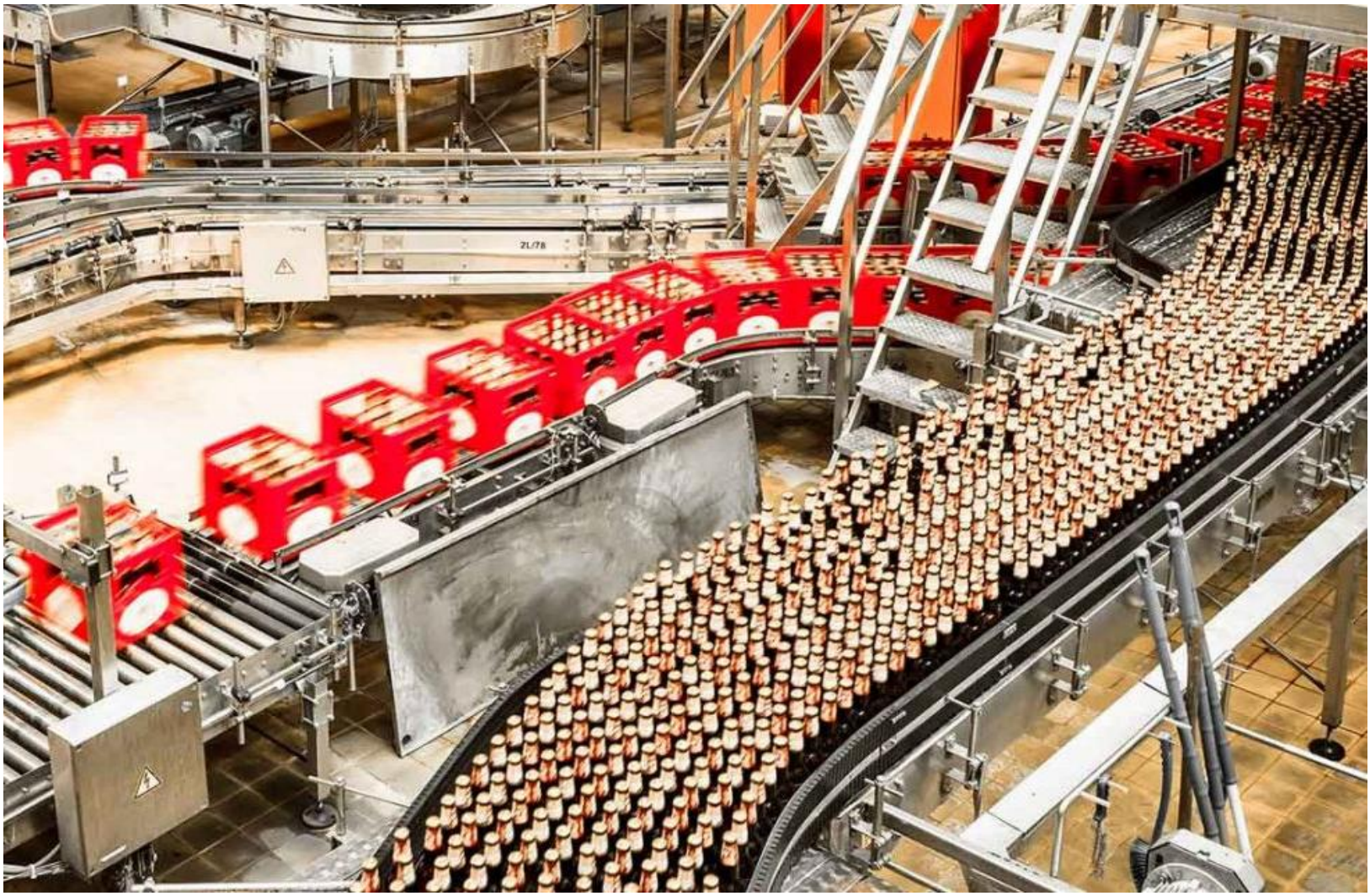
Food Processing Plant Design & Layout



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Food Processing Plant Design & Layout

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Module- 1. Introduction of food plant design and layout

Lesson 1. Introduction to plant design, situations, difference and considerations

1.1 Introduction

The manufacturing of food products of consistent quality and nutritional value at affordable cost is essential to the success of the food industry today. The efficient use of resources is, therefore, growing concern for all involved in handling of raw materials and energy for processing, production, distribution and retailing of food. The unique features of the raw materials of the food processing industries such as seasonality, perishability and variability in conjunction with sophistication required for processing to maintain high quality standards, necessitates special attention towards skilled technical manpower, effective technologies, efficient machinery in the food plant.

Plant design refers to the overall design of a manufacturing enterprise / facility. It moves through several stages before it is completed. The stages involved are: identification and selection of the product to be manufactured, feasibility analysis and appraisal, design, economic evaluation, design report preparation, procurement of materials including plant and machinery, construction, installation and commissioning. The design should consider the technical and economic factors, various unit operations involved, existing and potential market conditions etc.

1.2 Plant design specifies

- Flow charts and plant layouts spell out interconnections and raw material flows, permanent/temporary storage, shop facilities, office spaces, delivery and shipping facilities, access ways
- Equipments, utilities and services to be used
- Required instrumentation and interconnections for process monitoring and controls
- Strategic site location, plan and elevation

They also often provide economic analyses of plant profitability in terms of various product demand and price and material cost scenarios.

Plant design situations may arise due to one or more of the following:

- design and erection of a completely new plant
- design and erection of an addition to the existing plant
- the facility or plant operations and subsequent expansion restricted by a
- poor site, thereby necessitating the setting up of the plant at a new site
- addition of some new product to the existing range

- adoption of some new process /replacement of some existing equipment
- modernization / automation of the existing facility
- expansion of the plant capacity
- relocating the existing plant at a new site because of new economic, social, legal or political factors

1.3 Differences in the design of food processing and non-food processing plants

Many of the elements of plant design are the same for food plants as they are for other plants particularly those processing industrial chemicals. However, there are many significant differences, basically in the areas of equipment selection and sizing, and in working space design. These differences stem from the ways in which the processing of foods differs from the processing of industrial chemicals. Such differences occur because of the following considerations:

- The storage life of foods is relatively limited and strongly affected by temperature, pH, water activity, maturity, prior history, and initial microbial contamination levels.
- Very high and verifiable levels of product safety and sterility have to be provided.
- Foods are highly susceptible to microbial attack and insect and rodent infestation.
- Fermentations are used in producing various foods and bio chemicals. Successful processing requires the use of conditions, which ensure the dominance of desired strains of microorganisms growth or activity.
- Enzyme-catalyzed processes are used or occur in many cases. These, like microbial growth and fermentation are very sensitive to temperature, pH, water activity and other environmental conditions.
- Many foods are still living organisms or bio chemically active long after harvest or slaughter.
- In some cases foods (e.g. ripening cheeses) contain active living micro organisms, which induce chemical transformations for long periods of time.
- Crop-based food raw materials may only be available in usable form on a seasonal basis. Therefore, plant design may involve the modelling of crop availability.
- Food raw materials are highly variable and that variability is enhanced by the ageing of raw material and uncontrollable variations in climatic conditions.
- The biological and cellular nature and structural complexity of foods causes special heat-transfer, mass-transfer and component separation problems.
- Foods are frequently solid. Heat and mass-transfer problems in solids have to be created in ways that are different than those used for liquid and gas streams. The kinetics of microbe and enzyme inactivation during thermally induced sterilization and blanching and heat-transfer in the solids being sterilized or blanched are strongly linked.

- Food processing generates wastes with high BOD loads.
- Foods are often chemically complex systems whose components tend to react with one another. Certain types of reactions, e.g. Maillard reactions, oxidative rancidification, hydrolytic rancidification and enzymatic browning tend to occur with a high degree of frequency.
- The engineering properties of foods and biological material are less well known and more variable than those of pure chemicals and simple mixtures of chemicals.
- Vaguely defined sensory attributes often have to be preserved, generated or modified. These require sensory testing. Raw material variation, minor processing changes and trace contaminants leached from processing equipment and packages can often cause significant changes in these attributes. Frequently, we do not have mechanistic bases for linking these attributes to processing conditions and equipment design. Much current food engineering and food science research activity at universities is designed to provide such linkages.
- In the case of foods, prototype products have to be consumer tested so as to assure market acceptability before plants for large scale production are built.
- Mechanical working is sometimes used to induce desired textural changes. Examples include kneading and sponge mixing during the making of bread, the calendaring of pastry dough, shearing during extrusion texturization.
- Packaging in small containers is often used or required; and strong-package-product interactions exist. Packaging often requires care to maintain integrity of closure, reproducibility of fill elimination of air from head spaces and prevention of subsequent moisture and oxygen transfer. Segregation often causes problems in the packaging of powdered foods. Aseptic packaging is starting to be widely used.
- Food processing techniques and formulations are sometimes constrained by standards of identity and good manufacturing practice regulations and codes.
- Food processing is an art to a certain extent. Engineers and technologists are frequently uncertain as to weather portions of that art are really justified or necessary. It is sometimes difficult for them to translate the necessary portions of that art into quantifiable heat-transfer and chemical reaction processes on which rational designs can be based.

1.4 General design considerations

Food plant designs must provide necessary levels of sanitation, means of preventing product and material contamination and means of preventing or limiting product, raw material, and intermediate product deterioration due to naturally occurring processes. Great care must be exercised to achieve high levels of product purity and preserve product integrity. A brief description of some of the design considerations follows.

1.4.1 Food processing unit operations

Food processing involves many conventional unit operations but it also involves many which differ greatly from those usually encountered in the production of industrial chemicals. These include: freezing and thawing and other temperature-induced phase

transitions or phase transition analogs, freeze drying, freeze concentration, curd and gel formation, development of structured gels, cleaning and washing (the operation which occurs with the greatest frequency in food processing plants), leavening, puffing, and foaming, slaughtering, carcass disassembly, component excision, slicing and dicing, peeling and trimming, grading, cell disruption and maceration, pasteurization and sterilization, blanching, baking, cooking (for purposes of tenderization or textural modification), roasting (for purposes of flavour generation), radiation sterilization, mechanical expression, structure-based component separation, filling and packaging, canning and bottling, coating and encapsulation, sausage and flexible casing, stuffing, controlled atmosphere storage, fumigation and smoking, churning, artificially induced ripening, fermentation, pureeing, emulsification and homogenization, biological waste treatment, and controlled feeding of confined animals, poultry and fish.

1.4.2 Prevention of contamination

Prevention of contamination will involve the provision or use of filtered air, air locks, piping layouts that ensure complete drainage and present cross-stream contamination (particularly contamination of finished products by unsterilized or unpasteurized raw material and cleaning solutions), solid material and human traffic flow layouts that also prevent such contamination, suitably high curbs when pipes, conveyors or equipment pass through floors and where gangways pass over processing areas, bactericides in cooling water, culinary (i.e. contaminant-free) steam whenever direct contact between a product and steam is used, impermeable covers for insulation, dust covers over conveyors and clear plastic covers for electric lights, methods for washing bottles and containers, suitable barriers against pest entry, windowless construction, solid instead of hollow walls, or completely tight enclosure of hollow spaces in walls, air circulation system and external roof and wall insulation that prevent the formation of condensate which can drip into products or favour mould growth, ultra-violet irradiation of tank head spaces, electric light traps for flying insects, impactors for killing insect eggs, larvae, pupae and adults in grain, carbon dioxide and nitrogen fumigation of dry food storage bins, screening system to remove insects and insect parts, magnetic traps, iron screens for sieving equipment (so that screen fragments can be picked up by magnetic traps), metal detectors for rejecting packaged product that contains unwanted metal, and methods for storing and keeping track of segregated batches of raw materials and finished goods until necessary quality assurance tests have been carried out.

1.4.3 Sanitation

Sanitation, which helps prevent contamination, should be facilitated by providing or using: impermeable coated or tiled floors and walls, at least one floor drain per every 40 m^2 of wet processing area, special traps for such drains, pitched floors that ensure good drainage, polished vessels and equipment that do not contain dead spaces and which can be drained and automatically cleaned in place, sanitary piping, clean-in-place (CIP) systems, plate heat exchangers and other types of equipment which can be readily disassembled for cleaning if necessary, clearances for cleaning under and around equipment, grouting to eliminate crevices at the base of equipment support posts and building columns, tubular pedestals instead of support posts constructed from beams, and methods for removing solid particles which fall off conveyors. Air flow and human traffic flow patterns should be maintained to eliminate possibilities of containment transfer from dirty areas to clean ones. Very high levels of sanitation must be provided for foodstuffs that provide good substrates for the growth of micro organisms and when processing temperatures and conditions favour such growth.

1.4.4 Deterioration

To minimize product and raw material deterioration, provisions should be made for: refrigerated and controlled environment storage areas, space and facilities for product inspection and for carrying out quality assurance tests, surge vessels for processed material between different operations (particularly operations which are subject to breakdown), equipment for pre-cooling material stored in such vessels, means of cooling, turning over or rapidly discharging the contents of bins and silos when excessive temperature rises, occur, and standby refrigeration and utility arrangements which are adequate to prevent product and raw material deterioration in case of power interruptions or unusual climatic conditions.

1.4.5 Seasonal production

Food plants have to be sized to accommodate peak seasonal flows of product without excessive delay, and in some cases, have to be highly flexible so as to handle different types of fruits and vegetables. Modelling of crop and animal growth processes can be of great help in scheduling production and adequately sizing plants.

Lesson 2. Food plant design process

2.1 Introduction

The design process on all projects follows the same stages of development. However the extent and detail of the activities behind each stage are different with every project.There are a number of different industry formats for mapping the stages in the engineering process. A sequence that provides a simple fit with plant design activities is outlined in Figure 2.1. This is based on the overall project involve estimation of plant and/or equipment/s capacity, process scheduling and proper layout so as to meet special requirements and needs to be focused on theses. The following are the few aspects that make the food industry as a unique.

2.2 Feasibility study

The basis for the success of the design of any food processing plant is a comprehensive feasibility study and evaluation. The feasibility study involves an analysis and evaluation of the design concept from all the relevant angles. The study provides an immediate indication of the probable success of the enterprise and also shows what additional information is necessary to make a complete evaluation. It gives an insight in to: requirements of human, financial and material resources; plant and machinery, technology; and economic gains or profitability of the proposed venture.

The feasibility analysis involves a certain number of stages during which various elements of the plant design are prepared and examined to arrive at appropriate decision. The feasibility study can, therefore, be seen as a series of activities culminating in the establishment of a certain number of study elements and documents, which permit decision making. Identification stages, preliminary selection stage, analysis stage and evaluation and decision stage are the important stages.

2.3 Project idea

2.3.1 Identification stage:

Once a product idea occurs, the starting point of analysis is the establishment of the objectives to be attained. The objective may be to prove that it is possible and desirable to manufacture a certain product or group of products, to add a piece of equipment to the existing plant or to utilize certain resources.

The ideas for new products or diversification can be generated in an informal and spontaneous manner from customers, distributors, competitors, sales people, and others, or the entrepreneur can rely on a systematic process of idea generation.

Two key approaches for product identification and selection could be:

a) Look for a need and then the product to satisfy that need, or

b) Find a product idea and then determine the extent of the need.

2.3.1.1 Looking for a need:

Venture ideas can be stimulated by information which indicates possible need. This approach requires access to data and considerable analysis. However, if the perceived need is real, the product idea has a better than average chance of leading to a successful venture. The need may be one now being served inefficiently at high cost, or it may be presently unserved. The second implies that a considerable amount of creative design and development may be required to arrive at a product that appears to satisfy the need. The following is suggested for identification of the need.

- Study existing industries for backward and forward product integration to indicate input and output needs
- Analyse population trends and demographic data for their affect on the market
- Study development plans and consult development agencies for development needs and venture opportunities.
- Examine economic trends in relation to new market needs and opportunities.
- Analyse social changes
- study the effects of new legislations in relation to creation of new opportunities

2.3.1.2 Finding a product:

Each of the preceding suggestions for idea generation centres on the recognition of a need in order to arrive at a product idea. The suggestions that follow are product oriented. They are intended to stimulate product ideas which may meet one or more of the criteria previously discussed. Their use should result in a large number of ideas which can be subsequently examined with regard to need. The following list should be useful in conducting such an exercise.

- investigate local materials and other resources for their current utilization pattern, utilization potential and convertibility into more value added products
- examine import substitutions for indigenous production
- study local skills for production and marketing of value added products
- study implications of new technologies for improvement of existing products or to create / produce new ones
- study and analyze published sources of ideas

2.4 Preliminary screening of ideas:

By following the above approaches, it should be possible to develop a long list of potential venture opportunities. Obviously, it would not be realistic to conduct a detailed feasibility analysis for each idea. What is needed is a preliminary screening to eliminate the many ideas that have little or no hope for success and to provide, if possible, a rank-ordering of the remaining few. The screening can be conducted as two-phase process. In the first phase venture ideas are eliminated on a go/no-go basis. A "Yes" response to any of the following should eliminate the idea from further consideration.

- Are the capital requirements excessive?
- Are environmental effects contrary to Government regulations?
- Is venture idea inconsistent with national policies, goals and restrictions? Will effective marketing need expensive sales and distribution system?
- Are there restrictions, monopolies, shortages, or other causes that make any factor of production unavailable at reasonable cost?

2.5 Comparative rating of product ideas

After elimination of unattractive venture ideas, it is desirable to choose the best of those remaining for further analysis. Various comparative schemes have been proposed for rating venture ideas. In this section, factors that should be considered and some possible ranking methods are examined. For a product idea to lead to a successful venture, it must meet the following four requirements:

a) An adequate present market for raw and finished product/s

b) Market growth potential

c) Competitive costs of production and distribution

d) Low risk in factors related to demand, price, and costs

2.5.1. Present market: The size of the presently available market must provide the prospect of immediate raw material purchase and product/s sales volume to support the operation. Sales estimates should not be based solely on an estimate of the number of potential customers and their expected individual capacity to consume. Some factors that effect sales are:

- Market size (number of potential customers)
- Product's relation to need
- Quality-price relationship compared to competitive products
- Availability of sales and distribution systems and sales efforts required
- Export possibilities

2.5.2. Market Growth Potential: There should be a prospect for rapid growth and high return on invested capital. Some indicators are:

- Projected increase in need and number of potential customers
- Increase in customer acceptance
- Product newness
- Social, political and economic trends (favourable for increasing consumption)

2.5.3. Competitive costs of production and distribution: The costs of production factors and distribution must permit an acceptable profit when the product is priced competitively. The comparative rating process should consider factor likely to result in costs higher than those of competitive producers should:

- Costs of raw material inputs
- Labour costs
- Selling and distribution costs
- Efficiency of production processes Patents and licenses

2.5.4. Risks involved: Obviously it is impossible to look into the future with certainty, and the willingness to assume risk is the major characteristic that sets the entrepreneur apart. However, unnecessary risk is foolhardy and, while it may be difficult or impossible to predict the future, one can examine, with considerable confidence, the possible effect of unfavourable future events on each of venture ideas. The following factors should be considered.

- Market stability in economic cycles
- Technological risks
- Import competition
- Size and power of competitors
- Quality and reliability risks (unproven design)
- Initial investment cost
- Predictability of demand
- Vulnerability of inputs (supply and price)
- Legislation and controls
- Time required to show profit
- Inventory requirements

For purposes of preliminary screening, these factors can be subjectively evaluated.

Lesson 3. Introduction to feasibility study and analysis

3.1 Pre selection/Pre-feasibility stage

The preliminary screening may have several ideas which appear to be worthy of further study. Since a complete feasibility study is time consuming and expensive, it may be desirable to perform a pre-feasibility analysis in order to further screen the possible ideas. The purpose of a pre-feasibility study is to determine.

- Whether the project seems to justify detailed study
- What matters deserve special attention in the detailed study (e.g. market analysis, technical feasibility, investment costs)
- An estimate of cost for the detailed study

For many ideas the pre-feasibility analysis may provide adequate evidence of venture profitability if certain segments are more carefully verified. Emphasis depends on the nature of the product and the area of greatest doubt. In most cases market aspects and materials receive primary emphasis. The pre-feasibility study and report may include some or all of the following elements.

3.1.1 Product description: The product's characteristics should be briefly described, along with possible substitutes which exist in the market place. Also, allied products should be identified, which can or should be manufactured with the product under study.

3.1.2 Description of market: The present and projected potential market and the competitive nature of the market should be delineated.

- Where is the product now manufactured?
- How many plants exist and how specialized are they?
- What are the national production, imports, and exports?
- Are there government contracts or incentives?
- What is the estimated product longevity or future consumption?
- What is the price structure?

3.1.3 Outline of technological variants: The technology choices that exist for the manufacture of the product should be described briefly. Also, the key plant location factors should be identified.

3.1.4 Availability of main production factors: Production factors such as raw materials, water, power, fuel and labor skills should be examined to ensure availability.

3.1.5 Cost estimates: Estimates should be made of the necessary investment costs and costs of operation.

3.1.6 Estimate of profit: The data gathered should include estimates of profits of firms manufacturing similar products or, if the preliminary data are extensive, an actual estimated profit for the project under study.

3.1.7 Other data: In certain cases, local attitudes toward industry; educational, recreational and civic data; and availability of local sites, may be the most important in the evaluation of the suitability of a proposed product, especially in the case of the establishment of a new firm.

Thus pre-feasibility study can be viewed as a series of steps culminating in a document which permits determination of whether or not a complete detailed feasibility study should be made. It does not possess the depth the detailed study is expected to have, and the data usually are gathered in an informal manner.

3.2 Analysis stage

At the analysis stage various alternatives in marketing, technology and capital availability need to be studied. The analysis can be conducted at different levels of effort with respect to time, budget and personnel, depending on the circumstances. The complete study is referred to as techno-economic feasibility study. In some cases such a detailed study is not necessary. For example, if the product has an assured market, in-depth market analysis is not required. In some cases, a partial study of the market or of the technologies satisfies the data requirements for decision making. The detailed analysis should include the following.

3.2.1 Market analysis / study:

Market analysis can serve as a tool for screening venture ideas and also as a means of evaluating the feasibility of a venture idea in terms of the market. It provides:

- understanding of the market
- information on feasibility of marketing the product
- analytical approach to the decision making

In addition, it assists in analyzing the decisions already taken. Market analysis answers questions about:

- size of market and share anticipated for the product in terms of volume and value
- pattern of demand
- market structure
- buying habits and motives of buyers
- past and future trends
- price which will ensure acceptance in the market
- most efficient distribution channels,

- company's strong points in marketing

Market analysis involves systematic collection, recording, analysis, and interpretation of information on:

- existing and potential markets
- marketing strategies and tactics
- interaction between market and product
- marketing methods
- current or potential products

In collecting the market data, for whatever size market or type of product, it is helpful to follow an orderly procedure.

The initial step is to put down in writing a preliminary statement of objectives in as much detail as possible. A good procedure is to structure the objectives in question form. When setting objectives, always keep in mind as to how the information will be used when it is obtained. This helps in eliminating objectives that would not make a contribution to the market analysis.

3.2.2 Situational analysis related to market:

The situational analysis of the market involves analyzing the product's relationship to its market by using readily available information. The information reviewed and each question asked will give the analyst a feel for the situation surrounding the product. The state involves an informal investigation which includes talking to people in wholesale market, brokers, competitors, customers and other individuals in the industry. If this informal investigation produces the sufficient data to measure the market adequately, the analysis need not proceed further. Also, in some instances, where time is critical or where budget is a problem, the data gathered during the informal market analysis may be all that is available on which to base decisions.

Seldom do the data obtained during the situational analysis answer all the necessary questions. The informal analysis provides the basis for revision of the objectives and frequently indicates the most fruitful methods by which market can be studied. This also helps in preparing a comprehensive programme of market study. Such a programme should include a description of the tasks and methods by which each type of information is to be gathered. It should include not only the time schedule for each task, but also an estimate of costs likely to be incurred.

Basic steps involved in a market study for a new enterprise are:

- Define objectives of the study and specify information required
- Workout details of the study as under:

- identify sources of information (both secondary and primary)

- time and cost involvement

- methodology and action plan

- Select samples and decide contacts and visits
- Prepare the questionnaire as the survey instrument and field test the same
- Conduct the survey and analyze information
- Prepare the report with findings and interpretations

The analysis should generally contain:

- A brief description of the market including the market area, methods of transportation existing rates of transportation, channels of distribution, and general trade practices
- Analysis of past and present demand including determination of quantity and value of consumption, as well as identification of the major consumers of the product
- Analysis of past and present supply broken down as to source, information on competitive position of the product such as selling prices, quality, and marketing practices of the competitors
- Estimate of future demand of the product
- Estimate of the project's share of the market considering all above factors

3.2.3 Technical analysis:

The technical analysis must establish whether or not the identified venture is technically feasible and, if so, make tentative choices among technical alternatives and provide cost estimates in respect of:

1. fixed investment
2. manufacturing costs and expenses and
3. start-up costs and expenses

In order to provide cost estimates, tentative choices must be made among technical alternatives such as:

(i) level of product / manufacturing technology,

(ii) raw material inputs,

(iii) equipments,

(iv) methods,

(v) organization, and

(vi) facilities location and design.

The analysis report should incorporate:

- Description of the product, including specifications relating to its physical, mechanical, and chemical properties as well as the uses of the product Description of the selected manufacturing process showing detailed flow charts as well as presentations of alternative processes considered and justification for adopting the one selected
- Determination of plant size and production schedule, which includes the expected volume for a given time period, considering start-up and technical factors
- Selection of machinery and equipment, including specifications, equipment to be purchased and origin, quotations from suppliers, delivery dates, terms of payment, and comparative analysis of alternatives in terms of costs, reliability, performance and spare parts availability
- Identification of plant's location and assessment of its desirability in terms of its distance from raw material sources and markets. For a new project this part may include a comparative study of different sites, indicating the advantages and disadvantages of each
- Design of a plant layout and estimation of the costs of erection of the proposed types of buildings and land improvements
- Study of availability of raw materials and utilities, including a description of physical and chemical properties, quantities, needed, current and prospective costs, terms of payment, source of supply and their location and continuity of supply
- Estimate of labour requirements including a breakdown of the direct and indirect labour supervision required for the manufacture of product
- Determination of the type and quantity of waste to be disposed of, description of the waste disposal method, its costs and necessary clearance from the authorities
- Estimation of the production cost for the product

The elimination of inappropriate technology alternatives for producing the identified product can be done on the basis of side effects. The factors which may be considered as side effects include:

- contribution to employment
- requirements for scarce skills
- energy requirements
- capital requirements
- need for imported equipment
- support of indigenous industry
- multiplier effect of the venture operation

- environmental effects
- safety and health hazards

Information concerning manufacturing processes and equipment, which may facilitate the selection and decision making, may be obtained from: (i) existing manufacturers of the product, (ii) trade publications, (iii) trade associations and organizations, and (iv) equipment manufacturers.

3.2.4 Financial analysis:

The financial analysis emphasizes on the preparation of financial statement, so that the venture idea can be evaluated in terms of commercial profitability and magnitude of financing required. It requires the assembly of the market and the technical cost estimates into various proforma statements. If more information on which to base an investment decision is needed, a sensitivity analysis or, possibly, a risk analysis can be conducted. The depth of analysis would depend, to a certain extent, on the venture idea and the overall objectives of the feasibility analysis.

The financial analysis should include:

- For existing companies-audited financial statements, such as balance sheets, income statements and cash flow statements
- For new companies-statements of total project costs, initial capital requirements and cash flows relative to the project time table
- For all projects-financial projections for future time periods, including income statements, cash flows and balance sheets
- Supporting schedules for financial projections, stating assumptions used as to collection period of sales, inventory levels, payment period of purchases and expenses, elements of product costs, selling, administrative and financial expenses
- financial analysis showing return on investment, return on equity, break- even volume and price analysis
- Sensitivity analysis to identify items that have a large impact on profitability or possibility of risk analysis

The analyst may obtain profitability measures for the venture being studied in several ways. Common non-time value approaches to measure profitability are the pay back period and financial statement (accounting) rates of return. These rates of return are based on some net income figure divided by some investment base. Frequently used profitability measure of this type are: net income to assets, first-year earnings to initial investment, average net income to initial investment, and average net income to average investment.

Profitability measures, which consider the time value of money, that is, discounted cash flow methods, are net present value (NPV), internal rate of return (IRR), and the discounted benefit / cost ratio. When profitability measures other than financial statement rates of return are used as the investment decision criteria, the analyst needs estimates of the following:

- the net investment, which is gross capital less any capital recovered from the sale or trade of existing assets
- the operating cash flows, which are the after-tax cash flows resulting from the investment
- the economic life of the venture, defined as the time period during which benefits can be obtained from the venture and
- the appropriate discount rate.

With the relevant cash flows computed for the venture, the next step is to decide which investment decision criterion to use for the acceptance or rejection of ventures as well as their ranking. Theoretically, the net present value criterion is the best measure of profitability of the investment decision criteria used to evaluate new venture ideas, the internal rate of return appears as the technique to be of prime importance. The payback period is used primarily as a supplementary technique.

3.2.5 Sensitivity and risk analysis

Recognizing that the venture profitability forecast hinges on future developments whose occurrence can not be predicted with certainty, the decision- maker may want to probe further. The analyst may want to determine the impact of changes in variables such as product price, raw material costs, and operating costs on the overall results. Sensitivity analysis and risk analysis are the techniques that allow the analyst to deal with such problems.

The purpose of sensitivity analysis is to identify the variables that most affect the outcome of a venture. Sensitivity analysis is useful for determining consequences of a stated percentage change in a variable such as product price. It involves specifying the possible range for the variable, such as price, and calculating the effect of changes in this variable to profitability. With such a calculation, the analyst can determine the relative importance of each of the variables to profitability. However, only risk analysis can provide any indication of the likelihood that such events (change in product price) will actually occur.

Risk analysis takes into account the recognized fact that variables, such as product price, depend on future events whose occurrence can not be predicted with certainty. Hence, investment decision situations can be characterized with respect to certainty, risk and uncertainty. Since certainty seldom exists for future returns on investment, only risk and uncertainty are of interest. Uncertainty is used to refer to an event, such as technological breakthrough resulting in obsolescence, that is expected to take place although the probability of its occurrence cannot be forecasted during the venture's lifetime. Risk refers to a situation in which a probability distribution of future returns cannot be established for the venture. The riskiness of the venture can be defined as the variability or dispersion of its future returns. In practice, there are usually several variables and the aggregate risk of the venture cannot be determined easily because it is composed of numerous risks. The purpose of risk analysis is to isolate the risks and to provide a means by which various venture outcomes can be reduced to a format from which a decision can be made. A more detailed coverage can be found under profitability analysis.

3.3 Feasibility cost estimates

A lot of guess work goes into feasibility cost estimate. Attempts are always made to collect and update historical figures with additions for escalation / inflation and local factors, based on statistics and guess work. In such a situation what is expected is a rule of thumb or an order of magnitude estimate. The order of magnitude estimate is derived from the cost reports of completed ventures. Probability of this estimates accuracy is generally between +25, and 40 percent. Preliminary control estimate is often used in the feasibility report.

This is prepared, generally, after the completion of the process design and major equipment listing. Accuracy of this estimate may vary between + 15 and 25 present. Endeavour is usually made to achieve a +20 present accuracy in the feasibility report estimates. For a rule of thumb, the following are the percentages of the venture cost factors:

-Project development and detailed project report (DPR) preparation - 2 %

-Engineering and design - 13 %

-Brought out materials and equipment-55 %

-Fabrication and construction- 30 %

Depending on the type of venture, sector and complexity, these can vary on either side.

3.4 Break-Even Analysis

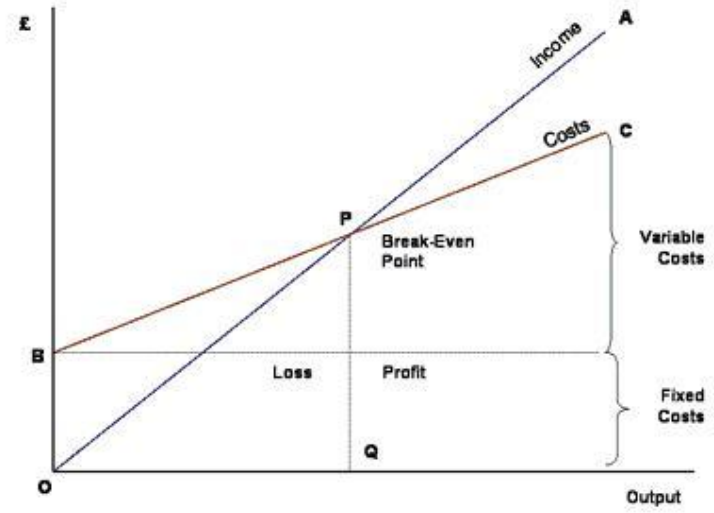
Break-even analysis is a technique widely used by production management and management accountants. It is based on categorizing production costs between those which are "variable" (costs that change when the production output changes) and those that are "fixed" (costs not directly related to the volume of production).

Total variable and fixed costs are compared with sales revenue in order to determine the **level of sales volume, sales value or production at which the business makes neither a profit nor a loss (the "break-even point").**

"A breakeven analysis **is used to determine how much sales volume business needs to start making a profit."**

3.4.1 The Break-Even Chart

The break-even chart is a graphical representation of costs at various levels of activity shown on the same chart as the variation of income (or sales, revenue) with the same variation in activity. The point at which neither profit nor loss is made is known as the "break-even point" and is represented on the chart below by the intersection of the two lines:



In the diagram above, the line **OA** represents the variation of income at varying levels of production activity ("output"). **OB** represents the total fixed costs in the business. As output increases, variable costs are incurred, meaning that total costs (fixed + variable) also increase. At low levels of output, Costs are greater than Income. At the point of intersection, P, costs are exactly equal to income, and hence neither profit nor loss is made.

3.4.2 Fixed Costs

Fixed costs are those business costs that are not directly related to the level of production or output. In other words, even if the business has a zero output or high output, the level of fixed costs will remain broadly the same. In the long term fixed costs can alter - perhaps as a result of investment in production capacity (e.g. adding a new factory unit) or through the growth in overheads required to support a larger, more complex business.

Examples of fixed costs:

- Rent and rates

- Depreciation

- Research and development

- Marketing costs (non- revenue related)

- Administration costs

3.4.3 Variable Costs

Variable costs are those costs which vary directly with the level of output. They represent payment output-related inputs such as raw materials, direct labour, fuel and revenue-related costs such as commission.

3.4.4 Break Even Point Calculation

Calculation of BEP, per unit of production, can be done using the following formula:

BEP	=	Total fixed costs
		Unit's selling price – Unit's variable costs

For example, suppose that fixed costs for producing 100000 units were

$30,000 a year. Variable costs are $2.20 materials, $4.00 labour, and $0.80 overhead, for a total of $7.00. If selling price was chosen as $12.00 for each units, then: Break even point will be $30,000 divided by ($12.00 - 7.00) equals 6000 units. This is the number of units that have to be sold at a selling price of $12.00 before business will start to make a profit.

3.4.5.1 Advantages and limitation of Break Even Analysis

It explains the relationship between cost, production volume and returns. The major benefit to using break-even analysis is that it indicates the lowest amount of business activity necessary to prevent losses.

However, it is best suited to the analysis of one product at a time

Module- 2. Location and site selection for food plants

Lesson 4. Introduction to plant location

4.1 Introduction

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.

4.1.1 When does a need of location decision arise?

The impetus to embark upon a plant location study can be attributed to reasons as given below:

- It may arise when a new plant is to be established.
- In some cases, the plant operations and subsequent expansion are restricted by a poor site, thereby necessitating the setting up of the facility at a new site.
- The growing volume of business makes it advisable to establish additional facilities in new territories.
- Decentralization and dispersal of industries reflected in the industrial policy resolution so as to achieve an overall development would necessitate a location decision at a macro level.
- It could happen that the original advantages of the plant have been outweighed due to new developments.
- New economic, social, legal or political factors could suggest a change of location of the existing plant.

Some or all the above factors could force a firm or an organization to question whether the location of its plant should be changed or not.

Whenever the plant location decision arises, it deserves careful attention because of the long-term consequences. Any mistake in selection of a proper location could prove to be

costly. Poor location could be a constant source of higher cost, higher investment, difficult marketing and transportation, dissatisfied and frustrated employees and consumers, frequent interruptions of production, abnormal wastage, delays and substandard quality, denied advantages of geographical specialization and so on. Once a plant is set up at a location, it is very difficult to shift later to a better location because of numerous economic, political and sociological reasons.

4.1.2 Raw material

On the basis of availability, the raw materials can be categorized into:

1. Ubiquitous-to denote those available almost everywhere and
2. Localized materials, having specific locations, which are further, divided into pure material which contributes nearly the total weight of it to the finished products, and gross material, which contributes only a small fraction of total weight to the finished products. It is obvious that ubiquitous hardly influence the decision of location. A material index has been proposed, which equals the weight of localized material used in the finished product divided by the weight of the finished product.

$$\text{Material Index (MI)} = \frac{\text{Weight of local market material used in the finished product}}{\text{Weight of the finished product}}$$

If the material index is greater than unity, location should be nearer to the source of raw material and if it is less than unity, then a location nearer to market is advised.

4.2 Location selection decision process

Possible formal steps in a plant/facility location decision process given below. The actual approach varies with the size and scope of operations.

1. Define the location objectives and associated variables.

2. Identify the relevant decision criteria

- quantitative-economic

- qualitative-less tangible.

3. Relate the objectives to the criteria in the form of a model, or models (such as break-even, linear programming, qualitative factor analysis).

4. Generate necessary data and use the models to evaluate the alternative locations.

5. Select the location that best satisfies the criteria.

The objectives are influenced by, owners, suppliers, employees and customers of the organization influence the objectives. They may stem from opportunities (or concerns) with respect to any phase of the production system (i.e. inputs, processing, or outputs). The following sections describe the variables, criteria and models relevant to the location decision process.

4.3 Factors involved in the plant location decision

Location studies are usually made in two phases namely,

1. the general territory selection phase and
2. the exact site / community selection phase amongst those available in the general locale. The considerations vary at the two levels, though there is substantial overlap as shown in the following Table.

Table 4.1 Factors involved in the two stages of plant location study

Location factors	General territory selection	Selection of specific site
Market	*	
Raw material	*	
Power	*	*
Transportation	*	*
Climate and fuel	*	
Human resource and wages	*	*
Regulatory laws and taxes	*	*
Community services		*
Water and waste		*
Ecology and pollution		*
Capital availability	*	*
Site characteristics		*
Security	*	*

A typical team studying location possibilities for a large project might involve economists, accountants, town planners, marketing experts, legal experts, politicians, executives, industrial engineers, ecologists etc. It is indeed an interdisciplinary team that should be set up for undertaking location studies.

4.4 Territory Selection

For the general territory / region / area, the following are some of the important factors that influence the selection decision.

4.4.1 Markets: There has to be some customer / market for the product. The market growth potential and the location of competitors are important factors that could influence the

location. Locating a plant or facility nearer to the market is preferred if promptness of service is required particularly if the product is susceptible to spoilage. Also if the product is relatively inexpensive and transportation costs add substantially to the cost, a location close to the market is desirable.

4.4.2 Raw materials and supplies: Sometimes accessibility to vendors/suppliers of raw materials, equipment etc. may be very important. The issue here is promptness and regularity of delivery and inward freight cost minimization.

If the raw material is bulky or low in cost, or if it is greatly reduced in bulk viz. transformed into various products and by-products or if it is perishable and processing makes it less so, then location near raw material source is important. If raw materials come from a variety of locations, the plant / facility may be situated so as to minimize total transportation costs. The costs vary depending upon specific routes, mode of transportation and specific product classifications

4.4.3 Transportation facilities: Adequate transportation facilities are essential for the economic operation of production system. For companies that produce or buy heavy bulky and low value per ton commodities, water transportation could be an important factor in location plants.

4.4.4 Manpower supply: The availability of skilled manpower, the prevailing wage pattern, living costs and the industrial relations situation influence the location.

4.4.5 Infrastructure: This factor refers to the availability and reliability of power, water, fuel and communication facilities in addition to transportation facilities.

4.4.6 Legislation and taxation: Factors such as financial and other incentives for new industries in backward areas or no-industry-district centres, exemption from certain state and local taxes, octroi etc. are important.

4.5 Site / community selection

Having selected the general territory / region, one would have to go in for site / community selection. Some factors relevant for this are:

4.5.1 Community facilities: These involve factors such as quality of life which in turn depends on availability of facilities like education, places of worship, medical services, police and fire stations, cultural, social and recreation opportunities, housing, good streets and good communication and transportation facilities.

4.5.2 Community attitudes: These can be difficult to evaluate. Most communities usually welcome setting up of a new industry especially since it would provide employment opportunities to the local people directly or indirectly. However, in case of polluting industries, they would try their utmost to locate them as far away as possible. Sometimes because of prevailing law and order situation, companies have been forced to relocate their units. The attitude of people as well as the state government has an impact on location of polluting and hazardous industries.

4.5.3 Waste disposal: The facilities required for the disposal of process waste including solid, liquid and gaseous effluent need to be considered. The plant should be positioned so that prevailing winds carry any fumes away from populated areas and that the waste may be disposed off properly and at reasonable costs.

4.5.4 Ecology and pollution: These days, there is a great deal of awareness towards maintenance of natural ecological balance. There are quite a few agencies propagating the concepts to make the society at large more conscious of the dangers of certain available actions.

4.5.5 Site size: The plot of land must be large enough to hold the proposed plant and parking and access facilities and provide room for future expansion.

4.5.6 Topography: The topography, soil structure and drainage must be suitable. If considerable land improvement is required, low priced land might turn out to be expensive.

4.5.7 Transportation facilities: The site should be accessible preferably by road and rail. The dependability and character of the available transport carriers, frequency of service and freight and terminal facilities is also worth considering.

4.5.8 Supporting industries and services: The availability of supporting services such as tool rooms, plant services etc. need to be considered.

4.5.9 Land costs: These are generally of lesser importance, as they are non- recurring and possibly make up a relatively small proportion of the total cost of locating a new plant.

Generally, the site will be in a city, suburb or country location. In general, the location for large scale industries should be in rural areas, which helps in regional development also. It is seen that once a large industry is set up (or even if a decision to this effect has been taken), a lot of infrastructure develops around it as a result of the location decision. As for the location of medium scale industries is concerned, these could be preferably in the suburban / semi-urban areas where the advantages of urban and rural areas are available. For the small- scale industries, the location could be urban areas where the infrastructural facilities are already available. However, in real life, the situation is somewhat paradoxical as people, with money and means, are usually in the cities and would like to locate the units in the city itself.

Some of the industrial needs and characteristics that tend to favour each of this location are.

Requirements governing choice of a city location are:

- Availability of adequate supply of labour force
- High proportion of skilled employees
- Rapid public transportation and contact with suppliers and customers
- Small plant site or multi floor operation
- Processes heavily dependent on city facilities and utilities
- Good communication facilities like telephone, telex, post offices
- Good banking and health care delivery systems

Requirements governing the choice of a suburban location are:

- Large plant site close to transportation or population centre

- Free from some common city building zoning (industrial areas) and other restrictions
- Freedom from higher parking and other city taxes etc.
- Labour force required to reside close to the plant.
- Community close to, but not in large population centre
- Plant expansion easier than in the city

Requirements governing the choice of a rural location are:

- Large plant site required for either present demands or expansion
- Dangerous production processes
- Lesser effort required for anti-pollution measures
- Large volume of relatively clean water
- Lower property taxes, away from Urban Land Ceiling Act restrictions
- Protection against possible sabotage or for a secret process
- Balanced growth and development of a developing or underdeveloped area
- Unskilled labour force required
- Low wages required to meet competition

Major problems related to regional location/plant site factors summarised in Table 4.1.

4.6 Techniques used in location decision

Three subjective techniques used for facility location are Industry Precedence, Preferential Factor and Dominant Factor. In the industry precedence subjective technique, the basic assumption is that if a location was best for similar firms in the past, it must be the best for the new one now. As such, there is no need for conducting a detailed location study and the location choice is thus subject to the principle of precedence - good or bad.

However, in the case of the preferential factor, the location decision is dictated by a personal factor. It depends on the individual whims or preferences e.g. if one belongs to a particular state, he / she may like to locate his / her unit only in that state. Such personal factors may override factors of cost or profit in taking a final decision. This could hardly be called a professional approach though such methods are probably more common in practice than generally recognized.

However, in some cases of plant location there could be a certain dominant factor (in contrast to the preferential factor) which could influence the location decision. In a true dominant sense, mining or petroleum drilling operations must be located where the mineral resource is available. The decision in this case is simply whether to locate or not at the source.

For evaluating qualitative factors, some factor ranking and factor weight rating systems may be used. In the ranking procedure, a location is better or worse than another for the particular factor. By weighing factors and rating locations against these weights a semi-quantitative comparison of location is possible. Let us now discuss some specific methods.

4.6.1 Equal weights method

Assign equal weights to all factors and evaluate each location along the factor scale. For example, a manufacturer of fabricated foods selected three factors by which to rate four sites. Each site was assigned a rating of 0 to 10 points for each factor. The sum of the assigned factor points constituted the site rating by which it could be compared to other site.

Table Decision matrix

Factor/Potential Sites	SI	S2	S3	S4
FI	2	5	9	2
F2	3	3	8	3
F3	6	2	7	3
Site rating	11	10	24	8

Sample calculation: 11 = 2 + 3 + 6

Looking at the above Table, one can see that site S3 has the highest site rating of 24. Hence, this site would be chosen.

4.6.2 Variable weights method

The above method could be utilized on account of giving equal weight age to all the factors. Now, think of assigning variable weights to each of the factors and evaluating each location site along the factor scale. Factor **Fl** might be assigned 300 points, factor **F2** 100 points and factor **F3** 50 points. The points scored, out of the maximum assigned to each of the factors, for each possible location site could be obtained and again the site rating could be derived as follows:

Table Decision matrix

Factor	Maximum points	Potential sites			
		S1	S2	S3	S4
FI	300	200	250	250	50
F2	100	50	70	80	100
F3	50	5	50	10	40
Site rating		255	370	340	190

Sample calculation: 255 = 200 + 50 + 5

Looking at the above Table, it can be seen that site S2 has the highest site rating of 370. Hence, this site would be chosen.

4.6.3 Weight-cum-rating method

This is another method of evaluating a potential location site. One can assign variable weights to each factor. A common scale for each factor then rates the locations. The location point assignment for the factor is then obtained by multiplying the location rating for each factor by the factor weight. For example, rating weights of one to five could be assigned to the three factors **F1** (human resource), **F2** (community facilities) and **F3** (power availability and reliability), as 5, 3, 2 respectively. Now for each of the factors, sites SI, S2, S3 or S4 could receive 0 to 10 points as follows and the site rating could be obtained.

Table Decision matrix

Factor	Factor rating points	Potential sites			
		S1	S2	S3	S4
FI	5	2	5	9	2
F2	3	3	3	8	3
F3	2	6	2	7	3
Site rating		31	38	83	25

Sample calculation 3l = 5 x 2 + 3 x 3 + 2 x 6

As shown in the above Table, the sample calculation should hopefully suffice to obtain the site rating. Hence, site S3 with the highest rating of 83 is chosen.

4.6.3.1 Another weight-cum-rating method

Another weight-cum-rating method establishes a subjective scale common to all factors. This involves assigning points against the subjective scale for each factor and assigns the factor points of the subjective rating for each factor. For example, five subjective ratings- Poor, Fair, Adequate, Good and Excellent are selected to be used in evaluating each site for each factor. For each of the factors, adequate was assigned a value zero and then negative and positive relative worth weights are assigned the subjective ratings below and above adequate for each factor as given in following Table.

Table Decision matrix

	Poor	Fair	Adequate	Good	Excellent
Fl Water supply	-15	-12	0	6	10
F2 Appearance of site	-3	-1	0	1	2

The range between minimum and maximum weight assigned to a factor in effect weights that factor against all other factors in a manner equivalent to the weight-cum-rating method described previous to this one. Each location site S1 to S4 are then rated by selecting the applicable subjective rating for each factor for each location and the equivalent points of that subjective factor rating assigned to the factor. Thus one can now obtain the following Table.

Table Decision matrix

Factor	Potential sites			
	S1	S2	S3	S4
FI	0	-12	6	0
F2	0	-3	2	-1
F3	0	0	0	0
Site rating	0	-15	8	-1

Sample calculation: -15 = (-12) + (-3) + (0)

Accordingly, site S3 with the highest rating of 8 would be chosen.

The location analyst presents to the management both the cost and the intangible data results. In such cases, management could take a decision based on a simple composite measure method illustrated below with the aid of a numerical example.

4.7 Composite measure method and location break-even analysis composite measure method

The steps of the composite measure method are:

- Develop a list of all relevant factors
- Assign a scale to each factor and designate some minimum
- Weigh the factors relative to each other in light of importance towards achievement of system goals. .
- Score each potential location according to the designated scale and multiply the scores by the weights.
- Total the points each location and either (a) use them in conjunction with a separate economic analysis, or (b) include an economic factors in the list of factors and choose the location on the basis of maximum points.

The following illustrates the composite measure method with a numerical example. There are three potential sites and five relevant factors like transportation costs per week, labour costs per week, raw material supply, maintenance facilities and community attitude. The costs are in rupees whereas for the last three factors, points are assigned on 0-100 scale. The data collected is shown in the following Table.

Table Payoff matrix

Factor		Potential sites		
		S1	S2	S3
Transportation cost/week Rs	FI	800	640	580
Labour cost/week, Rs.	F2	1180	1020	1160
Raw material supply	F3	30	80	70
Maintenance facilities	F4	60	20	30
Community attitude	F5	50	80	70

The location analyst has pre-established weights for various factors. This includes a standard of 1.0 for each Rs.10 a week of economic advantage. Other weights applicable are 2.0 on raw material supply, 0.5 on maintenance facilities and 2.5 on community attitudes. Also the organization prescribes a minimum acceptable score of 30 for maintenance facilities.

First of all, look at the economic factors Fl and F2 for which monetary values were possible. If one totals the costs for each site, one gets the costs for sites S1, S2 and S3 as Rs. 1980, Rs. 1660 and Rs. 1740, respectively. Thus, site S1 would be the worst cost wise. Site S2 would have an economic advantage over site S1 to the extent of RS. (1980-1660) = Rs.320. Similarly, site S3 would have an economic advantage over site SI to the extent of Rs. (1980-1740) = Rs.240. Now the monetary value in Rupees can be converted to a point scale using the fact that a standard of 1.0 is to be assigned for each Rs.10 per week of economic advantage. Thus one can get the following Table.

Table Decision matrix

Factors	Weightage	Potential sites		
		S1	S2	S3
Economic advantage	1.0	0	32	24
(Fl + F2) F3	2.0	30	80	70
F4	0.5	60	20	30
FS	2.5	50	80	70
Composite site rating		215	402	354

Sample calculation: 215 = (1.0 x 0) + (2.0 x 30) + (0.5 x 60) + (2.5 x 50)

4.8 Locational Break-Even Analysis

Sometimes, it is useful to draw location break-even charts, which could aid in deciding which location would be optimal. The location of a food factory in a South Delhi site will result in certain annual fixed costs, variable costs and revenue. The 0 figures would be different for a South Mumbai site. The fixed costs, variable costs and price per unit for both sites are given below in the Table.

Table Cost data

Location site	Fixed costs	Variable Costs	Price per tonne
South Delhi (Sl)	40,00,000	30,000	75,000
South Mumbai (S2)	60,00,000	24,000	82,000

Let us assume that the expected sales volume as estimated by a market

research team is 95 tonnes.

Now the break-even point is defined to be the point or volume where the total costs equal total revenue. Thus for each site Sl and S2, the break-even point can be determined by using a simple formula as follows:

Break-even volume (BEP)	=	Total fixed costs / Revenue per unit – Unit's variable costs

At the South Delhi Location S1

BEP	=	40,00,000 / 75,000-30,000	88.88	89 tonnes

and at the South Mumbai location S2

BEP	=	60,00,000 / 82,000-24,000	103.448	104 tonnes

Let us see what would be the profit or loss for the two sites at the expected volume of 95 tonnes. The calculations are shown in the following Table.

Table Cost comparisons

South Delhi (S1)	South Mumbai (S2)
Costs Fixed : 40,00,000 Variable: 28,50,000 Total : 68,50,000	Costs Fixed : 60,00,000 Variable : 22,80,000 Total : 82,80,000
Revenue: 75,000 x 95 = 71 ,25,000	Revenue: 82,000 x 95 = 77,90,000
Profit : = (71 ,25,000 - 68,50,000) = 2,75,000	Loss : = (77,90,000 - 82,80,000) = 4,90,000

Module- 3. Food plant size, utilities and services

Lesson 5. Food plant size and utilities

5.1 Plant size

Plant size / capacity for any food-processing unit refer to the planned rate of production of the identified product(s). It can be expressed in terms of either **volume** or **weight** or **number produced per unit time** of the product. The **time unit** for expressing the plant size could be taken as **hour** or a **shift** or a **day** or a **year**. It is always useful to take a decision about the size/capacity in the beginning of the plant design.

Knowledge of the plant size may help in:

- assessing the type and size of the plant and machinery needed
- assessing the size and caliber of the work force needed
- determining the requirements of total land area and covered space for the plant
- deciding the type of layout
- assessing the other physical facilities needed
- determining the type of sales efforts and distribution system
- financial or economic viability calculations

The size/capacity of the plant will depend on a number of factors such as:

- raw material availability
- market demand
- degree and nature of the market competition
- economic considerations i.e. acceptable return on investment / profitability

The interaction of each of the above factor with plant size can be assessed on the basis of information collected as part of the market study. Therefore, a comprehensive market study is a must.

5.1.1 Raw material availability

There may be adequate or unlimited demand for the product in the market with little or no competition, but the entrepreneur may not get adequate supplies of the raw material to produce the product in quantities one wishes. This would limit the size.

5.1.2 Market demand

Market demand for any product is the total volume that will be bought by a defined customer group in defined geographical area in a defined time period and in a defined environment. It is possible that the raw material is available in abundance. One can get as much raw material as one wish. But one can not sell all that one can produce. The demand for the product is limited. In this case, it is the market demand, which will determine the plant size.

5.1.3 Degree and nature of the market competition

There is no restriction on raw material availability. It is available in abundance. Also, there is enough demand for the product in the market. However, there exist a large number of manufacturers / processors for the product who are expected to provide stiff competition. In this case, the plant size may be restricted to a limit governed by the share of the market, which the entrepreneur may capture. Depending on the product, a 10 - 15% market share is considered to be adequate. The competition may involve price or quality or timely delivery or a combination of such features. To study the competition, the entrepreneur needs to have a list of major competitors, details of their product range, product features, output, market share and pricing.

5.1.4 Economic Considerations

Many times plant size is determined by the financial resources available with the entrepreneur as also by the degree of risk the entrepreneur is prepared to take. Sometimes it is also advisable to find the popular plant size of existing enterprises engaged in manufacturing/processing the product of choice.

In cases where the availability of raw material, market demand and the financial resources are not a problem, the entrepreneur may look for the size which will ensure him / her a minimum acceptable return/profit. **This size is called the minimum economically viable plant size**. However, when situation permits a plant size larger than the minimum economically viable size, a size, which will maximize profits, is selected.

The minimum acceptable return/profit viewed in two ways. In one case larger share of the capital investment may consist of the equity (entrepreneur's own capital) while in another case it may consist of the borrowed capital. In case of the former, the return/profit must be greater than the amount of interest earned if the entire capital of the entrepreneur was invested as fixed deposit in a scheduled bank. In case of the later, the return/profit must be greater than the interest paid on the borrowed capital.

While deciding the plant size/capacity one should also remember the following:

- Specify the number of days for which the proposed plant will work in a year. In general, it is customary to presume 300 working days. However, if the enterprise is to handle the seasonal product, it may work for less than 300 days.

- One shift consists of 8 hours. One shift working is the most popular pattern among small enterprises. Two and three shift working is largely limited to continuous enterprises and the medium and large-scale enterprises.

5.2 Food plant utilities

The principal plant utilities in a food plant **are process water, process steam**, **electric power** for motors and lighting, and **fuel**.

5.2.1 Process Water

Process water is required for washing the raw materials and for various cooling operations. In fruit and vegetable processing plants, water may be used for transportation (fluming) of the raw materials from receiving to processing areas. Water used in steam boilers may require ion exchange treatment to reduce its hardness. Total water requirement in fruit and vegetable processing may range from 5 to 15 m3 / ton of raw material.

5.2.2 Steam

Steam boilers are needed in most food processing plants to provide process steam, used mainly in various operations, such as heating of process vessels, evaporators and dryers, sterilization, blanching, and peeling. A medium size food plant (80 tons / day raw material) may require a boiler producing about 10 tons/h of steam at 18 bar pressure.

Two principal types of steam boilers are used in the food processing industry, i.e. the fire-tube and the water-tube boilers. The fire tube boilers operate at relatively lower pressure (1–24 bar) and produce cleaner steam. The water- tube units operate at higher pressures (100–140 bar) and they are suited for co- generation, i.e. electrical power and exhaust steam of lower pressure for process heating. Co-generation is economical in large food plants, requiring large amounts of low-pressure steam, e.g., beet sugar plants.

A standby steam boiler of proper capacity may be necessary to provide process steam during any boiler failure or breakdown.

Steam boilers are rated in Btu/h, kW or boiler HP (1 Btu/h = 0.293 W, 1 boiler HP = 9.8 kW). The heat flux in the boiler heating surface is about 0.75 kW/ m2. The boiler efficiency is about 85% with most of the thermal losses in the dry gases and the moisture. Steam generation is about 1.4 t/h per MW.

In order to maintain the concentration of accumulated dissolved solids in steam boilers below 3500 ppm, periodic discharge of hot water (blow down) is practiced.

Fuel is used in food plants mostly for generating process steam and process drying. Natural gas and liquefied propane (LPG) are preferred fuels in food processing, because their combustion gases are not objectionable in direct contact with food products. Fuel oil and coal can be used for indirect heating, i.e. through heat exchangers.

Culinary steam of special quality is used when steam is injected in food products. The steam must be free of objectionable chemicals used in boilers, which may be carried into the food being heated. Culinary steam is usually produced from potable water in a secondary system of a heat exchanger heated with high pressure industrial steam.

5.2.3 Electricity

Electrical power in food processing plants is needed for running the motors of the processing, control, and service equipment, for industrial heating, and for illumination. For a medium size food plant processing about 100 tons/day raw materials, the power

requirement may of the order of 500 kW. A standby power generator of about 200 k VA is recommended for emergency operation of the main plant, in case of power failure or breakdown.

Single-phase or three-phase alternating current (AC) of 110 V (60 cycles) or 220 V (50 cycles) is used in food processing plants. The electrical motors are either single-phase or three-phase squirrel cage.

Energy-efficient electrical motors should be used in various food processing operations. A measure of the efficiency of electrical power is the power factor (pf), defined as k W/ k VA, this which should be equal or higher than 0.85.

Illuminating (lighting) of industrial food plants should utilize fluorescent lamps, which can save significant amounts of energy.

5.2.4 Plant Effluents

Plant effluents consisting mainly of wastewater, but including solids and gas wastes require special handling and treatments to comply with the local laws and regulations.

Food plants should be designed and operated so that a minimum pollution is caused to the environment. The Environmental Protection Agency (EPA) in the US has issued codes and regulations that ensure the quality of natural water bodies is not damaged by effluent discharges from industrial plants. Similar regulations apply to atmospheric emissions of objectionable gases and dust. Environmental information needed to comply with EPA regulations for wastewater includes testing for pH, temperature, biochemical oxygen demand (BOD), fats oil and grease (FOG), and total suspended solids (TSS).

Large amounts of waste are produced in the processing of fruits and vegetables, as in canning, freezing, and dehydration operations. Smaller waste volumes are produced in dairy plants (with the exception of cheese and milk powder), and in dry-processing (milling) of grain (e.g., wheat flour).

A medium size fruit or vegetable processing plant handling about 100 ton/day of raw materials may discharge about 1000 m3/day of waste water.

Treatment of food waste water may involve one or more of the following operations:

1. Simple screening out of the suspended solids,

2. Gravel filtration,

3. solids settling in sedimentation tanks,

4. biological oxidation (aeration),

5. spray irrigation,

6. discharge into the local public sewer, and

7. discharge into a waterway.

Liquid wastes (waste water) can be disposed to the local waste (sewage) treatment plants, after removing some objectionable components, such as fat, oil, and grease to an acceptable

level, e.g., lower than 1000 mg/L. Pollution loads higher than 200 mg/L are common in food plant liquid wastes. It is more economical to pay pollution surcharges to the local sewage plant, whenever possible, than to build an expensive wastewater treatment facility.

Food preservation plants, located away from municipal sewage systems, dispose the process water to large storage ponds (lagoons), where a slow natural bio-oxidation of the organic waste takes place. The treated lagoon wastewater can be discharged to the land adjoining the plants.

Some solid food wastes can be sold at relatively low prices for animal feeds, either unprocessed or dried, e.g., solid citrus or sugar beet wastes. Some solid food wastes can be diverted to the land (grape pomace to vineyard), while some other can be mixed with the soil (composting).

The sanitary sewage of food plants, depending on the number of employees, should be treated in a different system than the process wastewater. It can be discharged to the local sewage system, if available. Otherwise, it is treated in septic tanks constructed near the food plant.

Relatively small amounts of gas wastes (odorous VOC) are generated by some food industries, such as bakeries (ethanol), fishmeal dryers, and edible oil refining plants. Also, odors from coffee and cocoa roasting may require some form of treatment. Treatment of objectionable gas wastes involves gas absorption equipment, such as wet scrubbers.

The design of treatment facilities for industrial wastewater, and solids/gas wastes requires the expertise of environmental engineers who are familiar with the local laws and regulations concerning environmental pollution.

Lesson 6.Illumination and Ventilation

6.1 Illumination of the Processing Facility

Pride in the workplace is easier to maintain in a well-illuminated plant than in a dark and dull facility. Working in an environment that is perceived to be clean promotes neat and tidy work habits. Good illumination enhances the operation of a well-run plant and promotes efficiency and safe working conditions.

Good lighting is an easy goal to reach and a quick fix to eliminate dark corners and unsafe work areas. The range of lighting hardware makes it possible to have a well-lighted plant. Industry recognizes standards that should be met or exceeded.

When a lighting system is designed, the following points should be considered

- Distribution pattern of the light and suitability in the area involved
- Illumination output of the light hardware
- Possibility that larger lamps can be used in the same fitting when more light is required
- Design and construction of the lamp and its fitting
- Change in lamp efficiency over time and ease of periodic servicing, cleaning, and replacement
- System cost

Light is measured in luminous intensity as candela (cd) in SI units.

Table 1 Recommended Levels of Illumination

Offices	Illumination (candela)
Designing, detailed drafting	200
Bookkeeping, auditing, tabulating, rough drafting	150
Regular office work, filing, index references, mail sorting	100
Reading or transcribing handwriting in ink or medium pencil	70
Reading high-contrast or well-printed material	30
Corridors, elevators, stairways	20

6.1.2 Light intensity and application

In any work area, the light should be diffuse and uniformly constant. For the most efficient use of available light, the ceiling should have a minimum reflectance of 75% and the

sidewalls 50 to 60%. The floor should be 20% reflective. To prevent eyestrain, glare should be avoided. The amount of light reflected off any surface is affected by the smoothness of the surface. When the surface is rough, the reflection will be scattered, and the reflected light will diffuse. When the paint surface is smooth, irregularities in the painted surface can cause glare. The color of the paint will also affect the amount of light reflected.

Because walls are normally fairly smooth, color is the dominant factor in determining reflectance and illumination. Light colors reflect high proportions of light, while dark colors absorb a lot of light. Table 2 provides reflection values for different colors of paint. There is obvious variation between shades of the same color. Human perception of color is influenced by the color of the light that illuminates it. When the dominant color in an area is cream, ivory or tan, white fluorescent lighting will be best. If the dominant colors are blue or green, the blue- type fluorescent lights will work best.

Table 2 Light Reflection by Different Colors of Paint

Color	Reflection (%)	Color	Reflection (%)
White gloss	84	Light blue	54
Flat white	82	Medium green	52
White, eggshell	81	Maple wood finish	42
Ivory white	79	Medium blue	35
Silver gray	75	Dark gray	30
Yellow	75	Oak wood finish	17
Cream	74	Walnut wood finish	16
Pink	72	Dark red	13
Light buff	70	Mahogany wood finish	12
Ivory tan	67	Dark brown	10
Medium yellow	65	Dark blue	8
Light green	65	Dark green	7
Medium buff	65	Black	5
Medium gray	58		

6.1.3 Types of lamps

Many types of lamps are used in processing areas. In most cases, fluorescent lamps are favored because they have about 2.5 times the efficiency of incandescent lamps. They also give soft diffused light without glare. Fluorescent lamps are best suited in areas where the lamp stays on for long periods of time. In places where lamps are frequently switched on and off, fluorescent light should not be used. Frequent on and off service not only results in a short lifespan of the lighting element but places an extra load on the starting transformer. Fluorescent lamps can be used for about 2500 to 4000 h before they need to be replaced. Incandescent lamps must be replaced every 800 to 1000 h.

Most installations use fluorescent lighting in all areas possible. In some high moisture areas, including cold rooms and where explosive vapors may be present, incandescent light fittings with vapor-proof fixtures are required. In the cereal industry, cereal dust can be very explosive when mixed with the right amount of air. In these cases, light bulbs and all fittings are completely enclosed and water tight.

At loading docks, large warehouses and outside areas, where extensive coverage is required, mercury vapor lamps are used. Mercury vapor lamps are several times more efficient than fluorescent lighting.

Incandescent lamps radiate more long-wave radiation in the yellow and red ranges, while fluorescent lighting is bluer. Incandescent lamps produce light and heat. This is an obvious drawback in cold storage areas. If fluorescent lighting is used in cold rooms, the tubes must be rated to operate at temperatures below 5°C.

The installation cost for fluorescent lighting is considerably greater than the cost for incandescent lighting. The energy savings will pay for this additional expense over time. All light bulbs should be replaced at regular intervals. Replacing them only if they are broken means that there will be one or two lights out at any given time. Lights have an average lifespan and should be replaced before they break.

6.2 Ventilation of the Processing Facility

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.

Module- 4. Food plant layout Introduction, Planning and Experimentation

Lesson 7. Plant Layout

7.1 Importance and function

Plant layout refers to an optimum arrangement of different facilities including human resource, plant and machinery, material etc. Since a layout once implemented cannot be easily changed and costs of such a change are substantial, the plant layout is a strategic decision. A poor layout will result in continuous losses in terms of higher efforts for material handling, more waste and rework, poor space utilization etc. Hence, need to analyze and design a sound plant layout can hardly be over emphasized. It is a crucial function that has to be performed both at the time of initial design of any facility, and during its growth, development and diversification.

The problem of plant layout should be seen in relation to overall plant design which includes many other functions such as product design, sales planning, selection of the production process, plant size, plant location, building, diversification etc. The layout problem occurs because of many developments including:

- change in product design
- introduction of new product
- obsolescence of facilities
- changes in demand
- market changes
- competitive cost reduction
- frequent accidents
- adoption of new safety standards
- decision to build a new plant

Plant layout problem is defined by Moore (1962) as follows: "plant layout is a plan of, or the act of planning, an optimum arrangement of facilities, including personnel, operating equipment storage space, materials handling equipment, and all other supporting services, along with the design of the best structure to contain these facilities".

7.2 Objectives and advantages

Some of the important objectives of a good plant layout are as follows:

- Overall simplification of production process in terms of equipment utilization, minimization of delays, reducing manufacturing time, and better provisions for maintenance
- Overall integration of man, materials, machinery, supporting activities and any other considerations in a way that result in the best compromise.
- Minimization of material handling cost by suitably placing the facilities in the best flow sequence
- Saving in floor space, effective space utilization and less congestion / confusion,
- Increased output and reduced in-process inventories
- Better supervision and control
- Worker convenience and worker satisfaction
- Better working environment, safety of employees and reduced hazards
- minimization of waste and higher productivity
- avoid unnecessary capital investment
- higher flexibility and adaptability to changing conditions

7.3 Types of layout problems/situations

The plant layout problems can be classified into four types as follows:

- Planning completely new facility
- Expanding or relocating an existing facility
- Rearrangement of existing layout
- Minor modifications in present layout

7.4 Flow patterns

According to the principle of flow, the layout plan arranges the work area for each operation or process so as to have an overall smooth flow through the production / service facility. The basic types of flow patterns that are employed in designing the layout are I-flow, L-flow, U- flow, S-flow and O - flow as shown in Figure 1. These are briefly explained below:

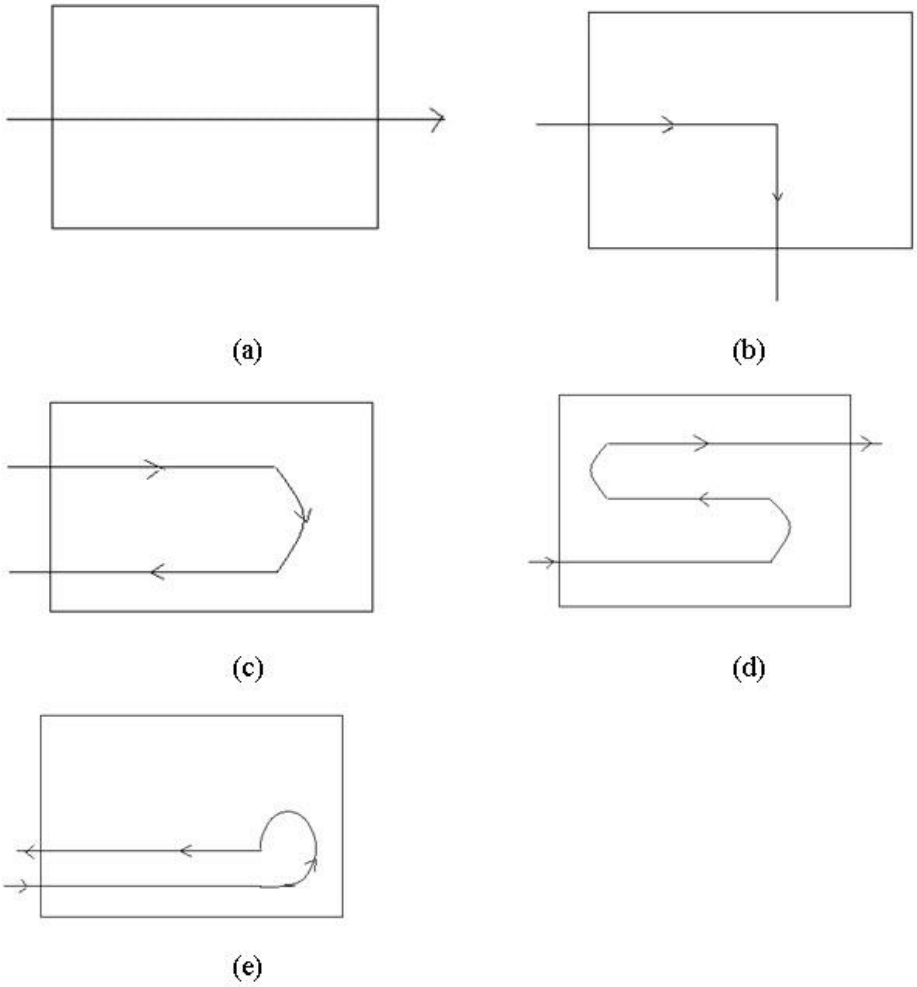


Figure-1 Basic types of flow patterns employed in designing the layout

(a) I-Flow: separate receiving and shipping area.

(b) L-Flow: when straight line flow chart is to be accommodated.

(c) U-Flow: very popular as a combination of receiving and dispatch

(d) S-Flow: when the production line is long and zigzagging on the production floor is required.

(e) O-Flow when it is desired to terminate the flow near where it is originated

7.5 Basic types of layouts

Depending upon the focus of layout design, the basic types of the layouts are:

1. Product or line layout
2. Process or functional layout
3. Cellular or group layout
4. 'Fixed Position' Layout

7.5.1 Product or line layout

This type of layout is developed for product focused systems. In this type of layout only one product, or one type of product, is produced in a given area. The work centres are organized in the sequence of appearance. The raw material enters at one end of the line and goes from one operation to another rapidly with minimum of work-in-process storage and material handling. The equipment is arranged in order of their appearance in the production process.

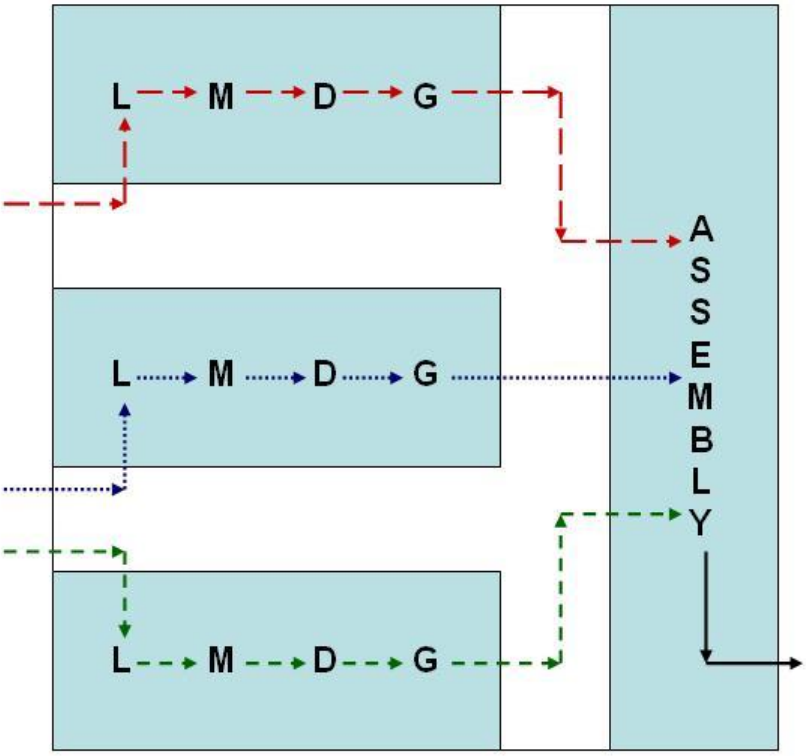


Figure 7.1 Product or Line Layout _module_4_lesson_7

The decision to organize the facilities on a product or line basis is dependent upon a number of factors and has many consequences which should be carefully weighed. Following conditions favor decision to go for a product- focused layout.

- High volume of production for adequate equipment utilization
- Standardization of product
- Reasonably stable product
- demand Uninterrupted supply of material

Some of the major advantages of this type of layout are:

- Reduction in material handing
- Less work-in-process
- Better utilization and specialization of labor
- Reduced congestion and smooth flow
- Effective supervision and control

The major problem in designing the, product-focused systems is to decide the cycle time and the sub-division of work which is properly balanced (popularly known as line balancing)

7.5.2 Process or functional layout

This type of layout is developed for process focused systems. The processing units are organized by functions into departments on the assumption that certain skills and facilities are available in each department. Similar equipment and operations are grouped together. The functional layout is more suited for low-volumes of production (batch production) and particularly when the product is not standardized. It is economical when flexibility (material can be rerouted in any sequence) is the basic system requirement. The flexibility may be in terms of the routes through the system, volume of each product and the processing requirement of the items.

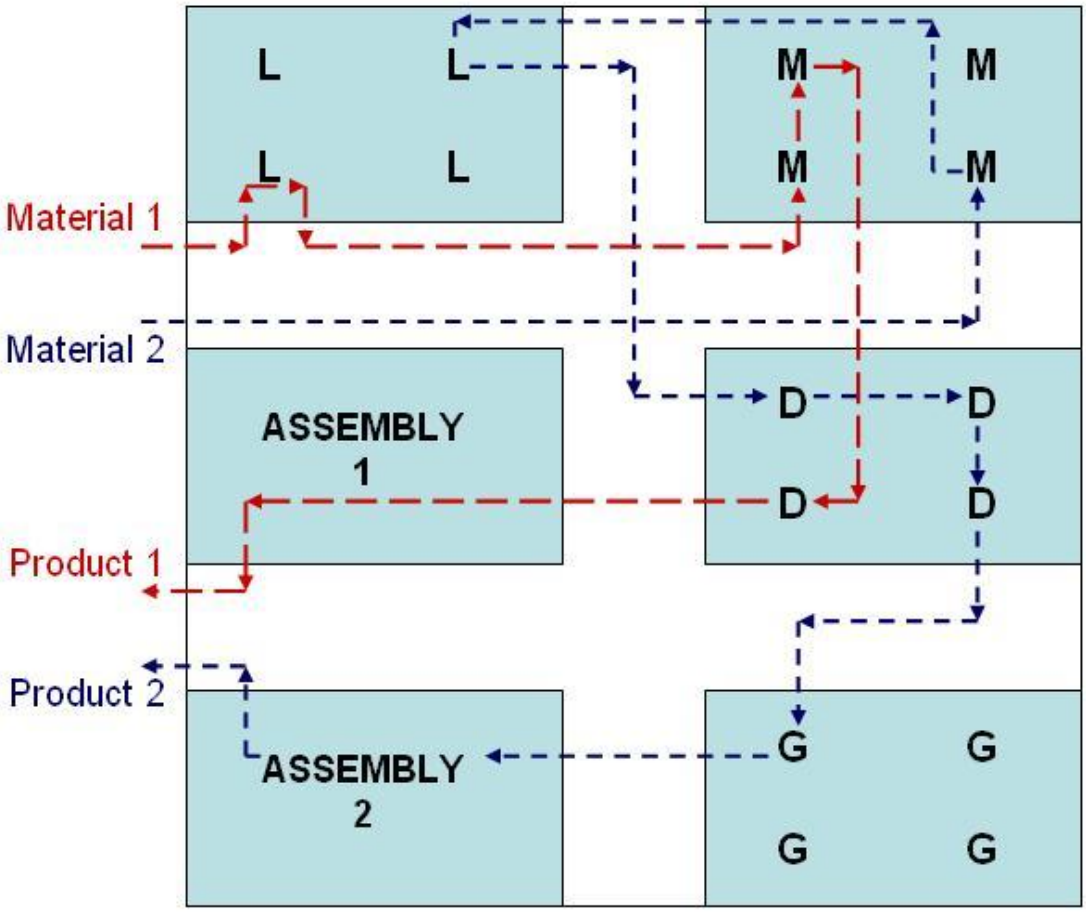


Figure 7.2 Process or Functional Layout

The major advantages of a process layout are:

- Better equipment utilization
- Higher flexibility
- Greater incentive to individual worker
- More continuity of production in unforeseen conditions like breakdown, shortages, absenteeism etc.

7.5.3 Cellular or group layout

It is a special type of functional layout in which the facilities are clubbed together into cells. This is suitable for systems designed to use the concepts, principles and approach of group technology. Such a layout offers the advantages of mass production with high degree of flexibility. We can employ high degree of automation even if the number of products is more with flexible requirements. In such a system the facilities are grouped into cells which are able to perform similar type of function for a group of products.

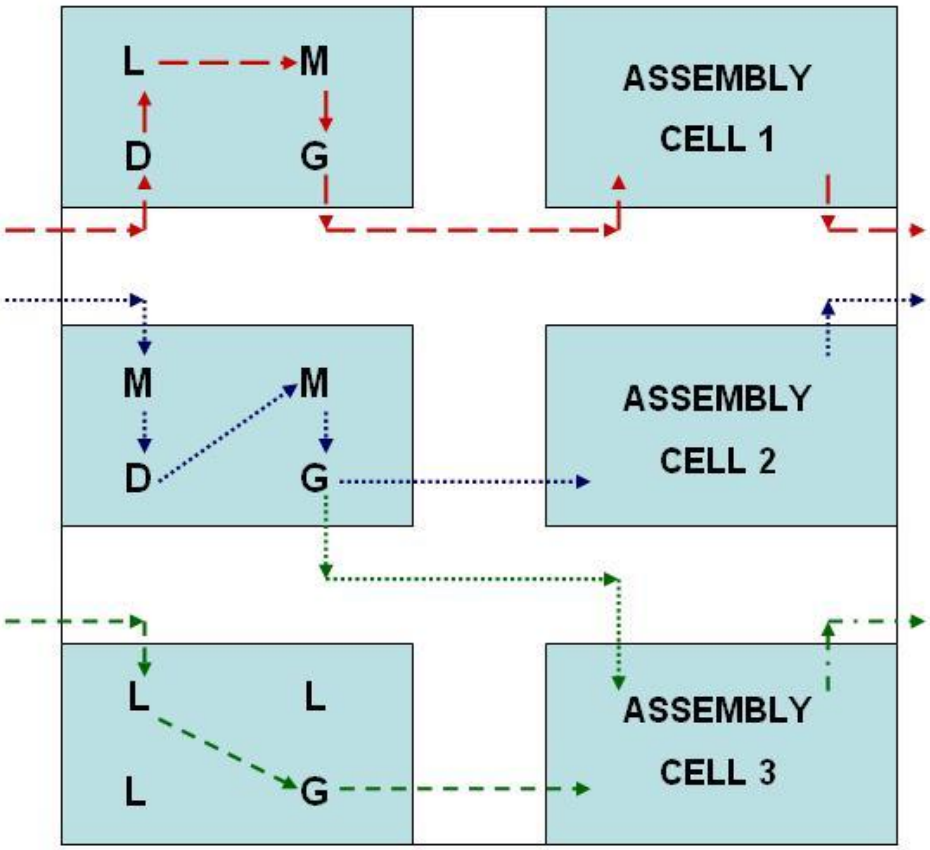


Figure 7.3 Cellular or Group Layout

Advantages :

- Also known as 'Group Technology'
- Each cell manufactures products belonging to a single family.
- Cells are autonomous manufacturing units which can produce finished parts.
- Commonly applied to machined parts.
- Often single operators supervising CNC machines in a cell, with robots for materials handling.
- Productivity and quality maximised. Throughput times and work in progress kept to a minimum.
- Flexible.
- Suited to products in batches and where design changes often occur.

7.5.4 'Fixed Position' Layout

This is suitable for producing single, large, high cost components or products. Here the product is static. Labour, tools and equipment come to the work site.

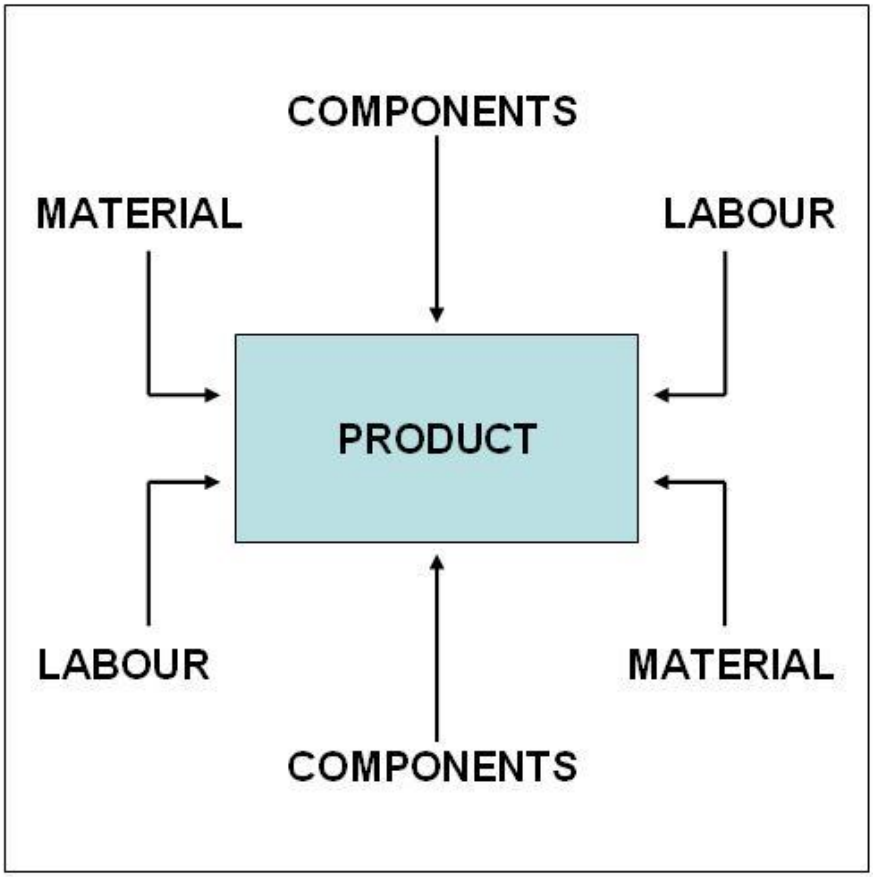


Figure 7.4 Fixed Position Layout

Lesson 8. Layout Design Procedure

The design of any layout is governed by a number of factors and the best layout is the one that optimizes all the factors. The factors influencing any layout are categorized into the following eight groups:

- **The material factor:** includes design, variety, quantity, the necessary operations, and their sequence.
- **The main factor:** includes direct workers, supervision and service help, safety and manpower utilization.
- **The machinery factor:** includes the process, producing equipment and tools and their utilization
- **The movement factor:** includes inter and intradepartmental transport and handling at the various operations, storage and inspection, the materials handling equipment.
- **The waiting factor:** includes permanent and temporary storage and delays and their locations.
- **The service factors**: include service relating to employee facilities such as parking lot, locker rooms, toilets, waiting rooms etc.; service relating to materials in terms of quality, production control, scheduling, dispatching, waste control; and service relating to machinery such as maintenance.
- **The building factor**: includes outside and inside building features and utility distribution and equipment.
- **The change factor:** includes versatility, flexibility and expansion

Each of the above mentioned factors comprise a number of features and the layout engineer must review these in the light of his problem. Usually the layout design process is a compromise of these various considerations to meet the overall objectives in the best possible manner.

The overall layout design procedure can be considered to be composed of four phases Viz.,

Phase I: Location

Phase II: General Overall Layout

Phase III: Detailed layout

Phase IV: Installation

Some important guidelines that help in the layout design are:

- Plan from whole to details

- First plan the ideal and then move to the practical aspects
- Material requirements should be central to the planning of process and machinery.
- modify the process and machinery by different factors to plan the layout
- Though there is always an overlap in the different phases of layout design the major steps that have to be followed in the layout design are outlined as follows:
- state the problem in terms of its objective, scope and factors to be considered
- Collect basic data on sales forecasts, production volumes, production schedules, part lists, operations to be performed, work measurement, existing layouts, building drawing etc.
- Analyze data and present it in the form of various charts
- Plan the production process and its arrangement
- Plan the material flow pattern and develop the overall material-handling plan
- Estimate plant and machinery requirements Select material handling equipment
- Determine storage requirements
- Design and plan activity relationships
- Plan auxiliary and service facilities including their arrangement
- Determine space requirements and allocate activity areas
- Develop plot plan and block plan i.e. integrate all plant operations
- Develop detailed layouts and plan building along with its arrangement
- Evaluate, modify and check the layouts
- Install layouts and follow up

The Systematic Layout Planning (SLP) procedure as presented by Francis and White (1974) is shown in Figure 8.1. We see that once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram. Space considerations when combined with the relationship diagram lead to the construction of the space relationship diagram. Based on the space relationship diagram modifying considerations and practical limitations, a number of alternative layouts are designed and evaluated.

8.1 Data collection

The development of any layout is dependent on the quality and quantity of facts that we have about the various factors influencing it. The data collection phase is not a one-time effort but an ongoing function. The data for overall plan is to be collected at initial stages where as the data for detailed layouts may be obtained at a later stage, the facts have to be obtained regarding various materials and processes, the flow routing and sequencing, space requirements and different activities and relationships.

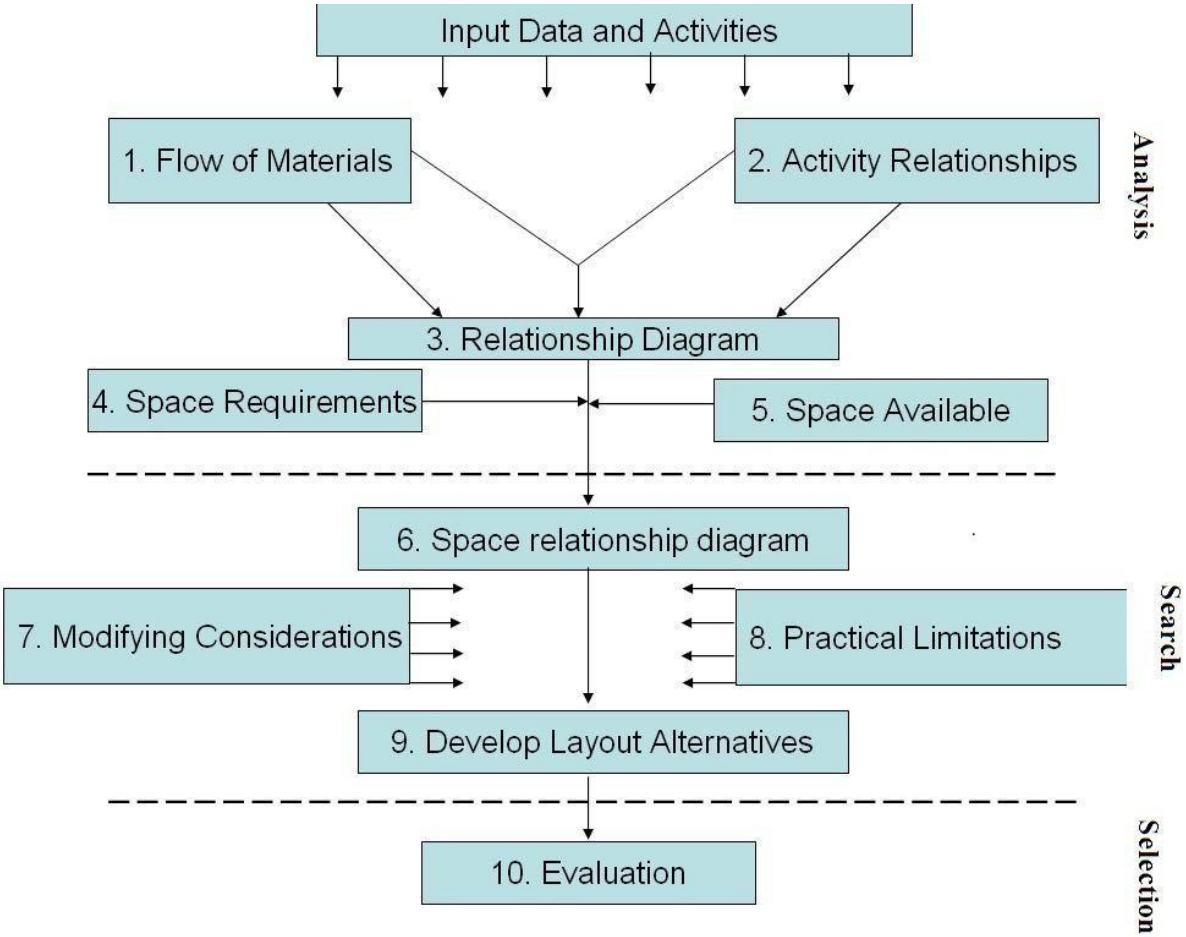


Figure 8.1 Systematic layout planning procedure

8.2 General guidelines / considerations

8.2.1 Site layout:

A good site layout provides safe and economical flow of materials and personnel. A material sheet for the site is therefore prepared which then allows the various processes to be positioned relative to one another. The services (e.g. boiler house, effluent plant etc.) are then added in the most convenient positions. The central buildings (administration, canteen, laboratories etc.) are placed in such a manner that the distances traveled by personnel to use them are minimized. Finally the road and rail systems are marked in. Typical sizes and clearances for the site layout are given in Tables 8.1 to 8.3. Having established site constraints and standards, a more detailed site layout can be made. The site layout thus prepared should then be considered to see whether the layout is consistent with safety requirements and that it assists action in any emergency as also the constraints and standards have not been violated.

Broad guidelines for preparation of the site layout are given below:

- Minimize the distance that materials have to travel to or from stores or during processing
- Separate the raw material unloading and finished product loading facilities
- Isolate the hazardous operations
- Locate storage areas close to unloading and loading facilities

- locate boiler room, power station, cooling towers, water pumping station etc. on periphery but adjacent to the area of largest use
- The usual clearances between pipes including flanges and lagging and between pipes and other objects should be 25 mm but this should be increased if hot pipes run near plastic pipes, cables etc.
- Steam and water mains, electricity and telephone cables etc. should, in general, run parallel to the road system and should avoid going through plant area
- Locate office building close to the main entrance
- Provide adequate parking facilities for vehicles waiting to load / unload, cars, scooters etc.
- Plan roads in such a manner that the vehicles do not pass through process areas. Ideally, outside of a plant should be accessible on all four sides by road
- Workshop and general stores should be located within easy access of the processing units.

Table 8.1 Typical clearances between various units for preliminary site layouts

Area	To	Clearance, m
Plant areas	To the adjacent unit, main roads or boundary	15
Boilers and furnaces		15
Blow down stacks with flares		30
Gas holders		30
Cooling towers		30
Effluent plants		15
Loading areas	To process units	15
Ware houses		30
Offices and canteens		30
Medical center		30
Garage		30
Fire station		30
Work shops		30
Main roads		12

Main roads	To building line excluding loading bays	9
		15
		15
Roads	Center line to loading bay head room	7
Paved areas and paths		4
Rail roads		5

Table 8.2 Typical areas and sizes for preliminary site layouts

Administration	10 m2	per administration employee.
Work shop	20 m2	per workshop employee
Laboratory	20 m2	per laboratory employee
Canteen	1 m2	per dining place
	3.5 m2	per dining place including kitchen and store
Medical center	0.1 - 0.15 m2 10 m2 minimum	per employee depending on complexity of service
Fire station (housing 1 fire, 1 crash, 1 foam, 1 generator and 1 security ,vehicle)	500 m2	per site
Garage (including maintenance)	100 m2	per vehicle
Main roads	10 m	wide
Side roads	7.5 m	wide
Pathways	1.2 m	wide upto 10 people /minute
	2 m	wide for 10 people / minute (near offices, canteen etc.)
Road turning circles	900 turn	11 m radius
	T junction	7.5 m radius
	minor roads	4 m radius

Minimum railroad curve	56 m	inside curve radius
Cooling towers per tower	0.04 m2/ kWh	mechanical draught
	0·08 m2 / kWh	natural draught

Table 8.3 Typical constraint allowances for preliminary plant layout

Equipment	**Safety**	**Horizontal**	**Vertical**	**Construction/ Erection/ General**
Centrifuges Crushers Mills		3 m	2 m + L	5 m access corridor
Dryers		1.5 m + L	2 m + L	2.5 m to building
Columns		1.5 m		3 m between adjacent columns
Furnaces and fired heaters	15 m to hazard	3 m		2 widths (center to center adjacent heaters)
Reactors Stirred vessels	15 m to hazard	1.5 m	3 m + L	4 m access area 40 m2for each 30 cm3 reactor volume
Heat exchanger (horizontal)		1.5 m +I channel 1.5-2 m shell side	1.5 m	
Tanks	15 m to hazard	1/2 dia (avg.) between tanks	3 m	
Pumps		2 m motor end 1.5 m sides		
Filters		1.5 m + L		
Compressors		1.5 m + L	3 m + L	2 widths (center to center adjacent compressors)

L: is the length of the longest internal part of the equipment that must be removed for maintenance or operation.

8.2.2 Plant layout

In general, a most economical plant layout is that in which spacing of the main equipment items is such that it minimizes the interconnecting pipe work and structural steel work. As a general rule, layout should be as compact as possible with all equipment at ground level and it should conform to access and safety requirements. The major considerations are listed below:

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.

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.

8.2.3 Layout of equipment

Thought should be given to the location of equipment requiring frequent attendance by operating personnel and the relative position the control room to obtain the shortest and most direct routes for operators when on route operation. However, the control room should be in a safe area. Some important considerations 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.

8.2.4 Space determination

In the layout planning process the space is allotted to different activities.

The theoretical minimum space, a plant can occupy, is the total volume of its various components. Various constraints prevent the attainment of this minimum. Such constraints include allowing adequate clearances for access during operation and maintenance and to allow safe operation. While determining the space consideration should be given to the following.

- Operating equipment
- Storage
- Service facilities
- Operators/workers

Allowance must be made for space between adjacent equipment/machines for movement of the worker, work-in-process, maintenance personnel etc.

Lesson 9. Experimentation in Pilot Plant

The pilot plant is a physical model and should be a "copy" of the corresponding industrial unit, with equipment scaled down in size to approximately 1/100 – 1/10 of the modelled unit.

Pilot plant experiments serve to obtain more information and data in the following areas:

1. Market survey: A determined new product amount can be produced in the pilot plant, to test its acceptance and to decide whether it would be economically profitable.

2. Design data: The behaviour of a given operation or unit process can be found under conditions impossible to duplicate in the laboratory.

3. Products and raw materials: A pilot plant is usually needed to characterize food products and to evaluate the development of certain raw materials into specific products.

4. Optimization data of a running plant.

9.1 Size and structure of the pilot plant

The most important criterion in determining the size and form of a pilot plant is the principle of similarity, a principle first formulated by Newton.

If, fluids are handled in the pilot plant, three types of similarities involved in fluid dynamics must be included:

1. Geometric similarity: Both the pilot plant and food processing plant should have the same physical form or at least the same geometric dimension relationships.

2. Kinematic similarity: The same velocity relationships should exist in both the pilot and food processing plants.

3. Dynamic similarity: In both the pilot and food processing plants, the same force relationships should exist. For example, the turbulence regime should be similar on both scales when fluids are handled.

If the process simulated in a pilot plant involves chemical the following similarities apply:

1. Thermal similarity.

2. Chemical and biochemical similarity.

9.1.1 Minimum and Maximum Size

Several factors can affect the size of a pilot plant. In general, the minimum size is set by the minimum product amount required for quality analytical control.

The maximum size of the pilot plant is set by the amount of processed product needed in order to test market acceptance.

9.2 Types and application

When product production in amounts large enough to conduct market acceptance tests is required, the pilot plant is called a semi-commercial plant.

The most common applications of a pilot plant are as follows:

1. Product studies

- Quality characterization
- Influence of process conditions on product quality
- Development of new products
- Studies of market acceptance
- Raw material characterization
- Evaluation of aptitude for industrialization of different raw materials
- Setting the most suitable process conditions from an economic point of view (cost minimization) and a product quality point of view (to obtain a product of given quality). Process technology is optimized.
- Study of process equipment alternatives to carry out given food processing steps or unit operations.
- Development of new process technology.
- Development of new process engineering or process equipment.
- Reliable evaluation of mass and energy balances and food physical properties
- Study of energy recovery possibilities in process systems

2. Raw material studies

3. Process technology and engineering studies

4. Auxiliary system requirement studies

Improvement and evaluation of alternatives for control systems

Module- 5. Symbols used for food plant design and layout

Lesson 10. Symbols used for food plant design and layout

Process diagrams can be broken down into two major categories: process flow diagrams (PFDs) and process and instrument drawings (P&IDs), sometimes called piping and instrumentation drawings. A flow diagram is a simple illustration that uses process symbols to describe the primary flow path through a unit. A process flow diagram provides a quick snapshot of the operating unit. A flow diagram should include all primary equipments and flows.

A technician can use process design document to trace the primary flow of food materials through the unit. The flow diagram is used for visitor information and new employee training. A process and instrument drawing is more complex. The P&ID includes a graphic representation of the equipment, piping, and instrumentation. Modern process control can be clearly inserted into the drawing to provide a process technician with a complete picture of electronic and instrument systems. Process operators can look at their process and see how the engineering department has automated the unit. Pressure, temperature, flow, and level control loops are all included on the unit P&ID. Process technicians use P&IDs to identify all of the equipment, instruments, and piping found in their units.

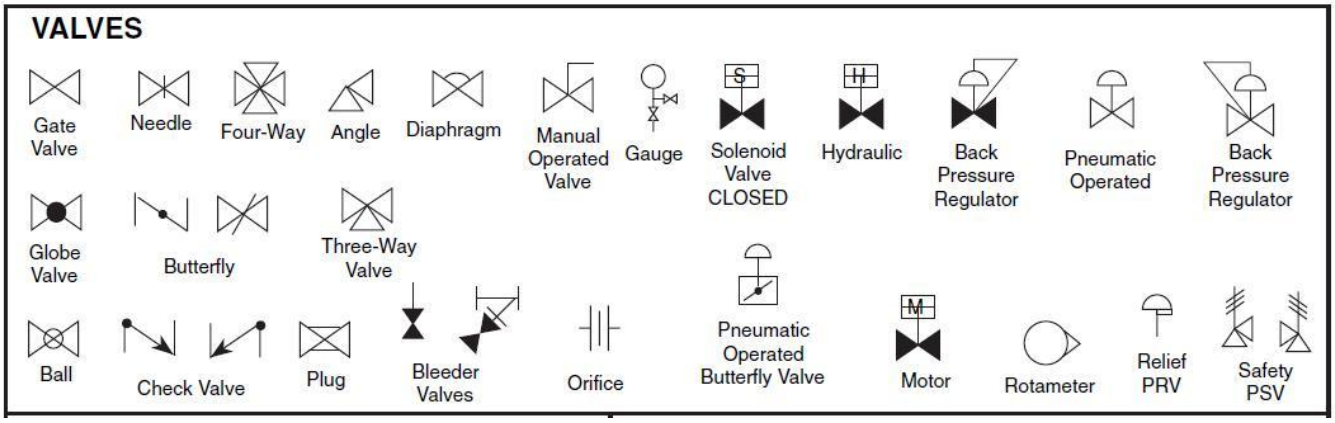


Fig. 10.1 Symbols used to represent different valves

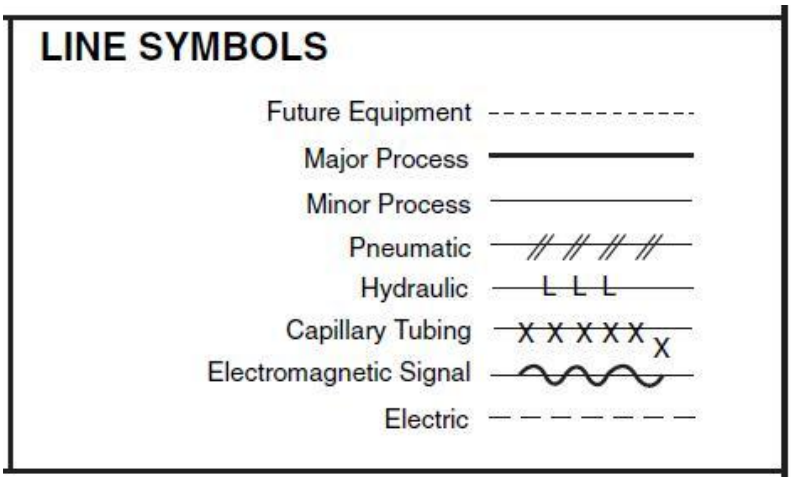


Fig. 10.2 Line symbols used to present diff purpose

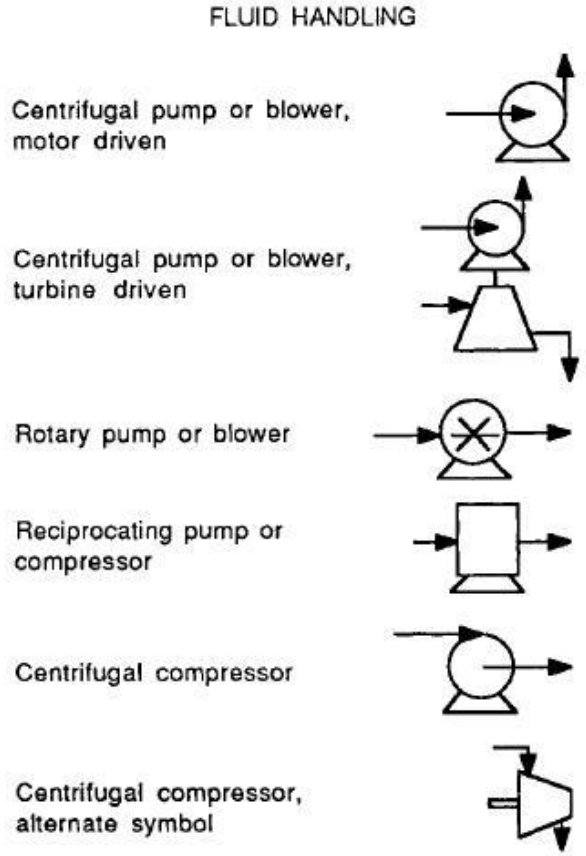
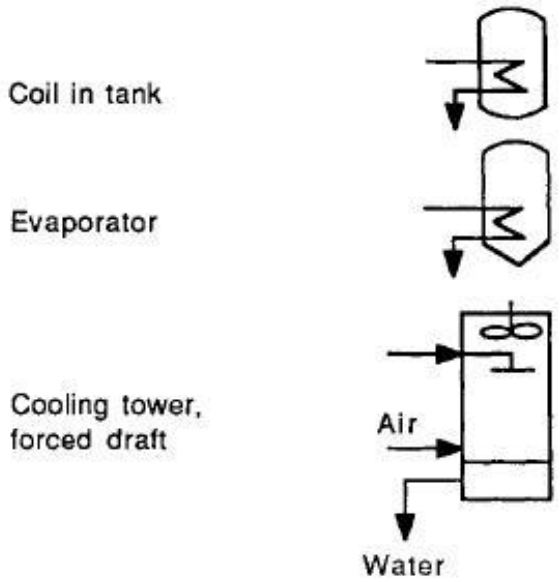


Fig. 10.3 sybols for different fluid handling equipment



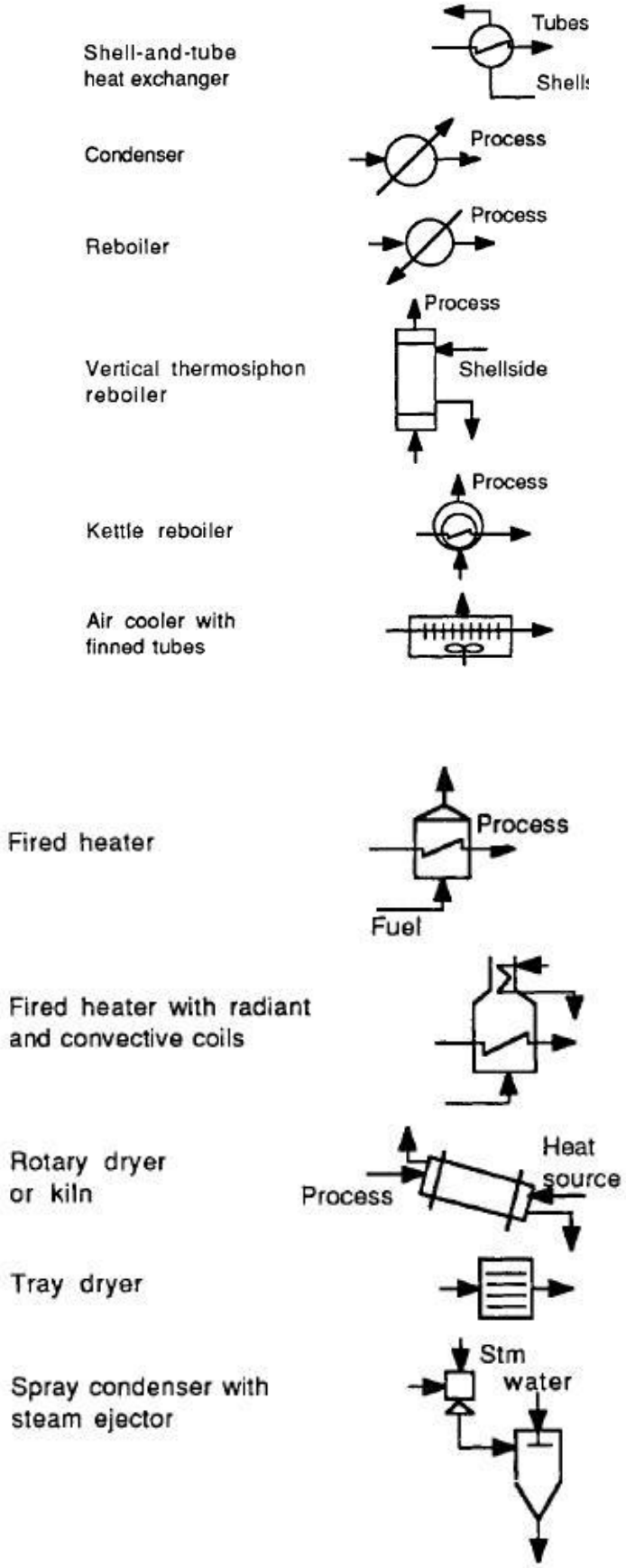


Fig. 10.4 Symbols for different heat transfer processes

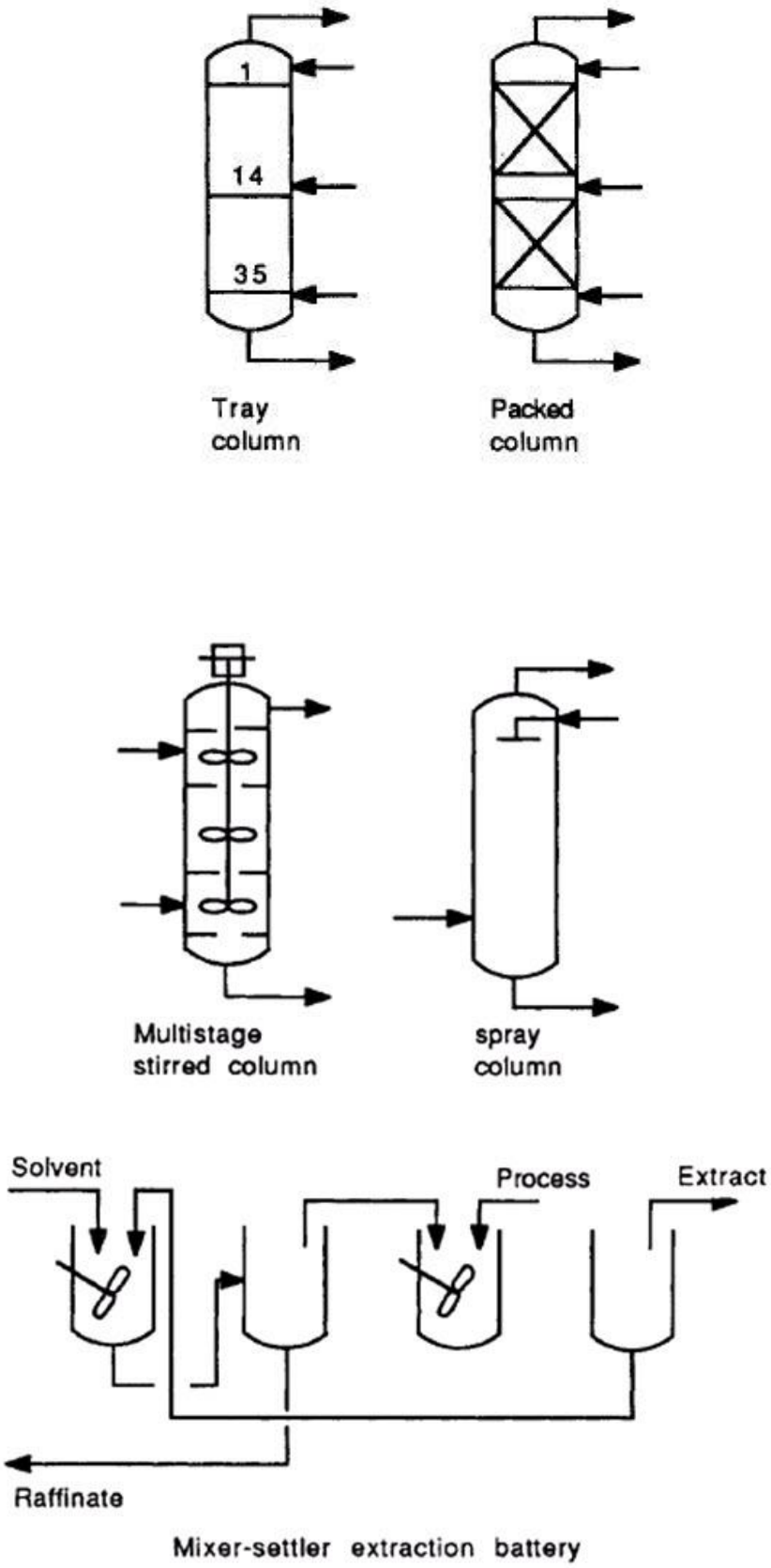


Fig. 10.5 Symbols for different mass transfer processes

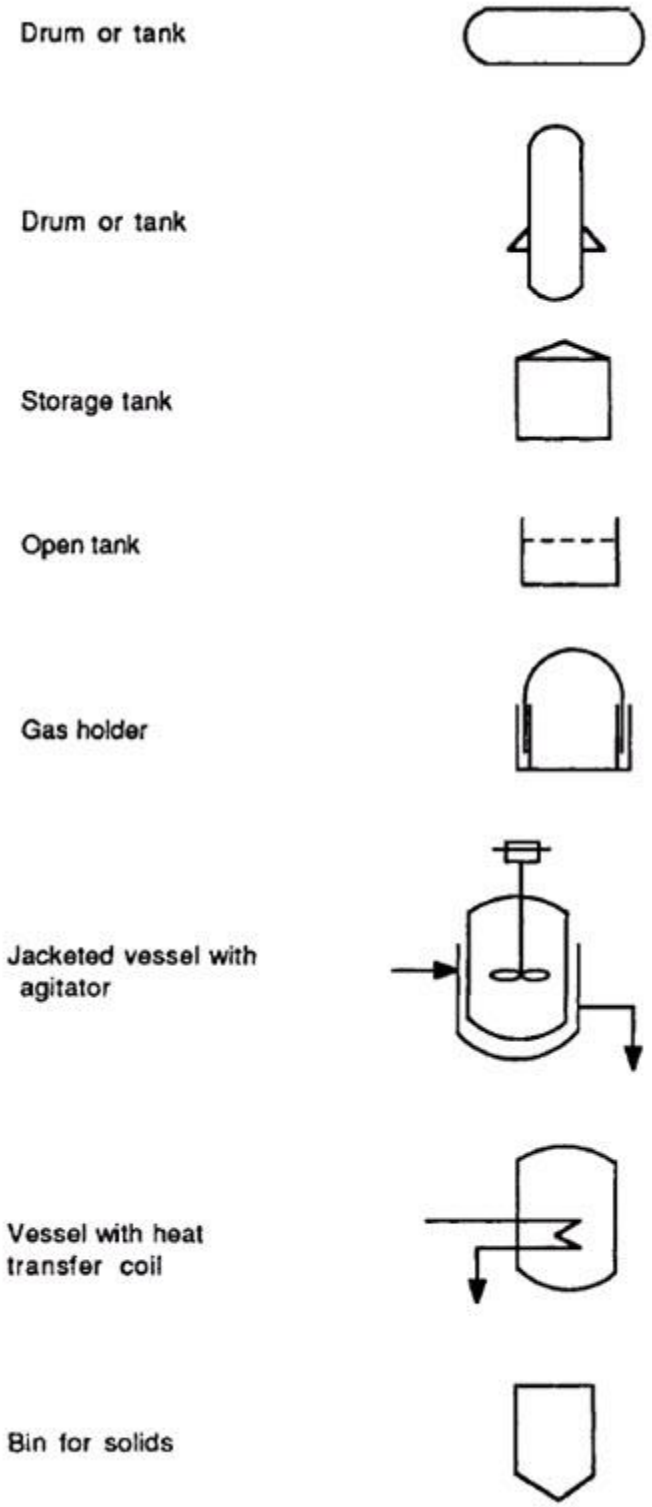


Fig. 10.6 Symbols for storage vessels

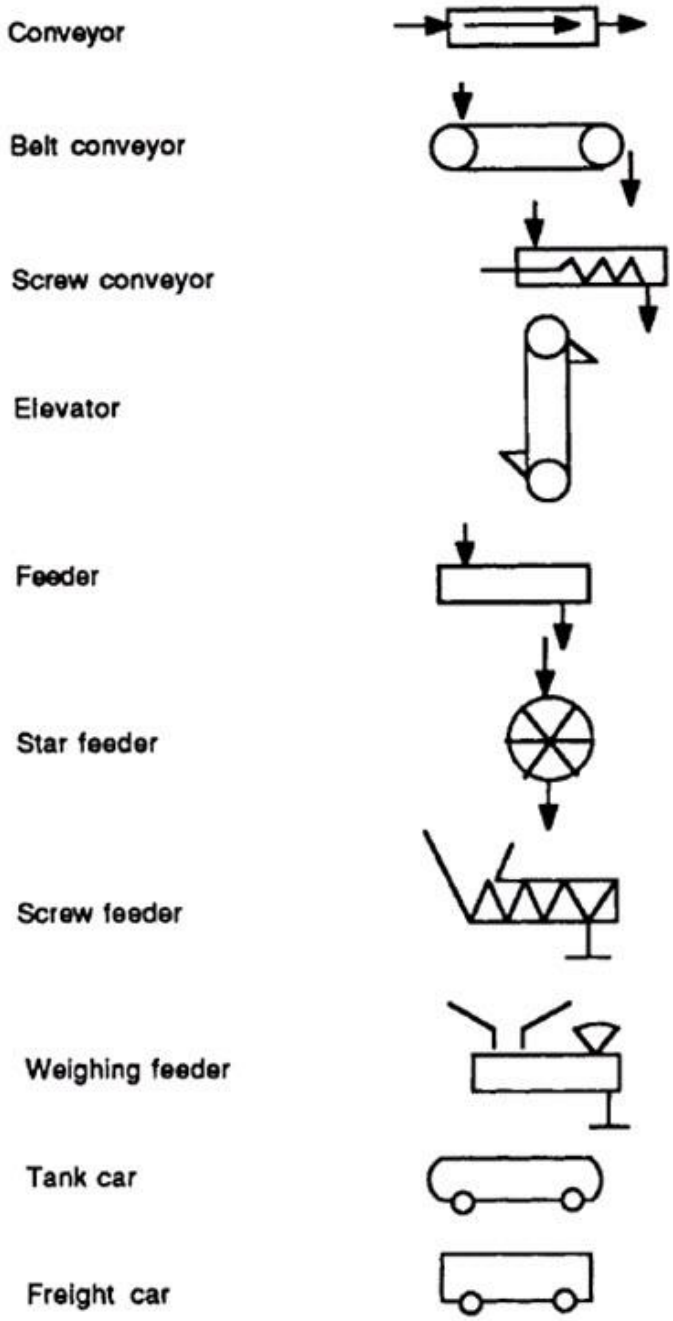
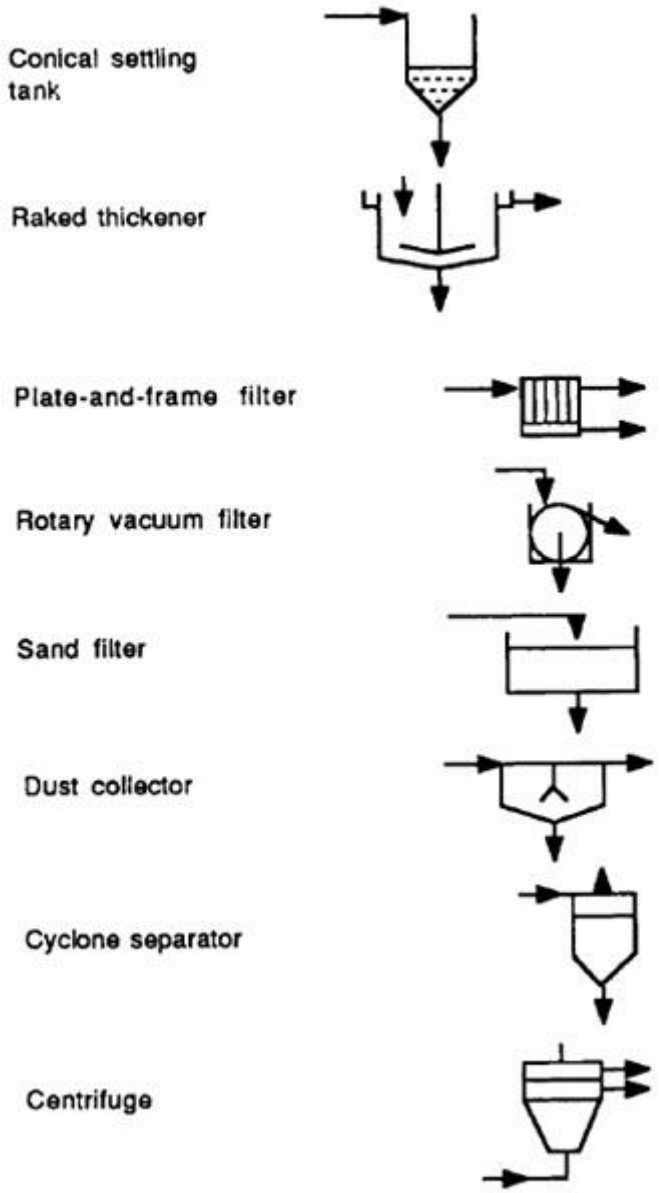


Fig. 10.7 Symbols for different conveyors and Feeders



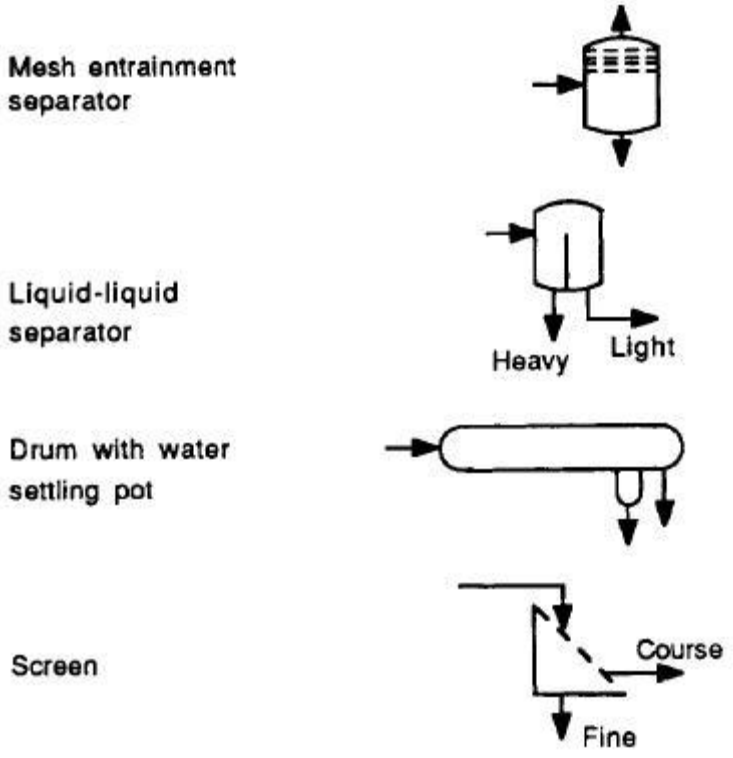


Fig. 10.8 Symbols for different separators

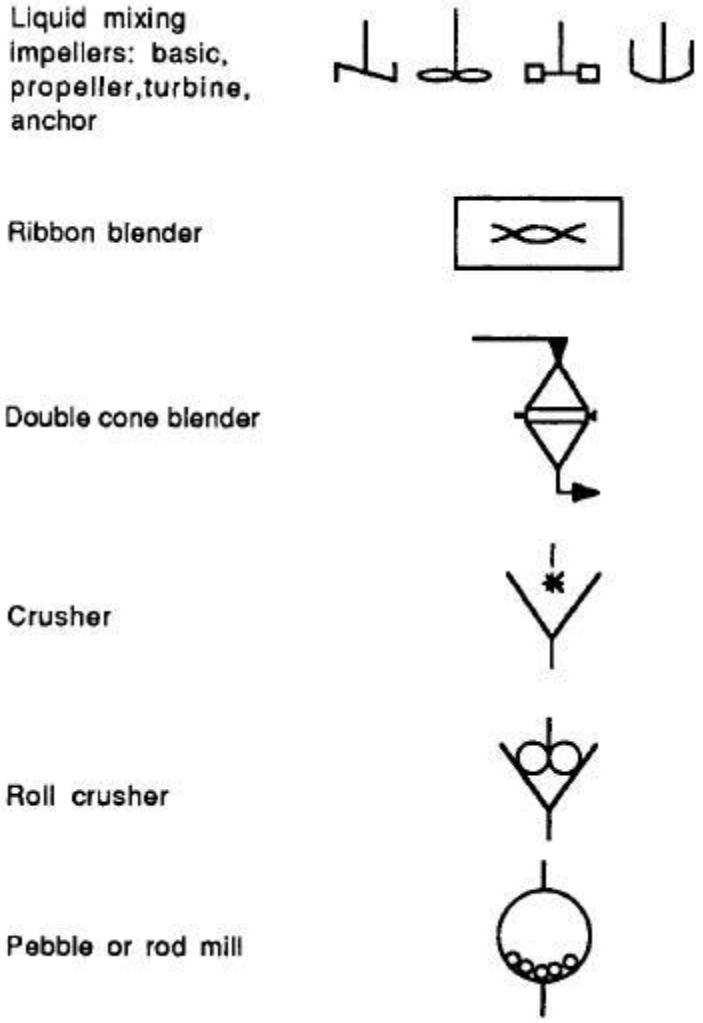


Fig. 10.9 Symbols for mixing and communition

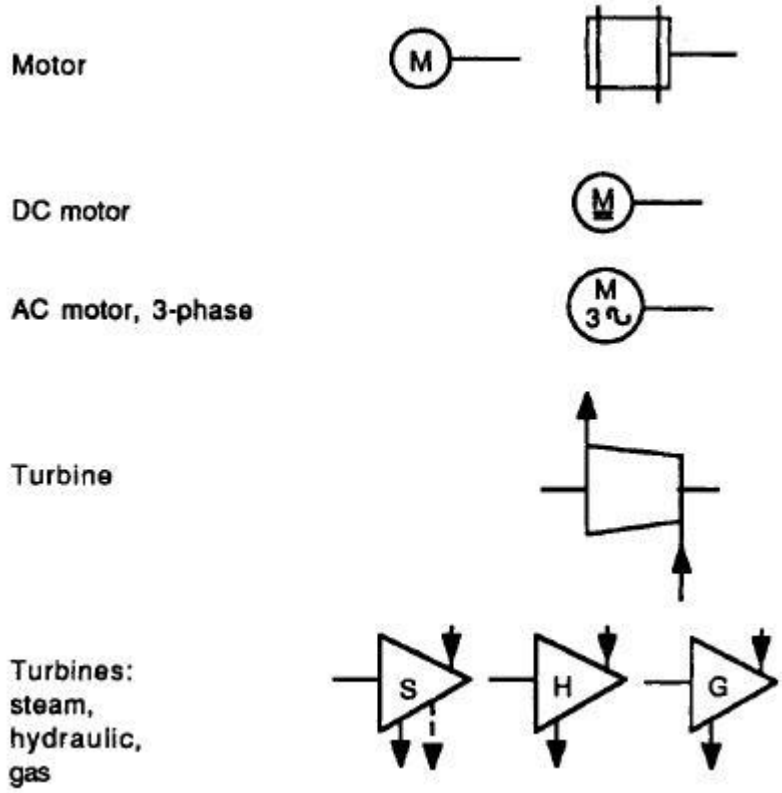
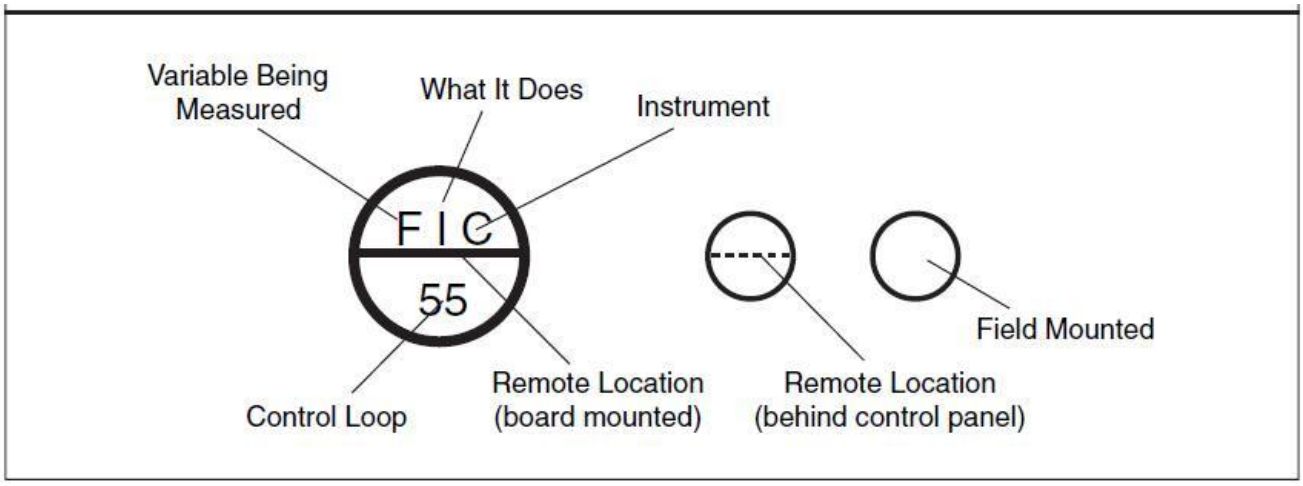


Fig. 10.10 Symbols for different drivers



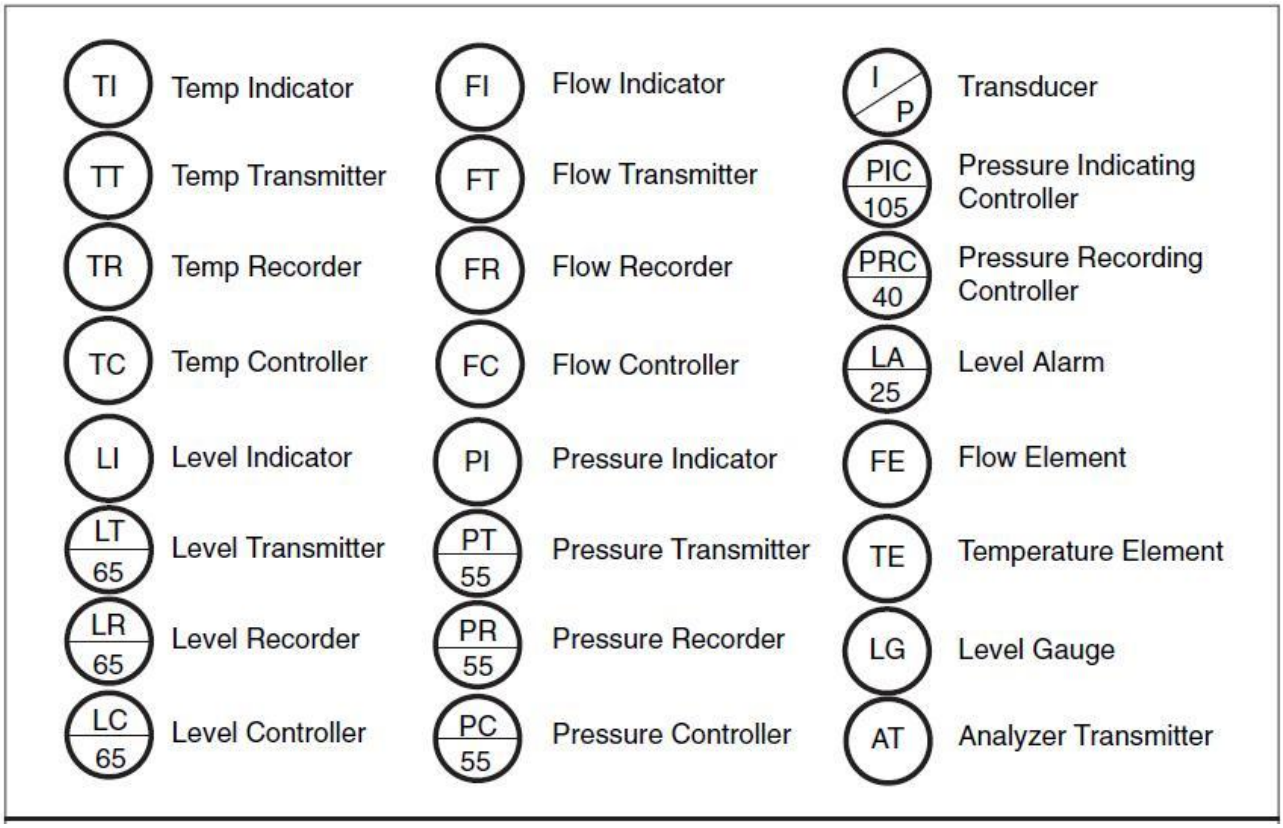


Fig. 10.11 Process control and Instrumentation Symbols

Lesson 11. Food processing enterprise

11.1 Introduction

Imagine a food processing enterprise that competes with several others. The enterprise produces a single product, has some control over the price it will charge and is primarily devoted to making a profit. Imagine further that the major characteristics of the market, the competitors, and enterprises own internal technology are well known to management and essentially static in time. Under these conditions one may explore some of the major economic decisions that might be made. One may start with the environment in which the enterprise exists and work inward, eventually reaching the level of decisions at which the analyst often works.

In studying the enterprise's environment one might wish to study in detail the customers, competitors, suppliers, and the legal, political, social and geographic factors which bear upon its operations. To avoid some of the chaos this might involve, it is assumed that all these things can be expressed by the demand curve of the enterprise. The demand curve expresses a part of the relationship of the enterprise with its market by simply giving the amount of product that can be sold as a function of the price charged for it. In this simple model, price is taken to be the major determining factor in the amount the enterprise can sell; and such obvious other factors as quality, advertising, sales effort, reputation, and service are left out of the picture. Thus the relationship between the price and the amount of product that can be sold is given by:

$P = a - b\,D$ for $0 \le D \le a/b$

$= 0$ otherwise

Here P is the unit price, D is the amount of product sold, and a and b are positive constants. It is assumed that the amount of product, D, is a continuous variable. The straight-line example, which has been given, might have been a curve; but the point is that one usually expects large volume to be associated with low price, and small volume to be associated with high price (Figure 1).

The analyst who knows the demand curve may then decide what price one will charge, and the curve will tell how much one can sell; or, one may decide what volume to produce and the curve will indicate the highest price at which one will be able to dispose of the production. Ultimately one will make the choice so as to maximize profit, and profit may be defined simply as the difference between total revenue or gross sales (TR) and total cost (TC),

Profit = TR - TC

The total revenue resulting from any price-volume choice may be computed directly from the demand curve.

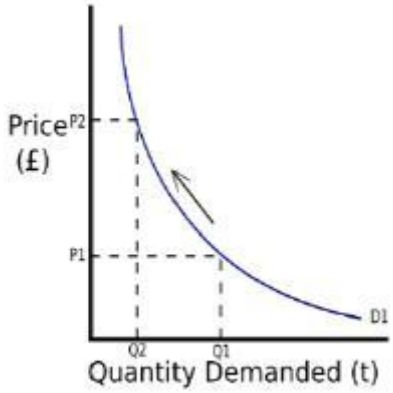


Fig 11.1 A Demand Curve

11.2 Total revenue function

Total revenue of the enterprise is simply the amount of product sold multiplied by the unit price charged. Therefore,

Total Revenue (TR) = (unit price) (volume) = PD

Where,

P = unit price, = (a – b D)

D = amount of product sold, (Volume)

Using the demand function, total revenue can be expressed in terms of D alone,

TR = (a – b D) D = a D - b D2 for $0 \leq D \leq a/b$

= 0 otherwise

Now if one were dealing with a peculiar enterprise, which has no costs at all, or has only costs independent of the volume of production, then maximizing profit would be achieved by maximizing total revenue. The volume that will maximize total revenue can be found by the usual methods of calculus (Fig 11.2).

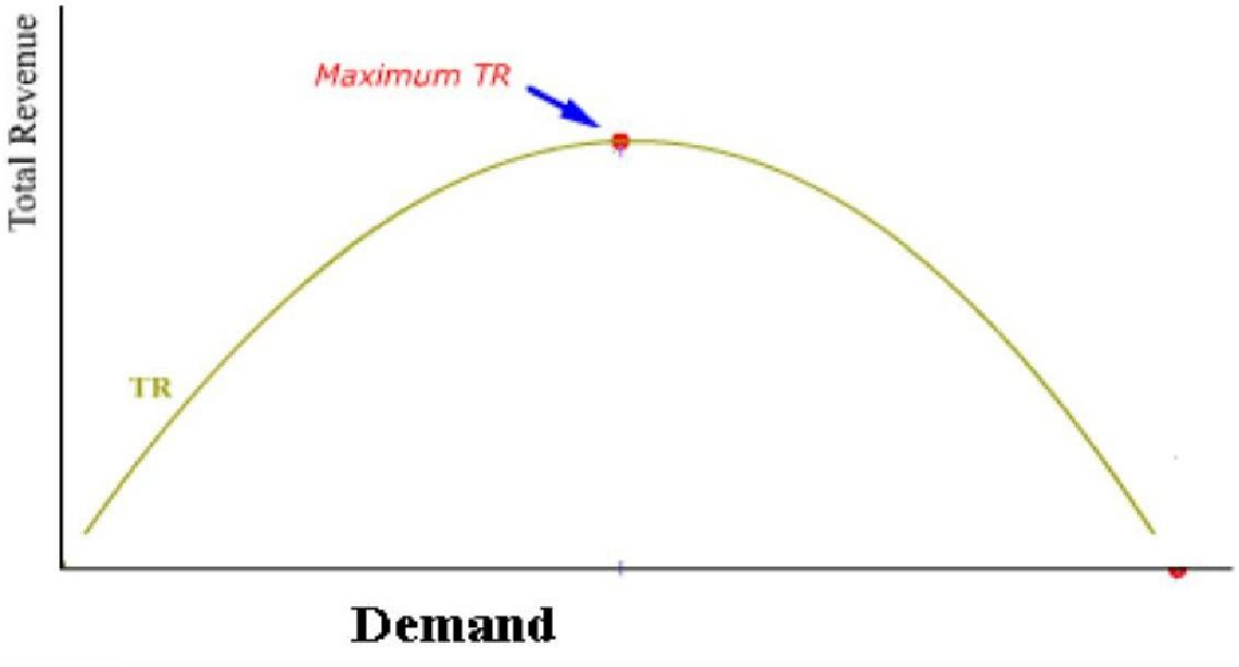


Fig 11.2 A total revenue function

One may be assured of a maximum by noting that is negative since b is a positive constant. **It may be noted that the derivative of total revenue with respect to volume is given the name "marginal revenue".** It expresses the rate at which revenue increases with increase in the volume of sales. Most enterprises, however, would not find that maximum total revenue resulted in maximum profit, thus one must investigate the problem of total cost of production in order to compute the profit in the more usual way.

11.3 Total cost function

Imagine that the analyst is able to examine the productive operations of the enterprise. At this point the analyst may be especially interested in how total cost changes with the volume of production. In estimating total cost it is helpful to divide the components of this sum into two classes called fixed costs and variable costs.

Fixed costs include all costs independent of the volume of production. These are the costs, which must be met irrespective of the level of production.

Variable costs include all costs which vary more or less directly with the volume of production: These costs include such things as direct labour costs and raw material costs that tend to rise as the number of units produced goes up. It may be difficult to discover just exactly how variable costs do 'vary with the level of production. Further, costs which are fixed in the short run may not be fixed in the long run. For example, if production is stopped, the enterprise may meet its fixed expenses for a short period in anticipation of renewed activity, however, this can not go on for long without resulting in liquidation or some other drastic modification of the cost structure. In spite of these difficulties, these cost classifications are sufficiently suggestive to give some important insights. To clarify these, let

TC (D) = total cost at a production level of D units

FC = fixed costs, independent of D

VC (D) = variable costs at a production level of D

TC (D) = FC + VC (D)

This is the general form of the enterprise's total cost function.

Consider a simple case in which the variable cost function turns out to be a simple linear function of the volume of production.

VC (D) = v D

The rate of change of the variable costs with the volume of production is called the "marginal cost," or sometimes the "incremental cost". In this case we have simply

This implies that marginal costs are constant, and that the cost of producing a small additional amount is always the same. If D is taken to be a discrete variable, then the marginal cost is simply the cost of producing one additional unit of product when the production is at some given level.

VC (D + 1) – VC (D) = marginal cost

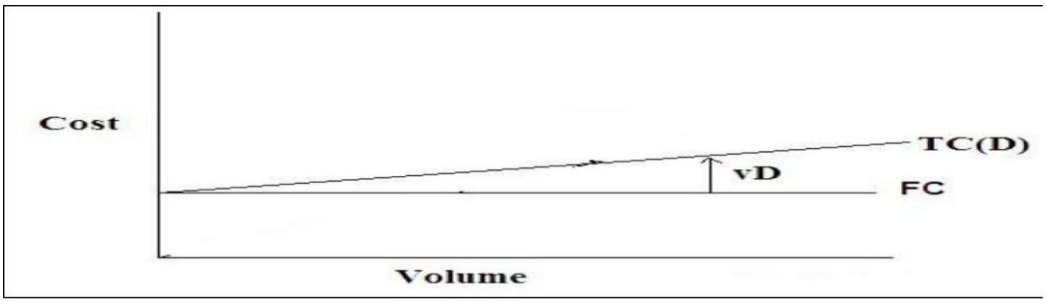


Fig 11.3 A total cost function

Using the simple-linear cost function (Fig 11.3), the total cost function becomes

TC (D) = FC +v D

and profit is given by

Profit = TR (D) – TC (D) = (a D – b D2) - (FC +vD)

= - FC + (a -v) D – bD2 for $0 \leq D \leq a/b$

= 0 otherwise

The-analyst who wishes to maximize profit under these conditions will then be interested in the value of D, which maximizes this function. Thus if

$a - v \geq 0$

If

$a - v \leq 0$

the profit will be maximized for

D=0

The situation, which confronts the analyst is shown graphically in Fig 11.4, in which it is assumed that

a - v ≥ 0

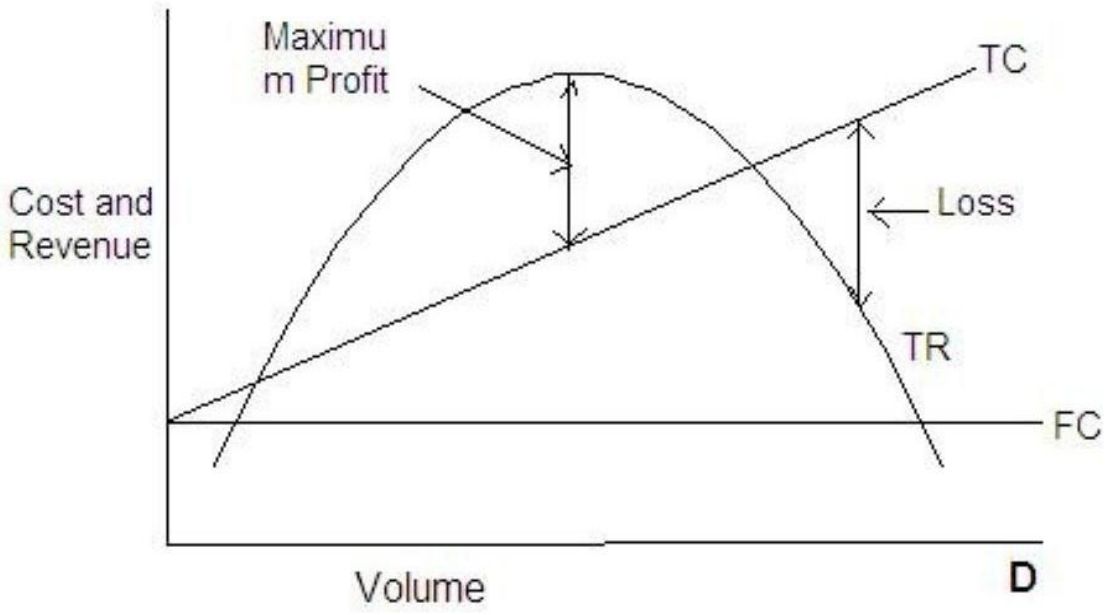


Fig 11.4 A profit - Loss function

An important -principle emerges here if one observes that at this level of production, marginal cost is equal to marginal revenue. For

Thus one might formulate a decision rule which says, "to maximize profit, increase production as long as marginal revenue is greater than marginal cost, but stop when the two are equal". Alternatively, "to maximize profit, increase production until the revenue from the last unit of product is just equal to the cost of producing it."

11.3 Break-even and shutdown Points

From Fig 11.4 certain other insights may be obtained. There are two points at which total revenue is equal to total cost, and thus profit is zero. These points are called the break- even points. Between the break-even points the enterprise will make a profit, but outside of these it will suffer a loss. The lower or left-hand break-even point is of special interest to the analysts since this is the level of, production that must be reached to get the enterprise out of the red. Many of the decisions of the enterprise about its activities depend heavily on the answer to the question; "Will the venture be able to operate at or above its break-even point?"

Another decision that may confront the analyst is whether or not to cease production entirely when conditions force volume down below the lower break- even point. This decision might be studied using the model, although this is not essential. Suppose the analyst finds that the enterprise is forced to produce at some level lower than the break-even point; one then has the following alternatives:

al = stop production

a2 = continue production at some level D1 below the break-even point

Assuming that no uncertainty or risk is involved in the analysis of this decision, one could compute the profit associated with each alternative:

Profit

a1 - FC

a2 TR (D1) – TC (D1)

The profit for a2 may be computed as follows:

TR (D1) – TC (D1) = TR (D1) – (FC + vD1)

Alternative a2 will be preferred if

TR (D1) - (FC + vD1) > - FC

TR (D1) > vDl

Thus one has the decision rule, "so long as total revenue exceeds variable costs, do not stop production." This rule must obviously apply in the short run, since the enterprise cannot go on sustaining a loss for very long.

11.4 Production

The problems and decisions discussed so far are largely the concern of top management, since they are in the realm of major company policy. The analyst at least early in the career, is more likely to be associated with decisions specifically related to the methods of production and operation employed. Thus one may be concerned with alternative production processes, alternative designs for the product, alternative operating procedures, and so on.

Ideally all the decisions should be studied from the overall viewpoint of the enterprise, with the aim of perhaps maximizing total profit as was previously shown. For obvious practical reasons, not every decision can be approached immediately from this viewpoint and thus one uses other, more immediate criteria. Typically much effort is devoted to reducing costs through the improvement of the product, the process, or the operating procedures. Although sometimes it may be true that if costs are reduced by a rupee, profit will increase by a rupee, things are usually not so simple. Suppose, for example, the analyst can show that by refusing to disrupt production in order to push through "rush" orders, costs can be reduced. Clearly profits may not be increased by an equal amount, since the customers may take their business elsewhere. In practice many decisions are approached from the viewpoint of minimizing costs because it may be difficult to measure profit directly, and good judgment indicates that higher profits are likely to result.

11.5 Economics of mass production

Suppose that management is confronted with the following decision. If the production process and equipment are kept substantially the same, what volume of production will minimize the average unit cost of production? This is the question of the economic

operating level for a plant. If we assume that under these conditions the plant's costs are given by a linear total cost function, as in Fig 11.5, then the average unit cost is simply given by

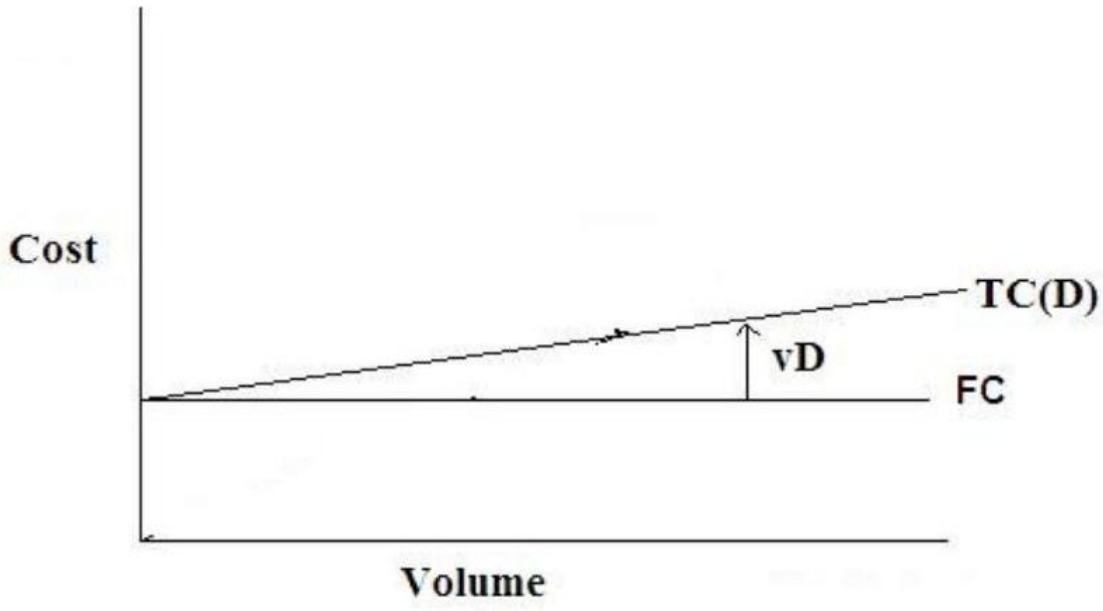


fig 11.5 Atotal cost function

In this situation the more one produces, the lower the average unit cost. This phenomenon is so important that it is given the name "economics of mass production" and forms the entire basis of much of the industrial development. The simple linear cost function leads to the conclusion that production may be increased indefinitely, always with the result of lowering average unit cost. Recalling that the plant and production process is being held substantially constant, this conclusion does not appear realistic. As one tries to obtain more and more production from the plant, the facilities are strained to their limit, expensive overtime operation seems necessary, scrap may increase, maintenance may be neglected and average cost may go up (Fig 11.6).

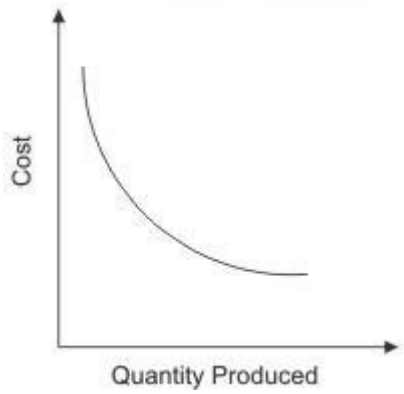


Fig 11.6 an average cost function

This would have been noted, one has assumed a somewhat more realistic total cost function, such as

TC (D) = FC + v1 D + v2 D2

In this case average cost is given by

and will be minimized when

This yields

The phenomenon of rising average cost which sets in when production goes above this level suggests that we might formulate the general hypothesis: As one tries to get more and more production out of a given plant and process, the unit cost will eventually go up. Thus one has to compromise between the conflicting effects of economies of mass production and the eventual up tuning of the average cost function. The best compromise in the sense of minimizing cost is given by the result obtained above.

At this point, another helpful decision rule may be obtained. At the point where average cost is minimum, it is easy to show that

AC (D) = marginal cost at D = v1 + 2 √ FCv2

Thus one could say that average cost would come down so long as marginal cost is below it. But when marginal cost exceeds average cost, it will rise. To minimize average cost, find the level of production where it is equal to marginal cost. A little thought will confirm the common sense of this rule.

11.6 A production management decision

The work of the analyst is partly that of transforming management problems into mathematical problems. If the analyst can discover or create a mathematical structure that reasonably reflects the management decision, then he/ she is in a position to use the mathematical structure or model to predict the results of various managerial choices. One way, and perhaps the only way, to become acquainted with the art of model building is to study some examples. Let us take a somewhat more detailed look at production by means of an especially useful model, which may be used to capture some of the complexity of production management decisions. Instead of considering a plant in terms of a production function, we now look more closely at what is inside the plant.

Suppose we have a food processing plant, and our business consists of buying vegetables from farmers, preparing them, and packing them in cans of our own manufacture. The plant consists of three departments: the can department, which produces the containers, the preparation department, which cleans and cooks the vegetables, and the packing department, which fills and labels the cans. At the moment, farmers are offering both peas and tomatoes, either of which could be processed in our plant. Our total cost and revenue structure is so simple that we can say each can of peas yields us a profit of Rs. 5.00 and each can of tomatoes yields a profit of Rs. 8.00. These profits are the same no matter what level of production for either vegetable we decide on if we are planning for the coming week, then our profit for the week will be (in Rupees).

Profit = 6P+8T

where, P is the number of cans of peas we turn out and T is the number of cans of tomatoes. At this point it may appear that since tomatoes are more profitable, we should entirely forsake peas and turn out all the tomatoes possible. However, usually things are not as simple as-that. First of all, we discover that the farmers in the area will have available no more than the equivalent of 20,000 cans of tomatoes and no more than the equivalent of 25,000 cans of peas. Thus our choices of P and T are limited by the availability of vegetables. It must be that

$P \leq 25{,}000$ $T \leq 20{,}000$

Next, we note that the capacity of our departments is also limited. Suppose both vegetables are packed in the same type of can, and the can department has a capacity of 30,000 cans per week. This puts another restriction on our production program.

$P + T \leq 30{,}000$

The preparation department, which operates 40 hours per week, requires 0.001 hours to process enough peas to fill a can and 0.002 hours to process a can of tomatoes. We then have a processing department restriction that says

$$0.001\,P + 0.002\,T \leq 40$$

or

$$P + 2T \leq 40{,}000$$

The packing department has a capacity of 50,000 cans of either type for the week, giving

$$P + T \leq 50{,}000$$

One might go on adding restrictions and conditions to make the problem more and more realistic, but at this point the decision about a production program is sufficiently complicated to suggest the difficulties that might be encountered.

The problem is still simple enough so that its solution may be graphically illustrated. Any decision as to a production program can be represented by a point on Figure 6, that is, a particular pair of values for P and T. By plotting the inequalities which express the restriction we can see exactly how our choice is limited. Because of the limited production by farmers our choice of P must lie on or below the horizontal line P = 25,000. Similarly, our choice of T must lie to the left of a vertical line T = 20,000. The other two restrictions are similarly plotted, with the result that our decision is limited in fact to P and T combinations lying in or on the edge of the shaded area in Fig 11.7.

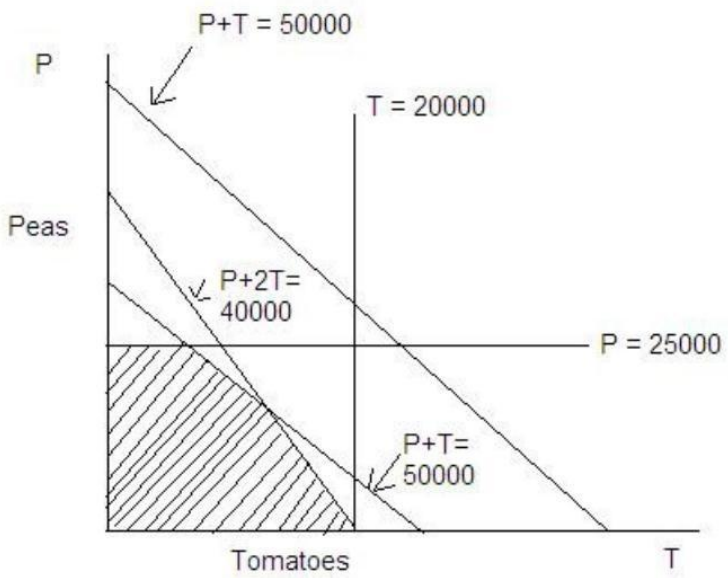


Fig 11.7 Possible production programmes and restrictions

The capacity of the canning department does not need to be considered in this particular decision, since the other restrictions prevent any possibility of reaching this capacity. At the moment we have more capacity than necessary in this department.

Module- 6. Food processing enterprise and engineering economics

Lesson 12. Engineering economics

12.1 Introduction

Engineering economy is the study of quantitative techniques for the evaluation of engineering alternatives based upon financial criteria.

In production systems engineering, economic choices are required when

1. phasing-in of new products and services, and phasing-out of existing products and services,
2. making a choice between alternative production technologies,
3. choosing plant location and layout, and
4. when deciding about the questions of equipment replacement etc.

12.2 Important terms of engineering economy

1. **Time Value of Money:** Time value of money is defined as the time dependent value of money stemming both from changes in the purchasing power of money (inflation or deflation) and from the real earning potential of alternative investments over time. The following are reasons why Rs.1000 today is "worth" **more than** Rs.1000 one year from today. 1. Inflation, 2. Risk, and 3. Cost of money
2. **Inflation:** It is the decrease in the purchasing power of a given sum of money with time due to complex national and international economic factors.
3. **Interest**: It is the money paid for the use of borrowed money. A production concern borrows money from individuals, commercial banks, insurance companies and government, and pays interest on the borrowed money.
4. **Interest Rate:** It is the ratio of the amount of interest paid at the end of a period or time, usually one year, to the sum of money borrowed at the beginning of that period. The sum borrowed is called the Principal. The interest rate is usually expressed as *i* percent per annum.
5. **Compound Interest**: If a sum of money is borrowed for more than one period of time, then in compound interest, the amount of interest payable at the end of any given period of time is calculated on the total amount payable at the beginning of that period of time. In business, compound interest only is charged.
6. **Rate of Return:** If a production concern invests an amount of money in setting up production facilities, then the **ratio** of the **net profit earned** by the company **at the end of a period of time** to **the sum invested** is called the Rate of Return on investment.
7. **Attractive Rate of Return**. This is the minimum rate of return which is used as a criterion by which a concern evaluates alternative investment proposals. An

alternative whose expected rate of return is less than the attractive rate of return is rejected.

8. **Payment:** Known also as cost, outlay, expenditure or disbursement, payment is any sum paid by a production concern for buying materials, paying wages etc.
9. **Receipt(s):** Known also as return, income, profit or revenue, **receipt is any sum received by a production concern from** sales of products and services etc.
10. **Cash flow:** It is the series of actual or estimated **payments** and **receipts** of a production concern over a period of time. The cash flow can be represented in the form of a cash flow diagram as shown in Figure 12.1.

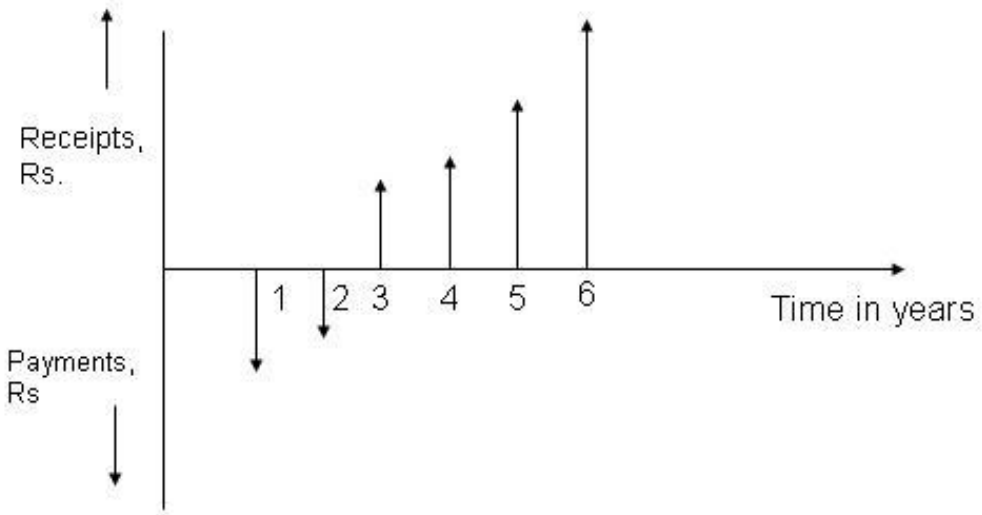


Figure 12.1 A typical Cash-flow diagram

11. **Sunk costs**: Engineering economic analysis is concerned with making choices between engineering alternatives. For this purpose all past payments or receipts (called Sunk Costs) '**concerning the alternatives are irrelevant**, and are therefore ignored. (sunk = done for)
12. **Opportunity Costs**:If a company invests certain sum of money into a certain venture (or proposal) with an element of risk, that sum is no longer available for investing in any other alternative venture**. The profits or returns los t as a result of not investing in a particular alternative is called the Opportunity Co st.**
13. **Asset**: An asset of a production concern is a valuable like land, building, machine, material etc.owned by the concern.
14. **Life of an Asset**: The life of an asset can be considered in three ways, *(a)* Actual or Technological Life of an asset is the duration during which it can fulfil its required functions. It is determined from technological considerations. *(b)* Accounting Life of an asset is the duration during which the investment made in acquiring the asset is to be recovere d from gross profits in the form of depreciation. *(c)* Economic life of an asset is the duration during which an asset performs its technological function economically. The asset is actually used by the production concern during its economic life only.
15. **Depreciation**: A company invests in assets expecting to earn profits by making use of those assets. However, net profits would accrue only after the investment made in acquiring the assets is recovered. Depreciation is systematic procedure of recovering every year a portion of investment made on an

asset during its accounting life. Income tax during a year is chargeable only on the net profit obtained by deducting the amount of depreciation from gross profits.

16. **Book Value of an Asset:** At any time during the accounting life of an asset, its book value is equal to its cost price minus the total amount of depreciation charged on it by that time.
17. **Salvage Value**: It is the actual or estimated value of an existing asset at which it can be sold now or at a certain date in the future.
18. **Retirement:** It is the disposal of an existing asset through sales or abandonment as scrap.
19. **Replacement:** It means acquiring a new asset through purchase or lease to perform the same or extended service which had so far been performed by another asset which has been retired.
20. **Defender and Challenger:** When an economic analysis is made to decide whether or not to replace an existing asset with another, the existing asset is referred to as the Defender and the proposed replacement as the Challenger.

Module- 7. Process scheduling and operation

Lesson 13 Process schedule

13.1 Introduction

Process schedule is one of the important activity of planning, before diverting raw material to different section for product manufacturing. It is prepared well in advance to give instructions to boiler operator, refrigeration plant operator, different process section incharge to plan for the activity of different unit operations for processing the material to have smooth operation of the process. It also helps to prevent product losses and to have efficient use of equipments, energy and water.

The benefits of scheduling include:

- Process change-over reduction
- Inventory reduction and levelling
- Reduced scheduling effort
- Increased production efficiency
- Labour load levelling
- Accurate delivery date quotes
- Real time information

13.2 Planning for process schedule

Preparation of process schedule is one of the important tasks in food plant operation for an engineer/technologist in order to prevent losses in terms of manpower, energy, services, and time. A well planned time schedule will help in preventing losses as well aid in routine work viz. Maintenance, breakdown, establishment etc.

After careful consideration of food building planning mentioned above, a process scheduled layout is drawn. Process scheduling means arranging the flow of products through various operations in the plant in such an order that maximises use of all labour and equipment, and the processing of the products is accomplished in the shortest possible time with minimum delays between processing of different products.

First of all "Basis of Plant Layout' is drawn according to item of manufacturer to decide definite line flow. To this skeleton layout are added as other information, such as operating rates, storage capacity, raw material required, man power required etc. as each section of plant is considered in relation to the equipment available.

Planning for operations involved in processing of any food product has to be done in advance so that maximum use is made of men and material with little waste of time. Process schedule which is more or less work plan ensures that the proposed operation will

run smoothly. It provides the basic information from which schedule of service requirements and list of equipment can be made. Time and operation graph can be made which will indicate at what time particular operation has to be performed. It may be noted that all operation for manufacture of any particular food product can not be started at time. There must be a sequence for performing an operation in the plant and that is why the process schedule is required.

The features of the plant considered during preparation of process schedule are:

· Reception capacity,

· Unit processing cost,

· Frequency of CIP,

· Installed capacity of the plant,

· Handling capacity of the plant,

· Running hours and Idol time of plant,

· Quantity of material received in different season,

· Capacity of the various equipments installed for the processing and production purpose viz. PHE, SEPARARTOS, PUMPS, CATLES, VAT, etc;

· Capacity of the services and providing machines viz. Air compressor, refrigeration, boiler, water, ETP, etc;

· Product dispatch timing

Example: Process schedule of a milk-processing plant handling approximately 1.5 lakh lit of milk in morning and evening:

Milk is received two times in a day approximately 82,000 lit in evening and 68,000 lit in the morning.

Considering the processing capacity of the plant 20,000 lit /hr.

Morning

Sr. No	Process	Start Time	End Time	Total Time
1	Sterilization of plant	7:30	8:30	01:00
2	Milk processing	8:30	13:30	05:00
3	CIP	13:30	16:40	04:10
	Hot water Rinsing	13:30	13:45	00:15
	Lye circulation	13:50	14:50	01:00
	Hot water Rinsing	15:00	15:15	00:15
	Acid circulation	15:20	15:50	00:30
	Hot water Rinsing	16:00	16:15	00:15
	Lye circulation	16:20	16:30	00:10
	Hot water Rinsing	16:30	16:40	00:10

Evening

Sr. No	Process	Start Time	End Time	Total Time
1	Milk processing	20:30	01:00	04:30
2	CIP	01:00	16:40	04:10
	Hot water Rinsing	01:00	01:15	00:15
	Lye circulation	01:15	02:15	01:00
	Hot water Rinsing	02:15	02:30	00:15
	Acid circulation	02:35	03:05	00:30
	Hot water Rinsing	03:10	03:25	00:15
	Lye circulation	03:30	03:40	00:10
	Hot water Rinsing	03:40	03:50	00:10

Lesson 14: Plant operation

14.1 Introduction:

The food plant today is faced with continually rising labour cost, higher prices of raw material, equipment and suppliers. As a result the progressive plant operator and equipment manufacturers have given considerable thought to the development and application of automatic equipment and controls to reduce man hours per unit of product, decrease product and container losses, and to increase overall plant efficiency. As operating costs increase more product per man-hours at a lower cost per unit must be realized to maintain a profitable operating balance. Progressive entrepreneurs today are recognizing the need for the development and use of modern material handling methods and equipment for the materials handling phase of any plant operation.

In setting up operations and designing material handling systems, it is essential that an analysis be made of the entire plant product flow. This analysis show the raw product in, the major product movement, the specialized or branch movements, the processes, the storages for the various products, and the out movements. It is particularly important to note the areas where high density traffic is found. It is also important to note the sequence of movements and provide for them so that the whole operation will move forward smoothly. The designer should take advantage of the many new material handling methods and equipment, utilizing each one where it is crates, cans, etc. can be moved by means of chain conveyors or they may be moved by trucks or pallets. Surprisingly enough, there may be places where some handling can best be made by means of manual labour.

Material handling systems for food products should be carefully selected so that it will not be affected by temperature change or severe vibrations. The material handling system should be simple in design, having ease of lubrication, corrosion resistant and low maintenance. The use of automatic stopping and starting controls, speed regulators, switches, and over-load safety devices are all important. Fig. 14.1 shows concept of material handling system in a dairy plant.

Fig. 14.1 Concept of material handling system in a dairy plant

Research in operations or operation research provide solution for above said complex problems arising in the direction and management of large systems of men, machines, materials and money in industry and business governance.

The significant features of operations research can be stated as:

- Decision making tool
- Scientific approach.
- inter-disciplinary team approach
- System approach
- Operations research largely depends on computation.
- Objective.

14.2 Models in operations research:

Operations research expresses a problem by a model: A model is a theoretical abstraction (approximation) of a real-life problem. It can also be defined as a simplified representation of an operations or a process in which only the basic aspects or the most important features of a typical problem under investigation are considered. The object of the models is to provide means for analysing the behaviour of the system for the purpose of improving its performance.

14.3 Techniques used in operations research:

- Linear Programming. It is used in the solution of problems concerned with assignment of personnel, blending of materials, transportation and distribution, facility planning, media selection, product mix etc.
- Dynamic Programming. It is used for optimization (for example, finding the shortest path between two points, or the fastest way to multiply many matrices). A dynamic programming algorithm will examine all possible ways to solve the problem and will pick the best solution. Therefore, we can roughly think of dynamic programming as an intelligent, brute-force method that enables us to go through all possible solutions to pick the best one.
- Queuing Theory. It is used in solving problems concerned with traffic congestion, servicing machines subject to breakdown, air traffic scheduling, production scheduling, and determining optimum number of repair for a group of machines.
- Inventory theory. It was also known as mathematical theory of inventory and production. It is concerned with the design of production/inventory systems to minimize costs. It studies the decisions faced by firms in connection with manufacturing, warehousing, supply chains, spare part allocation and so on; it provides the mathematical foundation for logistics.
- CPM and PERT Techniques. CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) may be important tools for effective project management. Any project with interdependent activities can apply CPM method of

mathematical analysis. Whereas PERT (statistical tool) is designed to analyse and represent the tasks involved in completing a given project.

- Game Theory (Competitive Models).It is a study of strategic decision making. Specifically, it is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers". It has been used to study a wide variety of human and animal behaviours. It was initially developed in economics to understand a large collection of economic behaviours, including behaviours of firms, markets, and consumers.

14.4 Introduction to linear programming:

Linear programming is one of the commonly used operations research techniques. It has its early use for military applications but now employed widely for various business/industry problems.

Definition*:* Linear programming is a mathematical technique for the purpose of allocating the limited resources in an optimum manner (*i.e.,* either maximum or minimum) to achieve the objectives of the business, which may be maximum overall profit or minimum overall cost. The word "linear" means that the relationships handled are those which can be represented by straight lines, *i.e.,* the relationships are of the form $y = ax + b$ and the word "programming" means "taking decisions systematically".

In other words, linear programming is the optimization (either maximization or minimization) of a linear function of variables subject to constraint of linear inequalities.

Thus, linear programming involves the planning of activities to obtain an "optimal" result *i.e.,* a result that reaches the specified goal best (according to the mathematical model) among all feasible alternatives.

(i) It attempts to maximize .or minimize a linear function of decision variables.

(ii) The values of the decision variables are selected in such a way that they satisfy a set of constraints, which are in the form of linear inequality.

Linear programming is based on the following basic concepts:

1. Decision Variables (Activities). Decision variables are the variables whose quantitative values are to be found from the solution of the model so as to minimize or maximize the objective function. For example, decision variables in a product mix manufacturing, represents the quantities of the different products to be manufactured by using its limited resources, such as men, machines, materials, money etc. The decision variables are usually denoted by $x1$, x2,……,xn.

2. Objective Functions. It states the determinants of the quantity either to be maximized or to be minimized. For instance, profit is a function to be maximized or cost is a function to be minimized. An objective function must include all the possibilities with profit or cost coefficient per unit of output. For example, for a firm which produces four different products A, B, C and D in quantities Q1, Q2, Q3 and Q4 respectively, the objective function can be stated as:

Minimise C = Q1 C1 + Q2 C2 + Q3 C3 + Q4 C4,

where C is the total cost of production, and C1, C2, C3 and C4 are unit costs of products A, B, C and D respectively.

3. Constraints (Inequalities). These are the restrictions imposed on decision variables. These may be in terms of availability of raw materials, machine hours, man hours etc. Suppose each of the above items A, B, C and D requires t1, t2, t3 and t4 machine hours respectively. The total machine hours are T hours, and this is a constraint.

Therefore it can be expressed as:

$$Q1\ t1 + Q2\ t2 + Q3\ t3 + Q4\ t4 \leq T$$

4. Non-Negative Condition. The linear programming model essentially seeks that the values for each variable can either be zero or positive. In no case it can be negative. For the products *A*, *B*, C and *D* the non-negative conditions can be :

Q_1	$\geq$	0	and also	t_1	$\geq$	0
Q_2	$\geq$	0		t_2	$\geq$	0
Q_3	$\geq$	0		t_3	$\geq$	0
Q_4	$\geq$	0		t_4	$\geq$	0

This implies that quantity produced can be at the most zero and not below that. Similarly, the machine hours expended for each unit *A*, *B*, C and *D* can be at the most zero and in no case it can be negative.

5. Linear Relationship. It implies straight line or proportional relationship among the relevant variables. It means change in one variable produces proportionate change in other variables.

6. Process and its Level. Process represents to produce a particular output. If a product can be produced in two different ways, then there are two different processes or decision variables for the purpose of linear programming.

7. Feasible Solution. All such solutions which can be worked out under given constraints are called "feasible solutions" and region comprising such solution is called the "feasible region".

8. Optimum Solution. Optimum means either maximum or minimum. The object of obtaining the feasible optimum solution may be maximization of profit or minimization of cost. Optimum solution is the best of all feasible solutions.

14.4.1 Assumptions in Linear Programming

- There is a well-defined objective function such as maximizing profit or minimizing cost.
- There are a number of restrictions or constraints (on the amount and extent of available resources for satisfying the objective function) which can be expressed in

quantitative terms. These may refer to man-hours, machine hours, raw materials, storage space, capital etc.

- The parameters are subject to variation in magnitude.
- The relationship expressed by constraints and the objective function are linear.
- The objective function is to be optimized w.r.t. the decision variables involved in the phenomenon. The decision variables are non-negative and represent real life situation.

14.4.2 Advantages of Linear Programming

(i) Linear programming helps the management to make effective utilization of limited production resources.

(ii) Linear programming improves the quality of decision making by replacing rules of thumb.

(iii) It provides feasibility in analyzing a variety of multi-dimensional problems.

(iv) It highlights the bottlenecks in the production processes.

(v) It helps in re-evaluation of the basic plan to meet changing conditions in the business (e.g., sales, demand etc.).

14.4.3 Limitations of Linear Programming

(i) The assumptions that all relations are linear may not hold good in many real situations.

(ii) In linear programming all coefficients and constraints are stated with certainty. (iii) The solution many times is in fractions which may not remain optimal when rounded-off. .

(iii) When the number of variables or constraints involved are quite large then it be com necessary to use computers.

(iv) It deals with only a single objective problems, whereas in real life situations there may be more than one conflicting objectives.

14.4.4 Applications of Linear Programming

Some of the applications of linear programming in industry, business, and other fields are as follows:

i. Product Mix. A company can produce several different products, each of which requires the use of limited resources. Linear programming helps to determine the quantity of each product to be manufactured in order to maximize profit.

ii. Production Planning. Linear programming helps in production planning (inventory control, manpower, equipment selection, etc.) in order to minimize total operations costs.

iii. Assembly line Balancing. Linear programming techniques help to minimize. total elapsed time in assembly process.

iv. Blending Problem. When a product can be made from a variety of available raw materials, each of which has a particular composition and price, linear programming technique is used to determine minimum cost blend.

v. Media Selection. Linear programming helps in determining the advertising media mix so as to maximize the effective exposure at minimum cost.

vi. Traveling Salesman Problem

vii. Physical Distribution. It helps in selecting most economical and effective location for the manufacturing plant and distribution centers.

viii. Staffing Problem. Linear programming helps to allocate optimum manpower to a particular job so as to minimize total over time cost and total manpower.

ix. Job Evaluation and Selection. Selection of suitable person for a specified job and evaluation of job in organization has been done with the help of linear programming.

x. Agriculture. To allocate limited resources such as land, labour, water supply and working capital etc. in the way so as to improve productivity.

xi. Routing Problem. To determine the most economic pattern and timings for flights so as to make the most efficient use of aircraft and crews.

14.4.5 Solution of Linear Programming Problems

Linear Programming Problems can be solved by following methods:

a. Graphical method, b. Simplex method, c. Transportation method and d. Assignment models

The graphical method can be used only for two or three variables; whereas the other methods can be used for any number of variables.

Illustrative Example on Formulation of Linear Programming Model

Example: The manager of an oil refinery must decide on the optimal mix of two possible blending processes of which the input and output per production run are given as follows:

Process	*Input (units)*		*Output*	
	Crude A	Crude B	Gasoline X	Gasoline Y
1	5	3	5	8
2	4	5	4	4

The maximum amount available of crude A and B are 200 units and 150 units, respectively. Market requirements show that at least 100 units of gasoline X and 80 units of gasoline Y must be produced. Formulate this problem as a linear programming model to maximize profit. The profit per production run from process 1 and process 2 are Rs 300 and Rs 400, respectively.

Solution: Linear Programming Model Formulation

Let,

Decision variables

x1 = number of units of Gasoline from process 1

x2 = number of units of Gasoline from process 2

Objective function, Maximize z =300 x1 + 400 x2

Subject to constraints:

$5x1+4x2 \leq 200$

$3x1+5x2 \leq 150$

$5x1+4x2 \leq 100$

$8x1+ 4x2 \leq 80$

$x1 \geq 0$ and $x2 \geq 0$

14.5 Introduction to queuing theory:

The formation of queues or waiting lines is a most common phenomenon in our everyday life. It occurs where the current demand exceeds the current capacity to provide that service.

Queues are also formed even when the service rate is higher than the arrival rate due to random pattern of arrival of customers. The examples of the places where the queues may be formed are barber's shop, ration shop, cinema ticket window, bus stop, bank counters, railway reservation counters, telephone booth, doctor’s clinic, repair shops, automobile service centers etc.

Besides these, queues are also formed in manufacturing industry in situations where in-process goods waits for next operation, or waits for getting moved to another place, machine waiting for repair parts or components waiting for assembly in assembly lines, blunt tools waiting for reground, workers waiting at the tool crib to obtain tools etc. This may increase production cycle duration which adds to the cost of the product and it may also delay the specified delivery period.

Queues may not be a physical line of customers; it may be merely a list of customers, units, orders etc. Some specified examples of such type of queues are: unconnected telephone calls waiting list of passengers for a berth etc.

The most important issue in waiting line problems is to decide the best level of service the organization should provide. Providing too much service would involve excessive cost on the other hand inadequate service capacity would result in long waiting lines which results in dissatisfaction of customers or sometimes loss of customers. Thus the ultimate goal is to achieve an economic balance between the cost of service and the cost associated with waiting for that service.

Queuing theory provides a large number of alternative mathematical models for describing and solving waiting line problems.

The economic balance between the cost of service and the cost associated with waiting can be achieved at either by:

1. providing more facilities at additional cost, or
2. replacing less efficient service facilities by more efficient ones, or
3. changing the pattern of arrival of customers for service, or
4. changing the pattern of providing service, or
5. effecting method improvements to reduce service time.

Queuing problems can be solved basically either by mathematical or simulation approaches.

14.5.1 Elements of queuing system

The basic queuing process (Queuing model) consists of:

a) Input Source

b) Queue

c) Service discipline & mechanism

The 'Customers' requiring service are generated over time by an "input source". These customers enter the queuing system and join the queue. At certain times a member of the queue is selected for service by some rule known as service discipline. The required service is then performed by the service mechanism, after which the customer leaves the queuing system.

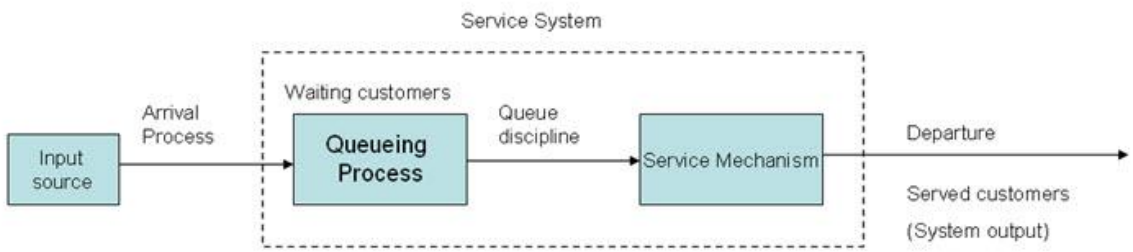


Fig. 14.2 The basic queuing process

The various elements of the queuing system are: Input source (population), Waiting line (queue), Service discipline, Service mechanism, System output and Customer behaviour.

14.5.1.1. Input source

Two important characteristics of the input source are: (i) its size and (ii) the pattern of arrival.

The size is the total number of customers that might require service from time to time. The size of the input source is generally assumed to be infinite. The railway reservation system, tax / toll both on highway etc. are the example of infinite queue.

The arrival of the customers may be either at a constant rate or at random. Most arrivals in a service system are at random. This is when each arrival is independent of its previous arrivals. The exact prediction of any arrival in random system is not possible. Therefore, the number of arrivals per unit time (rate of arrival) is estimated by Poisson distribution.

14.5.1.2. Queue

A queue is characterized by the maximum permissible number of customers that it contains. Units requiring service enter the system and join a queue. In some service systems only a limited number of customers are allowed in the system and new arrivals are not allowed to join the system unless the number becomes less than the limiting value.

The important characteristics required to study the waiting line are:

(i) Waiting time: It is the time that a customer spends in the queue before being taken up for service.

(ii) Service time: It is the time period between two successive services. It may be either constant or variable.

(iii) Waiting time in the system: It implies the time spent by the customer in the queue system. Waiting time in the system = Waiting time + Service time

(iv) Queue length: It implies the number of customers waiting in the queue.

(v) System length: System length is equal to the number of customers in the queue plus those being served.

14.5.1.3. Service discipline and mechanism

Service discipline refers to the order in which the customers waiting in queue are selected for service. It may be first-come-first-served, random or according to some priority procedure. The rules governing order of service may be.

(i) FIFO. First-In-First-Out. (i.e., first-come-first-served): According to FIFO, the customers are served in the order of their arrival. Examples are bank counters, railway reservation counters etc.

(ii) LIFO. Last-In-First-Out. According to LIFO, the items arriving last are taken out first. Example, in big godowns/warehouses, the items arrived last are taken out first.

(iii) SIRO. Service-In-Random-Order. (or Random and priority) Sometimes, certain customers are given priority for service i.e., the arriving customer is chosen for service ahead of some other customers already in the queue. Example: Serious patients are given priority for treatment, vital machines are attended to first in the case of their breakdowns, important orders are given priority in production scheduling.

First-come-first-served (FIFO) is usually implicitly assumed by queuing models unless otherwise stated.

Service mechanism consists of one or more service facility each of which contains one or more parallel service channels.

A server may be a single individual or a group of persons, *e.g.*, a maintenance crew. Furthermore, servers need not even be people, in many cases a server may be a machine or a piece of equipment, *e.g.*, fork lift truck. Service mechanism may vary depending upon the number of service channels, number of servers, number of phases etc. The four basic structures of service mechanism are:

(i) Single Channel Single Phase (Single Queue-Single Server). In this case the arriving units form one queue to be served by a single service facility:

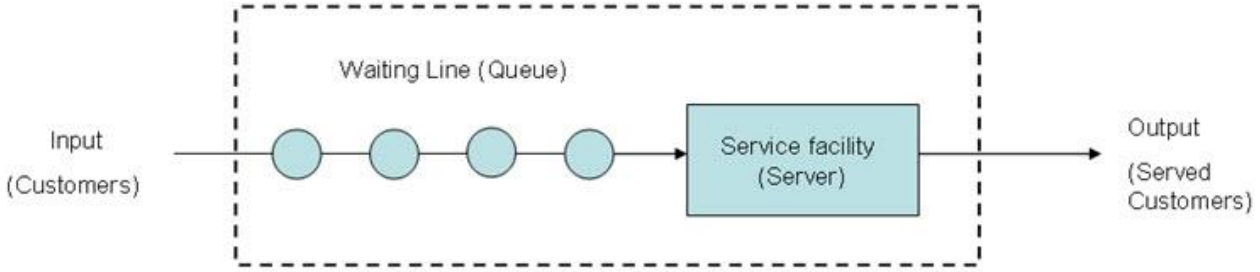


Fig. 14.3 Single channel, single phase system.

(ii) Single Channel, Multiphase (Single Queue, Multiple Servers in Series). In this case the customers are served at number of servers arranged in series. A two phase service means that once an arrival enters the service, it is served at two stations (or phases one after the other).

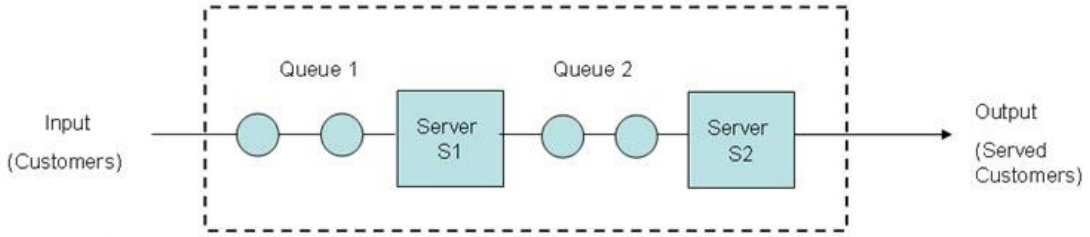


Fig. 14.4 Single channel, multiphase (2-phase) system.

(iii) Multi Channel, Single Phase System (Single Queue, Multiple Servers in Parallel). In this type there is a single queue and multiple servers arranged in parallel as shown in Figure 14.5.

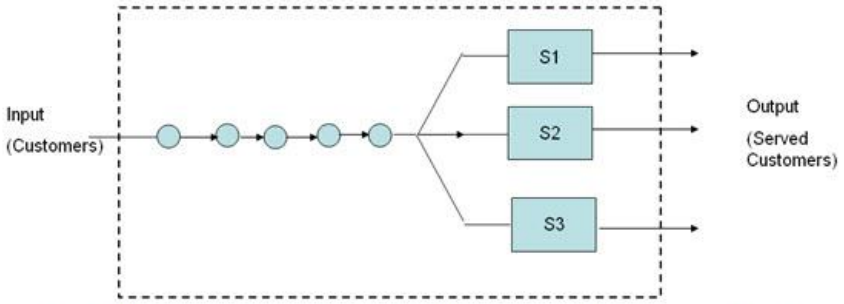


Fig. 14.5 Multiple channel single phase (Single queue multiple servers in parallel).

(iv) Multiple Channel, Multiple Phase. In this type there are multiple channels and the customers are served at more than one server as shown in Figure 14.6.

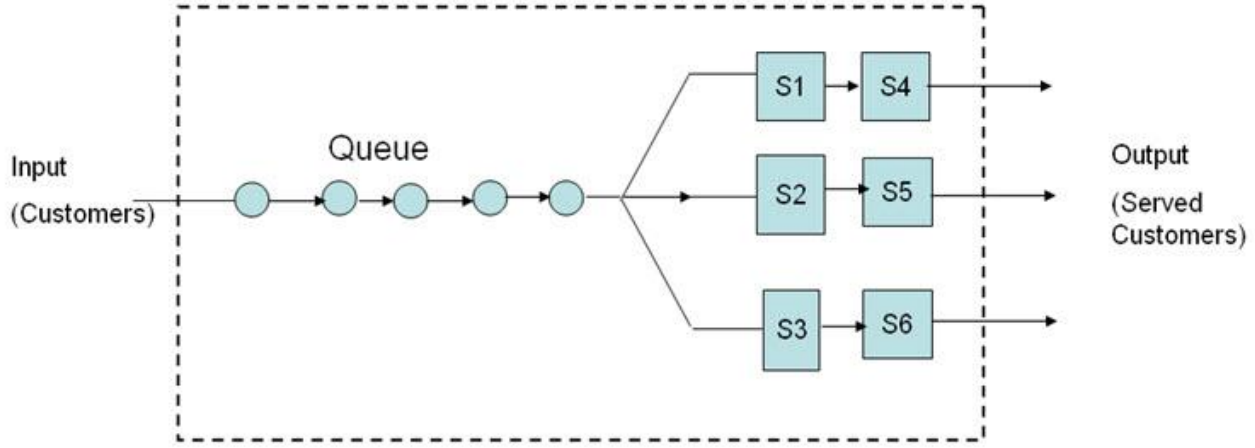


Fig. 14.6 Multiple channel, multi-phase (Three channel, 2 phase).

14.5.1.4. System Output

System output refers to the rate at which customers are rendered service. It depends upon service time required by that facility to render service and the arrangement of service facility. The average number of customers that can be served per unit time is called service rate. It can be obtained by constructing service time frequency distribution. Service rate is denoted by letter 'μ'. Reciprocal of service rate is called service time *i.e.,* Service time $=\mu^{-1}$

14.5.1.5. Customer Behaviour

Customer behaviour implies that reactions of the typical customers about queuing system of the service mechanism. Typical tendencies of the customers are:

(i) Balking: A new customer refuses to enter the system.

(ii) Reneging: A customer may leave the queue without getting service after waiting sometime.

(iii) Jockeying: A customer may keep on switching from one queue to another, when there are more than one service counters.

(iv) Collusion: The customers in the queue may demand service on their behalf as well as on behalf of others.

Module 8. Building materials and construction

Lesson 15. Building materials

15.1 Introduction

The building materials used vary considerably in different parts of the world. Though, basic materials used for the construction of food plant are common in almost all countries. More emphasis has been given for the materials which are commonly used in India. The use of cement, bricks, cement concrete, RCC, steel, stone, wood, metal, glass etc. are very common in most countries. In recent years, pre-fabricated blocks and pre-stressed RCC blocks are being employed for various applications. It is necessary to consider several factors such as environmental conditions in the plant, whether conditions, wear and tear, effect of acid and alkalis, safety, cost etc. for the selection of materials for different sections of food plants. There are different types of stones used for flooring and skirting and it should have desirable properties to with stand to prevailing conditions of different sections. Similarly requirement of type of wood depends on its position in a windows, doors and other applications, soft woods requires seasoning treatment and application varnish and oil paints to prevent yeast and mould growth. Selection of metal depends on type of vessels used for processing, particularly to with stand high pressure and to meet sanitary standards. The glasses used in the plant are specifically designed with wire mesh inside, so that no glass pieces will fall in the product. In certain sections like, butter, ghee cheese and fruit/vegetable product manufacturing, glasses are used to control sun light particularly UV light to prevent oxidation of fat and related defects in the product.

15.2 Factors to be considered for selection of building construction materials

- Effect of atmospheric conditions on the building
- Effect of prevailing conditions in the plant such as water, water vapor, high temperature, acids, alkalis and wear and tear.
- Durability of material under conditions to which it is exposed
- Ease of cleaning and maintenance
- Availability of the materials
- Cost of materials

15.3 Properties of building materials

The properties of different building materials are discussed in 15.4. Some general properties which are to be considered are discussed here. The use of building materials of organic origin which may be attacked by bacteria and other organisms should be avoided. Whenever soft wood and wood based products are necessary, protection against germs and moisture is very essential requirement. Many hardwoods such as teak have shown good serviceability for use of window frames, doors etc.

Insulating materials must be well protected to prevent entry of water vapour. The use of PUF panels for insulation of cold storage has changed the entire construction requirement of cold storages. The use of paints and bonding materials of organic origin should be avoided. The building materials are exposed to corrosion environment in dairy plant must be protected. Iron under moist condition rusts quickly and hence it must be protected by galvanizing, zinc coating or painting. The condensation of water vapor on a wall or pipelines may cause corrosion of metals and seriously damage the paint. Therefore, removal of water vapour from the processing room be taken into account.

15.4 Building materials

Generally building materials are classified into three groups as under.

(i) Solid materials – stones, bricks, iron etc.

(ii) Cement Materials – lime, cement etc.

(iii) Protective materials – paints, varnishes etc.

15.4.1 Bricks

Clay is the basic raw material for the preparation of bricks. Clay for brick is composed of alumina and silica and certain fluxing ingredients such as ferric oxide, lime, magnesia or CO_2 in quantities up to 20% except in firebrick, which may have silica content as high as 98%.

Bricks are obtained by moulding clay in rectangular blocks and then drying and burning of those blocks. It is manufactured by many places throughout the country in unorganized sectors. Brick is widely used as building material for making walls and as compared to other materials used for this purpose, it is cheaper. Brick contains alumina, silica, lime, oxide of iron, magnesia etc. and each constituent imparts specific characteristics in brick.

15.4.1.1 Properties of Brick

- Good quality brick should be well-burnt in kilns, uniform in size and colour, clear metallic ringing sound when struck with each other.
- No brick should have crushing strength below 5.50 N/mm^2. The bricks should not break into pieces when dropped flat on hard ground from a height of 1 m.
- Absorption of water should be more than 20% of its weight in 16 h immersion in water.
- Crushing strength: As per BIS, minimum crushing strength of brick is 3.50 N/mm^2
- 7 to 14 N/mm^2 : A grade; 14 N/mm^2 : AA grade
- Hardness: Bricks should be sufficiently hard.
- Presence of soluble salt: bricks should possess minimum salts.
- Shape and size: Rectangular shape with sharp edges. (Size: 190 mm x 90 mm x 90 mm (recommended by BIS)

- Soundness: Clear ringing sound when two bricks are struck with each other.
- Structure: homogeneous, compact, free from any defects like holes, lumps.

15.4.1.2 Constituents of good brick

(i) Oxides of aluminum (Al_2O_3): This ingredient renders the plastic property in the material required for moulding. However, excess of it causes the raw brick to shrink & wrap, while drying.

(ii) Silica or sand (SiO_2): It prevents the raw bricks from warping, shrinking and cracking. But excess amount of silica may cause brittleness.

(iii) Lime (CaO): Lime helps in preventing the shrinking of the raw bricks. A small proportion of lime present in a finely divided state also acts as a flux and causes the sand to fuse and bind the particles to gather. Excess of lime causes the brick to melt and run out of shape. Lumps of lime become quick lime after burning and when the brick is immersed in water or absorbs moisture from the air, the quick lime slakes, expands and causes the brick to split into pieces.

(iv) Oxides of iron (Fe_2O_3): A very small percentage of oxide of iron is helpful in (a) causing the sand to fuse a little at low temperature giving a pleasing tint to burnt brick.

(v) Magnesia (MgO): It gives the brick a yellow tint colour, if present in small quantities.

15.4.2 Fire brick

Fire bricks are very important for high temperature industrial applications. The materials which are capable of resisting high intensity of heat i.e. silica, alumina, magnesite, bauxite and chromite are added in fire brick. The composition of a good fire clay suitable for fire brick is 50-70% silica, 10-25% alumina, 2-2.5% iron oxide or lime magnesia, < 1.5% alkali.

15.5 Sand

It consists of small grains of silica ($Si0_2$). It is formed by decomposition of sandstones due to weather effects.

15.5.1 Types of sand

Sands available in market are classified based on the source as under.

(i) Pit sand

(ii) River sand

(iii) Sea sand

Based on the size of the sand, it is classified as under.

· Fine sand: It should pass through 1.59 mm opening (suitable for plastering)

· Course sand: It should pass through 3.18 mm opening (suitable for masonry work)

· Graveled sand: It should pass through 7.62 mm opening (suitable for concrete work)

15.5.2 Desired properties of sand

Objectives of mixing sand to prepare mortar are:

- To prevent excessive shrinkage.
- To improve the strength of mortar.
- To improve the setting power. Sand makes the mortar porous, which absorbs CO_2 from air and becomes hard.
- To increase the bulk and thus reduce the cost

The sand used for making mortar should be clean, coarse, hard, free from any clay, dust, mica particles and soft flaky pieces. Sand required for brick work needs to be finer than that for stone work.

15.6 Lime

The use of lime as cementing materials has been made since ancient times, but at present cement has replaced lime to a great extent. Lime is produced by calcinations of limestone.

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2$$

The lime which is obtained by calcinations of comparatively pure limestone is known as quick lime. It is made in kilns. Addition of water (about 32% of CaO) to the quick lime to prepare hydrate lime is called slaking of lime.

$$CaO + H_20 \longrightarrow Ca(OH)_2 + \text{Heat (hydrated lime or slaked lime)}$$

A thin suspension of slaked lime is known as the milk of lime

15.6.1 Use of lime

- Mortar for masonary work
- White washing
- Purification of water and sewage treatment
- Many industrial application

15.7 Limestone

Limestones ($CaCO_3$) either in pure or mixed with impurities is the parent material from which lime and cements are produced. Limestone is inert and insoluble in water in its natural condition. When limestone is burnt in kiln or calcined, CO_2 is separated and driven out in the form of gas and what remains is CaO in the form of lumps, called quick lime, which is soluble in water. When water is sprinkled on quick lime, it breaks in to powder, which is $Ca(OH)_2$ known as hydrated lime. The process is called slaking.

15.8 Cement

The ordinary cement was invented by a Joseph Aspdin in England in the year 1824. The inventor took a patent and called it Portland cement as it resembles in its colour after setting to a variety of stone found in Portland. The raw materials for cement are (i) lime stone (ii) coal (iii) clay and (iv) gypsum. Cement can be made by two different processes (i) dry and (ii) wet process.

15.8.1 Composition of ordinary/Portland cement:

Lime (CaO) : 62%

Silica (SiO_2) : 22%

Alumina (Al_2O_3) : 5%

Calcium sulphate ($CaSO_4$) : 4%

Iron oxide (Fe_2O_3) : 3%

Magnesia (MgO) : 2%

Sulpher (S): 1%

15.8.2 Function of cement ingredients:

The properties of cement depend upon its composition, burning treatment and fineness of grinding. Good quality cement should provide strength, binding and water resistant in addition to working, quick setting and plasticity during construction work. The role of different constituents of Portland cement is presented below.

1. Lime: It provides strength and setting property but excessive lime makes the cement unsound and causes the cement to expand and disintegrate. Its deficiency causes less strength and quick setting.

2. Silica: It imparts strength due to formation of dicalcium and tricalcium silicate. The excess of silica improves strength but causes prolonged setting.

3. Alumina: It imparts quick setting property and acts as flux. The excess of it weakens the cement.

4. Calcium Sulphate: This ingredient is in the form of gypsum and its function is to increase the initial setting time of cement.

5. Iron oxide: It imparts colour, hardness and strength to the cement.

6. Magnesia: It imparts hardness and colour. The excess of it makes the cement unsound.

7. Sulpher: A very small amount of sulpher is useful in making cement sound. The excess of it causes cement to become unsound.

8. Alkalies: The excess quantity causes staining in concrete.

15.8.3 Setting action of cement

When water is added to cement, the ingredients of cement react chemically and form various chemical compounds. The mixture goes on thickening till it achieves a rock like state. It is found that ordinary cement achieves about 70% of its final strength in 28 days and about 90% in one year.

The important compounds formed during setting action of cement are as under.

· Tricalcium aluminate ($3CaO. Al_2O_3$): It forms within 24 h after addition of water to the cement.

· Tetra-calcium alumino ferrite ($4CaO. Al_2O. Fe_20_3$): It forms within 24 h after addition of water.

· Tricalcium silicate ($3CaO. SiO_2$): It forms within a week after addition of water to the cement. It is responsible for imparting strength in early period of setting.

· Dicalcium silicate ($2CaO. SiO_2$): It forms slowly and imparts progressive strength.

The above 4 compounds in Portland cement are designated in short as C_3A, C_4AF, C_3S and C_2S respectively.

15.8.4 Types of Cement

15.8.4.1 Rapid hardening cement/ high early strength cement:

The setting time of this cement is the same as that of the ordinary cement. The high strength at early age is due to finer grinding, burning at higher temperature and increased lime content in the composition. This cement costs a little more than ordinary cement. The strength developed by this cement in four days equals that acquired by ordinary cements in 28 days. Thus, it is very important in increasing the speed of construction.

15.8.4.2 Quick setting cement

Under normal conditions, quick setting is considered as a defect, as it does not allow sufficient time for the concrete to be properly mixed and placed. The addition of 3 to 4 % of gypsum is added to the ordinary cement just to retard the setting action. But under certain conditions, when concrete is to be laid under water or in running water, quick setting cement is required. Fineness of grinding and the addition of a small percentage of aluminium sulphate accelerate the setting action. The setting action of such cements starts within 5 minutes after addition of water and it becomes stone hard in less than half an hour.

15.8.4.3 High Alumina cement:

This is manufactured by melting a mixture of bauxite and lime and grinding the resulting clinkers. Total alumina content shall not be less than 32% and the ratio by weight of alumina to lime shall not be less than 0.85 nor more than 1.3. It is not only rapid hardening cement, but has also higher ultimate strength. It gives 6000 psi compressive strength against 2500 psi compressive strength obtained in 7 days for Portland cement. Its initial setting time is more than 3.5 hours and final setting time is 4 to 5 hours as against 0.5 hours and 10

hours respectively in case of ordinary cement. It therefore allows longer time for mixing and placing concrete before it begins to set.

High Alumina cement is immune to thermal shocks and great heat is evolved during setting and hardening. It does not expand on setting. It possesses great resistance to corrosion action of acid and also to high temperatures. Thus it is found very useful in chemical plants, mines, dairies etc. and also for lining the furnaces. It is also high resistant to sea water.

15.8.4.4 Acid resistance cement

The addition of additives like sodium fluosilicate accelerates the hardening process and it increases the resistance to acid and water. It also contains acid resistant aggregates.

15.8.4.5 Coloured cement:

The cement of desired colour may be obtained by mixing pigments with ordinary cement. The amount of colouring material may vary from 5-10%. The use of chromium oxide and cobalt pigments imparts green colour and blue colour respectively while iron oxide and manganese oxide gives brown/red colour and black or brown colour respectively.

15.8.4.6 White cement

It is prepared without colouring oxides. The process of making the cement is slightly different as coal is not used for burning. White cement is used for fixing marbles, filling of joints in flooring and glazed tiles. It is relatively costly as compared to Portland cement.

15.9 Mortar

The paste prepared by adding required quantity of water to a mixture of binding material like cement and sand is known as mortar. The proportion of cement to sand varies between 1:2 and 1:6 depending on the use of mortar. It is desirable to use the mortar within 30 minute after addition of water. After setting of mortar, it should be kept damp or wet by sprinkling water to avoid drying of mortar for about 7 to 10 days.

15.9.1 Properties of mortar

The properties of good mortar are listed below.

· Good adhesion with the building.

· Capable of developing required stresses.

· Capable of resisting penetration of water

· Durable

· Good workability-mobility

· Good placeability

15.9.2 Uses of mortar

- Binding material for building materials (bricks, stone etc.)

- Plaster work
- Bedding layer for building units
- Joining of cement pipes, filling of cracks.

15.10 Cement concrete

The cement concrete is a mixture of cement, sand, pebbles or crushed rock and water which when placed in the skelton of forms and allowed to cure, becomes hard like a stone. The cement concrete in which steel reinforcement is placed at suitable places to increase tensile stress is called Reinforced Cement Concrete (RCC). The proportion of cement, sand and course aggregates varies from 1:2:4 to 1:3:6 depending on the nature of work. As per BIS, the concrete is designated in 7 grades. These grades are M 10, M 15, M 20, M 25, M 30, M 35, M 40 (M refers the mix and number indicates the compressive strength of 28 days in N/mm^2). The following points are important for R.C.C.

- < M 15 should not be used in R.C.C. work
- Water-cement ratio by weight should be 0.45 –0.55
- Weight of water = 28-30% weight of cement + 4-5% weight of total aggregate.
- Thickness of R.C.C. work : 80 to 150 mm
- Proper mixing of all materials – using mechanical mixer is very essential.
- Placing of concrete within 30 minutes
- Consolidation using vibrator helps in reducing air bubbles and increases the strength of R.C.C . Hand consolidation which includes ramming, tamping, spading, slicing with suitable tools.
- Provide expansion and contraction joints if length exceeding 12 m.
- Dummy joint – 3 mm width and 1/3 to $1/5^{th}$ of slab thickness in depth and it is filled with filler materials.

15.10.1 Curing of concrete

The concrete surface is kept wet for certain period after placing of concrete so as to promote hardening of the mixture. Curing period is about 7 to 14 days. Ponding with water, covering with wet jute bags, intermittent spraying with water etc. may be used for curing.

15.10.2 Water proofing cement concrete

The impermeability of concrete is very essential. If concrete is made dense and free from cracks, it is watertight. This can be achieved by closely adhering the following points.

- Using high class Portland cement
- Adopt correct proportioning of sand, cement and aggregate.
- Using clean and non-porous aggregates

- Proper mixing at optimum water quantity.
- Careful placing, tamping and curing.

Using suitable water proofing compound.

15.11 Stones

Stones are obtained from rock, a portion of the earth's crust having no definite shape or chemical composition. Stones are used as the construction material for the following.

- Material for foundations and walls of buildings, dams, bridges
- Material for road and concrete making in the form of either broken or crushed stones called aggregates/ gravels/ peebles.
- Used as thin slabs for paving/flooring.
- Used as roofing tiles
- Lime stones are used as a flux material in the blast furnaces
- In view of several artificial materials developed recently for flooring and roof, the use of natural stone in many applications has become limited.

15.11.1 Requirements of good structural stones

When stone is used as structural material, the following considerations are to be considered.

(i) Strength: It should be sufficiently strong against crushing. The stones having more compact grains with higher density are stronger. A dense and compact stone has very few or no pores and thus does not absorb water. A stone of igneous origin is stronger than one of sedimentary formation. A crystalline stone is superior to a non-crystalline one and the finer the crystalline structure, the stronger it is. The specific gravity of good stone should not be less than 2.7. It is desirable to have crushing strength of building stone more than 100 N/mm^2. The crushing strength of some commonly used stone is given below.

· Granite: 75-127 N/mm^2

· Sand stone: 64 N/mm^2

· Lime stone: 54 N/mm^2

· Durability: It depends on (a) chemical composition (b) physical structure (c) weathering effects and (d) place or position in the structure. It depends on type of stone and working conditions.

· Appearance: The appearance of a stone in relation to the design is of great importance from an architectural point of view. Appearance depends on the colour and the ease with which stone can be dressed, rubbed or polished, for which slightly softer stone is selected. It is desirable that the colour of stone is uniform, no weathering effect, and free from clay holes.

· Dressing properties: The ability of stone for cutting, carved etc is important for building material. In order to perform dressing operations with ease, it should be relatively soft with compact grains. Stone should be homogeneous in texture rather than crystalline. The development of many machines and advancement of technology, the dressing of even hard stone has become quite easy for many applications of stones.

· Hardness: It is expressed in terms of co-efficient of hardness. The common accepted norms for various categories of hardness are greater than 17 considered as high, between 14 to 17 as medium hardness and less than 14 as poor hardness.

· Wear percentage: If the value of wear is more than 3 percent, then the stone is regarded as unsatisfactory.

· Seasoning and Weathering: After quarrying stone should be seasoned for 6-12 months and there should not be any change in various properties. A good quality of stone should not show remarkable weathering effect.

· Texture: Stone should be free from cavities, cracks etc.

· Toughness: It is expressed in terms of toughness index. The common accepted norms for various categories of toughness are greater than 19 considered as high, between 13 to 19 as moderate toughness and less than 13 as poor toughness.

· Water absorption: The absorption of water should not exceed 0.6 % of weight.

15.11.2 Basis of classification of stones

There are 4 basis of classification of stones as under.

1) Geological (based on mode of formation)

2) Physical (depending upon structure)

3) Chemical (depending on composition)

4) Practical (based on use)

15.11.3 Use of stone

Use of natural stone is various purposes is given below.

(i) Structure (ii) Face work

(iii) Paving (iv) Basic material

15.11.4 Stone Quarrying

The process of taking out stone from natural rock is knows as quarrying.

15.11.5 Artificial stones

- Cement concrete blocks
- Mosaic tiles

- Terrazo
- Ceramic tiles

15.12 Wood

Wood is of two types – hard wood and soft wood. Hard wood is used for building construction and soft wood is mostly used for packaging material and boxes. Plywood is obtained from inferior quality wood after some processing, and it is used for making furniture. Hardwood is seasoned to reduce moisture content and is also treated with creosote oil. Hard woods are used in the room where moist conditions prevail and it is properly seasoned to prevent any kind of mould growth and contamination. Soft woods are used in the dairy for cold store doors and covered with stainless steel sheet.

Soft wood is obtained from trees of Deodar, Kali, Chir, Pine, Walnut and Spruce etc. Soft woods are resinous and light in colour. It is general characteristics that trees having needle like leaves give soft wood.

Sal, Teak, Shisham, Pyngado, Oak, Beach and Ash are some of the examples of hard wood obtained from broad leaf trees. Hard woods are relatively darker in colour, heavy, close grained and strong. They are non-resinous.

15.12.1 Timber wood

Timber wood is suitable for building or engineering purposes. When in living tree, the timber is called 'standing timber'. When trees are cut down, it is called 'rough timber' and when it is sawn into various market sizes, such as beams, battens, posts, planks etc., it is called 'convert timber'

15.12.2 Seasoning of wood

The growing tree contains a large amount of moisture which may be 150% of the dry weight of the timber. The process of removal by drying the excess moisture from the wood in a controlled manner to prevent the shrinkage which occurs, causing cracks and other defects is called seasoning. Seasoning may be natural or artificial. Natural seasoning is best but it takes long time. Artificial seasoning may be water seasoning, boiling or kiln seasoning.

15.12.3 Preservation of wood

Timber is liable to attack by dry rot and other fungi. The function of a preservative is to poison the food matter in the timber. But this poison should not be dangerous to carpenter and must not wash out in rain. The best time to apply preservatives is the early summer. The usual methods of preservation are tarring, charring, painting, creosoting, solignum paints and Ascu treatment.

Tarring consists of coating the timber with hot coal tar. Tarring is adopted only for work of rough character such as timber fences, ends of doors and window frames built into walls.

Charring is adapted to the portions which are embedded in the ground. The ends of posts are charred over a wood fire to a depth of about ½" and then quenched with water. Painting consists of applying 3 or 4 coats of an oil paint. Solignum paints are effective preservatives against attack by white ants. The process of Ascu treatment for the

preservation of wood has been developed at the Forest Research Institute at Dehradun. The powder developed for the purpose is dissolved in water. Six parts of powder are dissolved in 100 parts of water and then applied or sprayed on timber.

15.12.4 Fire proofing

Wood can catch fire very easily and it is difficult to make it fireproof. However, chemicals such as 2 coats of 2% solution of Borax or sodium arsenate are effective in retarding the action of fire.

15.13 Metals

Metals are used in the dairy for different purposes. Mild steel is used for fabrication of sheds, grills, foundations, pipelines, and as structural steel. Cast iron is used for drainage of effluent as well as for the fabrication of various components of machines. Stainless steel is used for fabrication of dairy equipment and milk pipelines.

15.13.1 Stainless steels (SS)

Stainless steels were invented to overcome the problem of corrosion which is a major concern of food and many other industries. The alloy of steel containing iron-chromium-nickel is known as stainless steels which do not rust in sea water and are resistant to acids and several other chemicals. Stainless steels typically contain between 9 and 30 percent chromium and varying amounts of nickel, molybdenum, copper, sulfur, titanium, niobium, etc., may be added to obtain the desired mechanical properties and service life. Having all these properties, SS are widely used in dairy and food industry. Stainless steel is considered noble metal for use in dairy industry. Stainless steels are classified based on the chemical composition and it provides information to overcome many types of corrosion. Some of the limitations of SS employed in food and dairy industry are attack by lactic and malic acids at elevated temperature and poor thermal conductivity. However, these limitations may be overcome by carefully selection & fabrication, optimized operating condition, care and maintenance of the equipment.

15.13.1.1 Classification of SS

Stainless steels are basically classified as austenitic, ferritic, martensitic, duplex and super-austenitic grades. Each of these main groups contains a number of alloys that are defined according to the chemical composition and specified in European and American international standards. Apart from chromium, the alloy constituents molybdenum, nickel and nitrogen are of great importance to the corrosion resistance. Carbon will always be present to a certain degree, and it is important for the welding properties. In addition, copper, manganese, sulphur, titanium and niobium are used as alloy constituents to impart certain properties. Stainless steel is typical wrought alloy AISI (American Iron and Steel Institution) series designations, includes: 200 (high manganese austenitic), 300 (austenitic), and 400 & 500 (ferritic & martensitic). Martensitic and ferritic steels are magnetic and martensitic steels are typically hardened by heat treatment and are not easily formable. Austenitic steels harden when cold worked. Duplex grades (austenitic/ferritic) are more resistant to stress corrosion cracking than austenitic and are tougher than ferritic grades.

15.13.1.2 Desirable properties of SS

The properties of stainless steel play an important role in the design of various equipments. The use of high quality SS in fabrication of processing equipments helps not only to prevent corrosion but also ensures purity of food product handled in those equipments. In addition to this, stainless steels are easy to clean and maintain and a number of different products can be manufactured in the same equipment. If properly utilized, equipment made of stainless steel can be expected to last for many years. In selecting austenitic stainless steels, a number of factors other than corrosion performance should be considered. Among these are their usually attractive appearance, good mechanical properties, and excellent fabrication characteristics. On a life-cycle basis, the alloys are often the most cost-effective. Important characteristic to be considered in selecting the proper type of stainless steel for a specific application are listed below.

· Corrosion resistance

· Resistance to oxidation and sulfidation

· Strength and ductility at ambient and service temperatures

· Suitability for intended fabrication techniques

· Suitability for intended cleaning procedures

· Stability of properties in service

· Toughness

· Resistance to abrasion, erosion, galling, and seizing

· Surface finish and/or reflectivity

· Physical property characteristics such as magnetic properties, thermal conductivity and electrical resistivity

· Total cost, including initial cost, installed cost, and the effective life expectancy of the finished product

15.13 Steel

Steel is an intermediate stage between cast iron and wrought iron. The cast iron contains 2-4 % carbon while wrought iron has carbon content less than 0.15%. In steel, the carbon content varies between 0.25 to 1.5 %. There is no graphite in the steel. The steel becomes harder and tougher as its carbon content increases. Steel is used for various applications in dairy industry.

15.14 Aluminium

Aluminium is used as frame work for doors and windows in dairy and food processing plants. The desirable properties of aluminium which makes it suitable are light weight, softness, and appearance. Its use is limited by the fact that it is tarnished and corroded by ordinary alkaline dairy cleaners and sterilizers.

Lesson16. Building construction

16.1 Plant flooring

Flooring requirements for different sections of food plant has specific needs depending on the type of sections. The flooring of process section has its typical requirement of resistance against acids, alkalies and thermal shocks, this will be met by specific type of stones e.g. mandana stones. The flooring of cold store has specific requirement of non-slippery flooring with hygienic conditions to be maintained, such requirements will be met by semi vitreous tiles. The flooring of RMRD has specific requirement of good mechanical strength, resistance against the detergents, less noise problem etc. The flooring of section for fermented liquid products like, Dahi, Cheese, Yoghurt etc., requires vitreous category of tiles to maintain hygienic conditions. Thus, flooring materials for different sections are selected based on the need of the particular section to meet sanitary standards.

16.2 General requirement of plant floors

It is necessary to use different types of the flooring material depending upon the use of the flooring surface. One single type of floor in the entire plant is not possible if wear is to be kept to a minimum. Plant floor requires different types of flooring in order to cope with hazards and other problems of various sections. It is desirable that floors should impervious, durable and long lasting. The material of flooring should be such that it can be cleaned easily, if required, non-slippery and cost effective. The flooring is designed considering the effect of washing and cleaning as well as and the ability to withstand changes of temperature by provision of adequate expansion joints.

The provision of adequate fall and drains helps not only to avoid the possibility of water pools but also assists the rapid removal of milk spillage and cleaning solutions. This helps in reducing the corrosion effect to the flooring materials. Normally, the fall should not be less than 1 in 80 for effective removal of liquids. Drainage channels should be at least 15 cm from the wall and drainage channels should not be placed along side walls, as far as possible. Water seepage may cause corrosion of structural steel and weakens the flooring base or R.C.C. Fig. 16.1 shows a cross section of construction of floor.

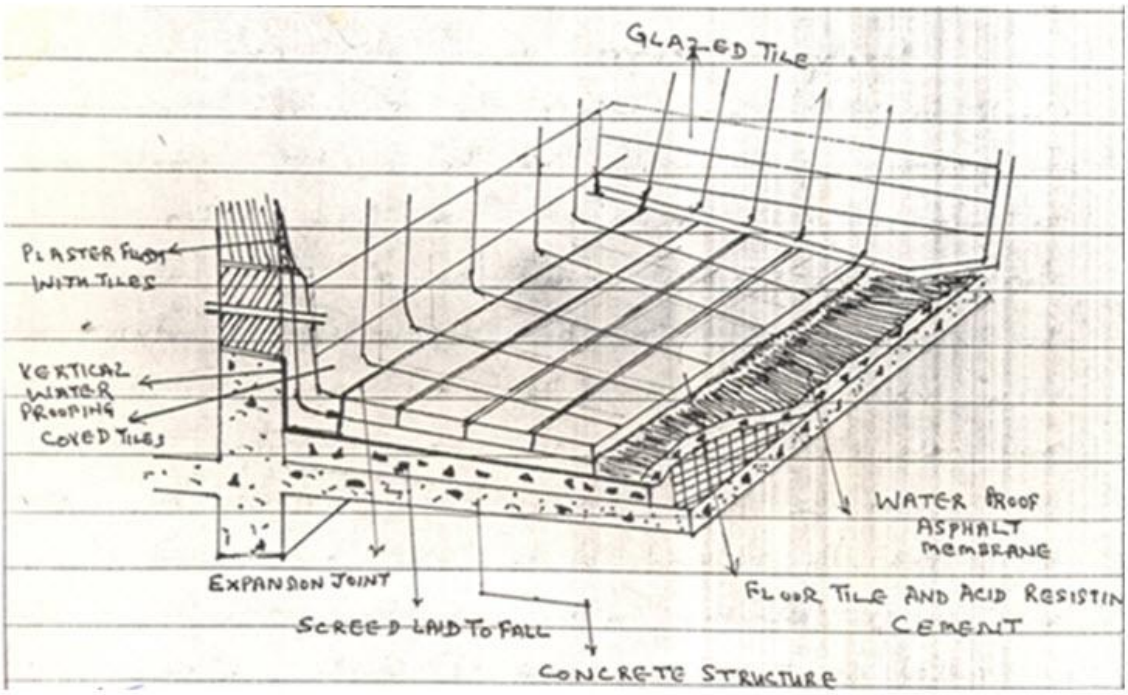


Fig 16.1 Cross section of floor construction

16.3 Structural base

The structural base is usually of concrete or R.C.C. A concrete structural base may be cast as a slab directly on the ground/R.C.C. or it may be suspended slab pre-cast concrete units. It should be designed to resist all the static and dynamic stresses with provision of heavy foundation required for installation of equipments. The structural base should be made of good concrete and thoroughly compacted.

16.4 Waterproof membrane

One of the most important features at the time of planning and designing of the food plant floor is the use of water proof membrane in the floor to prevent liquids from penetrating to the base structure. The membrane should be impervious to water, resistant to corrosion, tough enough to resist damage during repairs of the floors and support loads. All joints should be thoroughly sealed to provide a continuous membrane surface. The membrane should be laid to have falls at the base structure and be extended to some distance up the walls. The material used for the membrane must be strong and yet flexible. Acid resistant asphalt laid at least 10-12 mm thick on a layer of bitumen felt is most commonly used. The best results are obtained when the asphalt is laid in two layers with all construction joints broken, i.e. two layers don't have their joints coinciding. Good quality bituminous roofing filled with lap joints sealed with bituminous compounds is also used. Plastic films of polyethylene, polysorbetylene and polyvinyl chloride are also used for the purpose. Properties of water proof membrane are as under.

- Water proof membrane should be impermeable to water.
- It should be resistant to corrosive liquids and substances.
- It should be strong enough to support the required load.

16.4.1 Types of water proof membranes

· Plastic sheet

· Chemicals

· Asphalt or Bitumen layer in the form of a thicker layer which is applied on walls to prevent leakage of water.

16.5 Flooring materials

Portland cement concrete is mostly commonly used as flooring material. The floors are resistant to abrasion and alkali. However, it is vulnerable to weak acids and deteriorates under the influence of liquid waste i.e. milk.

High alumina cement concrete resists acid solution above a pH 5.0 and is favorable than plain Portland cement. However, it is attacked by weak solutions of alkali and it loses its strength and resistance to abrasion under hot moist conditions. Hence, it is not regarded as a suitable flooring material for dairy plant.

Portland cement concrete often gives good service even where milk spillage occurs provided that regular cleaning takes place to remove the dairy wastes. Concrete floor shrink for several months after lying, but subsequently it expands and contracts with variations of temperature and moisture content. Such expansion and contraction may be of the order of 0.05% which may give rise to cracking or curling. Where plain concrete floors are likely to wet, joining gaps of about 12-13 mm (0.5″) width should be left open down to the waterproof membrane, and after the concrete has set, they should be filled with asphalt or other suitable joining material. The floors which may be subjected to considerable attrition and abrasion, the structural base should be covered by a topping of more resistant granolithic concrete.

Granolithic concrete contains more cement than ordinary cement concrete and gives good results in dairies, although its surface can be corroded slowly by lactic acids, milk residues and acid detergents. There is no shrinkage after laying concrete tiles which is made of granolithic concrete and cured under controlled conditions. They are laid in cement mortar of ratio 1:3. The joints between 1/8 and ½ inches wide must be completely filled with the same mortar. Concrete tiles may be tinted and similarly tinted mortar should be used for the joints.

Ceramic floor tiles can be used for flooring where moderate resistance to wearing is expected. These tiles are resistant to attacks by acids and alkalis. These tiles are available in different sizes such as 6″ x 6″, 9″ x 4.5″, 9″ x 6″, 9″ x 9″, 12″ x 12″ etc. These tiles should be thick so as to resist impact damage. Coved tiles should be used at joints between floors and walls. The tiles should be properly laid using appropriate bedding mortar and high grade filling material.

16.5.1 Requirements of a food plant floor or characteristics of a food plant floor

- They should be impervious, smooth and easy to clean.
- It should be able to withstand the effect of lactic acid.
- It should be able to resist the effect of the cleaning solution, steam or hot water.

- It should be strong enough to withstand the effect of falling objects, cans, boxes (impact resistance)
- It should have high resistance to abrasion (wear and tear).
- It should have desired slope towards drains
- In processing section, the slope should be 1:80.
- In bottling section and RMRD, the slope should be 1:40.

16.5.2 Different types of floor:

- Cement concrete floor
- Terrazzo floor used in offices
- Tile floor having either natural stones or synthetic tiles
- Metal floor
- Grill floor

16.6 Bedding and jointing for tile floors

The optimum result can be achieved by adopting most appropriate way of laying and filling the joints. The materials used for the purpose mainly depend on the type of flooring material used in different sections of a plant. Some of the ways of bedding and joining the floor tiles are given below.

16.6.1 Portland cement

Portland cement mortar is most commonly used for bedding material for fixing floor tiles/stones. Portland cement mortar is resistant to alkalis, but it is attacked by acids and dairy wastes. It is necessary to take adequate care to make water tight joint.

16.6.2 Super sulfated cement

Super sulfated cement is a mixture of ground blast furnace slag, calcium sulfate and Portland cement. It requires special care during hardening after laying. It is resistant to acidic and alkalis.

16.6.3 Rubber latex cements

Rubber latex cements are available for in situ floorings and are based on polyester and epoxy resins. Unsaturated polyesters which in the presence of a catalyst, react with another resin such as styrene, are usually employed for polyester flooring. It is susceptible to attack by alkalis and therefore cannot be used in dairy plants.

16.7 Metal tiles, plates and grids

Metal tiles of two main types.

1) anchor steel plates

2) cost iron metal tiles

Both types are very suitable to resist impact and abrasion in dairies. They also resist the action of alkalis but they are subject to attack by weak acids.

The anchor plate is usually 12″ x 12″size made of 10 gauge steel in the form of a shallow tray of about 7/8″ thickness and the wearing surface is punched to give downwardly projected twisted anchors which anchor the plate to the bedding material. For laying the anchor plates, upturned tray is filled with concrete and after inversion it is tamped into position until it is firmly embedded in the concrete.

The cast iron metal steel is made of a square or a right angled triangle, apart from the hypotenuse, the sides of each type are 12″ long and the tile is about 1″ thick and has a projecting foot at each corner. These tiles are bedded in cement mortar and tamped down until the feet rest firmly on the structural base, so that the stresses on the tile are transferred evenly to the structure.

Metal plates are used frequently on dispatch docks and in cold stores to provide very durable wearing surfaces over concrete flooring. Metal grids are sometimes incorporated in floor surfaces as reinforcement against abrasion and are embedded in the topping so that the upper side of the grid is flush with the floor surface.

16.7.1 Cast iron grill floor

Cast iron tiles have a hollow honey comb-like structure which gives a strong surface and has no slipperiness. This type of tiles has no problem of looseness from concrete surface. It gives less noise than metal tiles when cans are moved over it. This floor has high impact and abrasion resistance. Some time, concrete part of cast iron grill floor may be eaten away due the action of h milk or acid. .

16.7.2 Cement Concrete Floor

The general construction includes a structural base of RCC or concrete, a screed laid to fall, a water proof membrane, a bedding mortar and a top finishing surface or layer or a wearing surface.

16.7.3 Curing of concrete:

Curing of concrete is necessary to increase the strength and water tightness as cement reacts with water at a slow rate and it then becomes hard. The aggregate then formed has no reaction but it forms a strong bond and fills in the pores. Normally the structural base is 10-15 cm thick. Concrete food plant generally comprises cement to sand to aggregate in the ratio 1:3:5.

16.8 Bedding mortar:

The layer of the bedding mortar is generally kept around 2-3 cm thick. It has a ratio of cement to sand as1:3. Its function is to give attachment to the top surface.

16.9 Terrazzo floor

It is similar to concrete floor, and is generally used in offices, labs and such other places where decorative effect is required. Before hardening the top surface, marble chips of irregular shape are fixed on the upper surface and pressure is applied so that the marble chips get embedded on the wet top surface of the cement floor. After hardening, the surface is finished smooth so that the marble chips fixed on the top give a good appearance. Colored cement may be used to impart better look. Its main limitation is that it cracks when it comes in contact with hot and cold water due to thermal expansion and contraction.

16.10 Tile floor

Two types of tiles can be used viz. natural stone or synthetic (artificial) tiles.

16.10.1 Natural Stone or Kota Stone:

It is obtained from quarries and is then cut to the required size. They are available in different colors like red, buff, light green, brown and yellow. Acid resistant Kota stone (popularly known as *Mandana* stone) is also available, which can be used in the food industry. In order to be used in the food plants, the stone should have a minimum thickness of about 3 - 4 cm. They may be square or rectangular and should have a 90^0 angle edges. The top surface should be polished and the bottom is kept unpolished to get better gripe with bedding mortar.

16.10.2 Concrete or Cement Tiles/ Artificial Tiles

These tiles can be made by making the desirable size mould using mortar and then hydraulic pressure is applied to make it non-porous and stronger. Marble chips of different colors may also be included in this type of tiles. Cement may be high alumina cement or colored cement. The size of the tiles may be 12″ x 12″, 18″ x 18″ etc. These tiles are cured in water for 5-7 days and subsequently laid on bedding mortar. Various types of grinders are employed for surface finish of the floor. These types of tiles are rarely used as many other verities of tiles are available.

16.11 Maintenance of floors

The following points should be considered for the maintenance of the floor of different sections of food plant.

1. Regular cleaning floors is essential for hygiene, safety and long life of floor.
2. All the joints should be carefully observed for any water/milk/chemical penetration through the joints. Seal the joints using cementing material, if any defect is noticed.
3. Remove waste water etc. from the floor in order to cause insanitary or slippery conditions.
4. Floors soiled with oil should be cleaned by scrubbing with detergent and water.

5. In milk handling plant Lactic acid are formed as milk sours, therefore, early removal of spilled milk is desirable.

6. Use appropriate chemicals or combination of chemicals for floor cleaning. Don't sprinkle chemicals on the floor as it may damage the floor surface. Use mild detergent solution with low free sulphate is recommended for floor cleaning.

7. Hand scrubbing with brushes or electric scrubbing followed by rinsing with clean water is recommended.

16.12 Structural aspects of foundations, roofs, ceilings, walls, doors and windows

Structural aspects of plant building are very important as it is necessary to design the plant considering strength and vibrations of machines. The design aspects of roofs, ceilings, walls etc. are carefully designed to maintain required hygienic conditions in the plant. The basic principles of design of dairy building are the same as that of normal factory building. Adequate care is necessary to consider sanitary aspects while designing and selecting building materials.

16.12.1 Foundation

Foundation of building should be strong enough to support super structure and to resist vibrations and impact load of heavy machineries. The design of foundation depends upon the nature of structure which they have to carry and the properties of soil the soil. The structure may consist mainly of load bearing columns/walls which are required to support the structure. It is necessary to work out the total load to be supported. The actual design of foundation is based on these aspects as well as the quality of sub-soil.

16.12.1.1 Traditional strip foundation

This is the most usual variety and consists of concrete say 9 inches thick laid at the bottom of the trench 3 feet deep. The width that the concrete extends beyond the faces of the wall depends upon the bearing capacity of the soil. It is necessary to follow standard guidelines to decide the width of the concrete. These aspects depend on the local soil conditions as well as factor of safety to consider in the design of the building. It is not possible to generalize the design aspects of foundation. There are regions where the traditional foundation with load bearing wall is not recommended owning to soil conditions reveling in that area. Column and beam type of structure may be required to support the load and other stresses.

16.12.1.2 Stepped foundation

The foundation of building should be strong enough to support the superstructure. The size of foundation is governed by its depth and width which are determined by the soil type and load acting on it. The size of the foundation should be determined on the basis of bearing pressure of the soil in which it is built.

A typical section of stepped foundation for 13.5 inch thick wall is shown in Figure 16.1

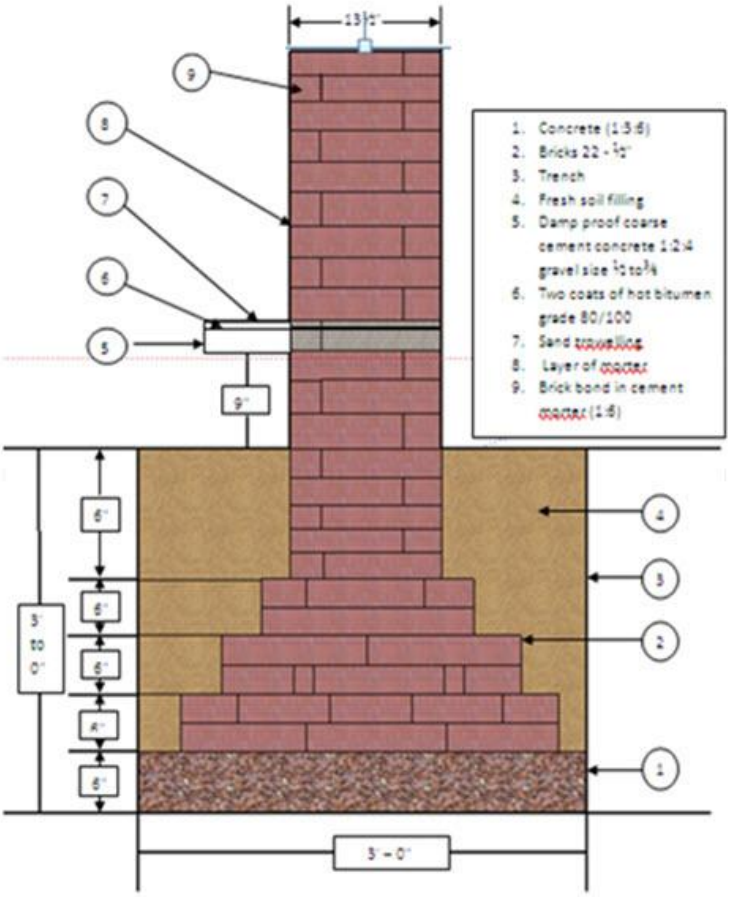


Fig 16.2 Section of stepped foundation

16.12.2 Walls

Walls for plant buildings are made of brick, concrete, concrete block, aluminum and glass. Bricks are widely used for the construction of walls. It is relatively cheaper and proper plastering and painting makes the walls quite water proof. In many sections, glazed tiles are laid up-o the height of 7 feet or more for ease of cleaning. With adequate care, repairs can be made without spoiling the appearance of the building.

Concrete walls are relatively costly and repairing is difficult. Provision is necessary to tackle the need of unsightly repairs. Aluminum partition walls can be made using flat panel construction or corrugated sheets. Glass panels used in building give good lighting but it is essential to keep the glass surfaces clean.

Walls which are made up of brick or stone are mainly two types.

- Partition wall: To divide an area into two or more compartments or cabinets, etc. The width of partition wall using standard brick is about 4″.
- Load bearing wall: Walls which can take loads of structure of ceiling or of superstructure. The width of the load bearing wall using standard brick is 14″ or 9″.

16.12.2.1 Construction of brick walls

The dairy buildings are of two types namely single or two storey building having load bearing walls. Another type of building is having column and beams which supports the entire load of the building. The load of the building is transferred to the soil by beam and

columns. It may be multi-storied building or even single storied building. In this case, walls are simply dividing the area in to different portions/sections. The strength of wall is not much important as the entire load is taken by beams and columns. If the size of room is small in case of load bearing structure, beam is not required. The external walls take the load and transfer it to the soil. In construction of walls using bricks, it is desirable to staggered the joints. Mortar of suitable proportion of cement to sand ratio is recommended for different types of walls. Optimum quantity of water is necessary in the mortar for proper spreading and setting of plaster.

16.12.2.2 Surface finishing for walls

Plastering using cement to sand ratio of 1:2 or 1:3 is used for surface finish of walls. The plaster is generally applied in two coats (1) floating coat and (2) finished coat. The floating coat of the plaster is 1.5 to 2.0 cm thick. The main purposes of plastering are as follows.

- To hide irregularity of walls (grooves)
- To avoid unevenness of wall during construction
- To improve the appearance of the wall
- It provides or facilitates the application of suitable paint
- It also prevents deterioration and protects the wall from external atmospheric effect.

Ceramic glazed tiles/vitrified tiles are also used for the purpose of wall finish.

16.12.3 Ceramic/Glazed Tiles

Glazed tiles are laid up to the height of 2 m in the processing room and other sections of dairy plant. The use of glazed tiles provides a surface which can be easily cleaned and hygienic conditions can be maintained. These tiles also make the wall waterproof.

16.12.3.1 Classification of Tiles

- Non – vitreous: Non-vitreous tiles has a high degree of moisture absorption greater than 7% of the weight of the tiles. Even though, it does not prevent the tiles from having high degree of strength and it also facilitates installation because of their adherence to the mortar.
- Semi-vitreous: These tiles have a high density that limits the moisture adsorption to 3-7% of the weight of the tiles.
- Vitreous: These tiles have a moisture absorption of 0.5 to 3.0%.
- Impervious: These tiles are the hard and their moisture absorption is less than 0.5% and they are readily cleaned off stains and dirt.

In lower portion of the wall of RMRD and cold store, damage may occur. Skirting is provided in the processing room to make lower portion of the wall hard. Bumper rails in cold store and railing on the walls are provided to prevent the damage due to crates/cans.

Wherever walls are not covered with tiles, they are plastered and painted. Use of good quality paint is recommended for painting of walls.

16.12.4 Doors and windows

Doors and windows are subject to gruelling condition existing in food plant. The door of stainless steel is the best choice in many food plants. Hard wood or water proof plywood may be used for making doors and windows. Aluminum or aluminum alloys can be used but the alkaline cleaning materials which are used in milk plants may spoil the surface. Doors of ordinary steel sheet on a steel base are sometimes used, but in such cases, the whole door must be galvanized or protected against corrosion.

Plastic sheet can be used with a wooden or metal frame. There are many options available for the selection of doors and windows. It depends on the requirement, cost, maintenance etc.

Doors for cold rooms must be thermally constructed from timber/PUF panels and cladding of S.S. may be used for protection of insulation. All door fittings should be of rust proof material and of robust construction, particularly in case of swing doors. The locking mechanism for cold store room doors must always be such that it can be operated from inside the cold room.

16.12.4.1 Doors

The provision of doors in a building should be carefully made considering the movement of materials, persons, location of door, size requirement, type of door etc. The height of the door should be more than 2m inside the frame. Regarding the width of the door, it should be designed for the particular requirements. Usually, it varies from 0.75 m to 1.5 m depending on the type of the room. When the width is more than 1 m, double shutters may be used. The normal height of door is 2 m but it may be more in case of workshop, boiler room and garages. A rolling shutter may be used for large size doors especially in boilers, garages and workshop. The number of doors depends on the type of room and size of the room. Hardwood or laminated plywood may be used for preparation of doors. Wood or plywood doors should be protected from moisture and water by painting.

Types of doors:

- Ledged door
- Ledged and braced door
- Frame and ledge door
- Frame and panelled door
- Louvered door
- Flush door
- Door without hinges
- Sliding door

- Rolling steel door
- Collapsible door
- Revolving door

Flush doors are manufactured in standard sizes to facilitate mass production. It consists of a skeleton or hollow frame of rails and stiles covered with plywood or any other type of reconstructed wood. Louvered doors maintain free flow of air and also maintain privacy. The door without hinges such as sliding door, rolling door etc. are used in large size doors.

16.12.4.2 Windows

The purpose of providing windows in building is to get ventilation and natural light. Openable windows provide both air and light, while non-openable windows provide only light. The size of window and its location are very important to achieve optimum advantage. In deciding the location of windows cross ventilation is kept in mind for office building. Fixed glass windows are also provided in plant building to get natural illumination. It is recommended that

1/10th of the floor space is allowed for the window, of which one half should be capable of opening, when required. Another thumb rule adopted is that window area is equal to the square root of the cubic contents of the room.

The exact location of the windows depends also on the purpose for which the room is used. For example, in an ordinary living room, the sill of the window should be kept at about 2.5 feet over the floor level while in bathrooms or a lavatory. The window will be kept at a higher level, so that even when the shutter is open, there should be privacy to the occupant. The window sill should be at a height of about 0.8m height from the floor. The height and width of the window depends on the type of window and number of windows. Entry to dust and insects should be prevented in the product processing room by providing a wire mesh. Total window area may be 20-25% of floor area.

16.12.5 Roofs and ceilings

The use of R.C.C.is widely used for roofs and ceilings. The R.C.C. is designed and executed properly to prevent leakage of water. Water proofing work is necessary to eliminate the chances of water penetration in the R.C.C. Use of good quality materials and proper workmanship during R.C.C. work is necessary to get better result. It is necessary to carry out curing of R.C.C. immediately after setting of the R.C.C. White ceramic/glazed tiles may be laid on the terrace to reduce the heating effect and to make the R. C. C. water proof. It depends on the local weather conditions to decide the need of water proofing requirements.

Slope is provided on the top to facilitate drainage of water. The thickness of the slab varies from10 cm to 15 cm depending on the size of the room and other structural considerations. Height of processing section is more in order to facilitate the service pipelines.

Roofs are classified as flat, semi-steep and steep depending on the slope provided. Flat roofs have rise from zero (level) to 8 inches per horizontal foot. The rise in semi-steep roofs varies from 3.25 to 12 inch rise per horizontal foot. The rise of steep roofs varies from 13 to 24 inch rise per horizontal foot. In many factories and food plants roofs are generally flat or semi-steep type.

The roof sheet of different materials such as PVC, fibre glass (FRP), polycarbonate etc. in various design are available for making roof of factory. These materials have advantage of light in weight and colour choice based on the requirement of the plant. Construction of a satisfactory roof is possible only when high standards are maintained during all phases of its construction. The selection of material for roof mainly depends on the weather conditions of the place. There are options available to select the best possible roof for the plant. Ceilings of the food plant must be smooth and impervious so that it can be easily cleaned and maintained. In the plants where air ducting is necessary, it is carefully planned with false ceiling of appropriate material.

16.13 Drain and drain layout for food plant especially dairies

The ratio of milk to water used in various dairy plants varies from 1:1 to 1:3 depending on the type of plant. The old figure of water use was quite large but now water conservation measures resulted in to considerable low level of water consumption. Water is mainly used for washing of equipments, floors, milk crates/cans, hot water, chilled water etc. When water is used in dairy plants, it is necessary to provide drains and piping arrangement to transfer the waste water to effluent treatment plant (ETP) of the dairy. The drains and pipeline layout should be such that it maintains hygienic conditions in the processing area and waste water containing milk resides is efficiently collected from all the sections and finally supplied to the ETP plant.

16.13.1 Drainage system for plants

Drainage system is very important in any dairy and food plant. Therefore, it is one of the essential considerations at the stage of planning and design of processing building. It is important to provide adequate numbers of sanitary drains coupled with waste water conveying system to transfer the effluent to the treatment plant. Any shortcomings may lead to choking of drainage pipelines and unhygienic conditions in the plant. Cast iron or PVC pipelines are commonly used for conveying of effluent in dairy plants. The planning and lay out of the drainage system is done in such a way that it is possible to separate high BOD and low BOD effluent. This is necessary to adopt different methods for the treatment of effluent. Anaerobic method of treatment of high BOD effluent is getting considerable importance in dairy industry as its operating cost is low and it generates methane gas which can be used for boilers. The following points should be considered while planning and laying of drainage system.

1. Select the most appropriate type of drains and entire system considering hygienic conditions.
2. Use the drains which can be cleaned easily.
3. Provide adequate number of drains considering the maximum flow of water.
4. Use of 4″-5″ (100 mm to 125 mm) diameter pipe for drainage lines for handling milk plant wastes.
5. Regular cleaning of sanitary drains is recommended to avoid chocking of drainage system.

16.13.2 Floor traps for plant floors

A trap is a device which is used to prevent sewer gases from entering the processing area of the building. The traps are located below or within a plumbing fixture and retains small amount of water. The retaining water creates a water seal which stops foul gases going back to the processing area of the building from drain pipes. A good trap should maintain an efficient water seal under all conditions of flow. In Gujarat, sanitary trap used in large capacity dairy plant are popularly known as Amul trap (drain) which is fabricated using 2 mm thick stainless steel and is available with the sanitary design for dairy and food industry. These are available in various specifications and finish based on the need of industry.

Drains for plant floor may be square type or round type. A trap is placed beyond or underneath the drain. A typical floor trap is given in Fig. 16.3 which has two cast iron cover plates, the lower one perforated and the upper one slotted. The top plate retains big size materials such as bottle caps, threads, glass pieces etc. while lower perforated plate retains relatively smaller size materials. The debris retained on these plates can be removed.

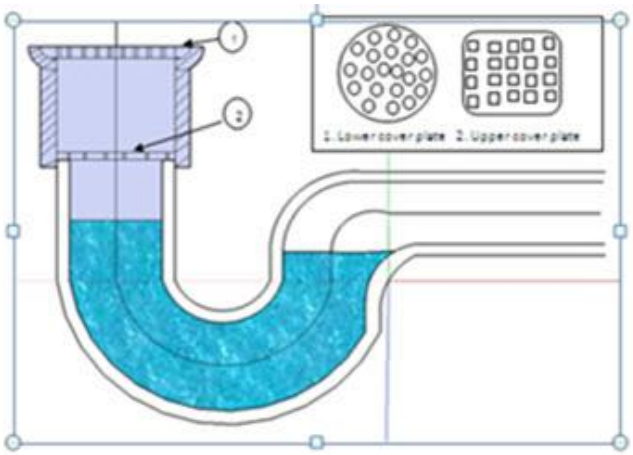


Fig 16.3 Floor trap with cover plates

16.13.3 Design consideration for drainage system of food plant

The efficient collection and conveying plant effluents are two important considerations for the drainage system. There are two categories of drainage system.

1. Drainage system for different sections of plant and laboratories,

2. Storm water drainage system for collection of rain water from roof, surface water from paved areas. This water is quite clean and can be handled for useful applications such as water re-charging of wells/tube wells. The system consists of big size cannels and cement pipelines of big diameter, pumping etc. This system of rain water management is also very important in order to eliminate water accumulation in the plant premises.

Since drainage system for different sections of food plant is continuously in use throughout the year and hence adequate attention is required to design and laying of the system. Some of the important points to be considered are indicated below.

Floor in the processing section should be laid with adequate fall so that water runs quickly to drain. This is also important to extend the life of the floor. The minimum slope should be

1:80 and slope up to 1:40 is considered better from point of view of drainage. The recommended slopes in floor towards drain for processing room is 0.25 inch per foot and 1/8th inch per foot for cold store. The probable places where spillage may occur, the slope should be arranged in such a manner that liquids will flow to the drain by the shortest route.

The arrangement of drains in a large processing room is shown in Fig 16.4. In this layout, the entire floor of the large milk processing unit is divided into 8 segments and 8 floor traps have been placed to catch liquid flow from the floor segments. Liquid falling on any of the segments will quickly move towards nearest trap. Drains underneath the traps run in straight lines as shown in Fig 16.4 and meet the main drain line which later joins the main sever line. This type of layout is highly recommended for large milk processing rooms. For small processing rooms, this type of arrangement may be provided on the side of the wall keeping about 30-40 cm distance from the wall.

Vitrified salt glazed clay/concrete/PVC sever pipeline may be used to transfer the effluent to treatment plant.

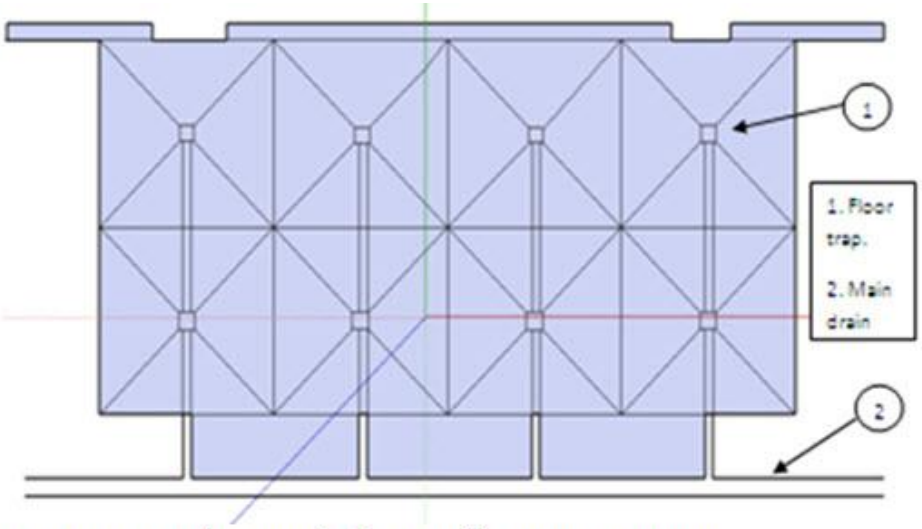


Fig 16.4 Drain layout of a large milk processing room

16.14 Paints, coatings and mold prevention

The purpose of painting is to protect the building and engineering materials from corrosion and rusting. This will greatly enhances the useful life of the building and equipments. Painting and coatings also decorative look to the building. The selection of appropriate paint and coating material is very important to get optimum result. The control of mold growth over the building and other parts of walls, ceilings, cold storages etc. is one of the essential requirements in dairy and food plants.

16.14.1 Paintings

The objectives of painting are as under.

- It protects the surface from weathering effects and effect of other gases and fumes.
- It prevents decay of wood and wood based products.
- It prevents corrosion in metals used in dairy plants.

- It gives good appearance to the surface.
- Painting makes the surface smooth for easy cleaning.
- It makes the surface hygienically good, clean and attractive.

Paint is made of two broad components pigments or solid powders and vehicles (carriers), which transfer the pigment onto surface. Paint consists of base material, carrier, drier, colouring pigments and solvent. A base is a solid substance in a fine state which forms the bulk of paint. It forms opaque layer over the surface of the material to be painted. Vehicles are the liguid substances which hold the ingredients of paint in liquid suspension. Paints and other protective coatings deteriorate rapidly in dairy plants because of constant exposure to moisture, acid, alkali and high humidity. Painted surfaces showing evidence of deterioration must be attended immediately to maintain coating of the paint on the surfaces. It is noticed that break in colour film may cause similar failure surrounding the area. If timely maintenance is not carried out, then hygienic conditions will be adversely affected. It is possible to extend the life of painted surface inside the plant by minimizing condensation of steam/water vapour by installing mechanical ventilators.

Adjoining rooms at different temperatures differ in vapour pressure which causes moisture migration from one room to another. Under such conditions, moisture may penetrate the paint film on the colder surface. In order to minimize this effect, the wall of the warmer room must have an impervious paint film to provide a vapour barrier.

The surfaces to be painted should be cleaned and dried before applying paint coating. Apply rust inhibiting primer on bare unpainted steel before applying colour coating. If previously painted surface is to be repaired, clean the metal surface by using wire brush and then apply the colour. Concrete and plastered surfaces should be thoroughly cleaned by means of wire brush to remove loose paint before applying new paint.

Dairy products readily pick up solvent fumes from paint and therefore, it is necessary to avoid brushing or spray painting in room containing milk or milk products. During painting, every effort should be made to provide the best possible ventilation both to minimize product contamination and to reduce the nauseating effect of the paint fumes on the painters. Ventilation should be continued until the paint is dry and the room is free of solvent fumes.

16.14.2 Characteristics of ideal paint

The following are the ideal properties of paint.

- Good spreading power
- Low cost
- Ease of application
- Drying in reasonable time
- Form hard and durable surface
- No effect on the health of painters/workers

- No effect of weather
- Attractive and pleasing appearance
- No cracks on drying
- Produce uniform film

16.14.3 Types of paints

16.14.3.1 Oil paint

It is oil based ordinary paint which is applied on wood, plywood, metal surfaces walls etc. It is necessary to apply oil primer before the application of two coats of oil paint. The surface to be painted should be free from moisture before the application of primer coat. These pains are available in glossy and mat finish variety to select as per the requirement. It can be applied with brush/spray painting or roller painting.

16.14.3.2 Plastic paint

It is water base colour which is commonly used for painting walls, ceilings, etc. It can be diluted with water. It is commonly applied with brush or roller. It is necessary to prepare the surface form the application of plastic paint. A primer coat of cement paint is applied on the surface and then wall putty is filled to make the surface smooth. The surface to be painted should be clean and rubbed with sandpaper/water paper to get very smooth surface. Subsequently, two coats of plastic paints are applied on the surfaces to be painted. Thousands of colour sheds can be prepared by addition of coloring agents in these paints. Colour suppliers have computerized system to add metered amount of coloring agents in the base of the colour. Hence, there is a wide range of colour sheds to select for the requirement. When the paint dries, film of binders, pigments and other solid is left on the surface. These paints are generally available in thick consistency and water is required to be added for uniform application on the surfaces. After drying of paint, surface can be washed.

16.14.3.3 Aluminum Paint

It consists of very finely ground aluminum suspended in a medium composed of a quick drying spirit varnish or slow drying oil varnish, according to the requirement. It protects iron and steel from corrosion far better than any other paint. It is widely used for painting marine pillars (supports), oil storage tanks, gas tanks, etc. It also resists heat to a certain extent, so it is applied to radiators, hot water pipes. It is also good for decorative purpose.

16.14.3.4 Anticorrosive paint

This paint consists of oil and strong drier with chromium oxide or lead or zinc chrome as pigment.

16.14.3.5 Emulsion paint

It contains binding material such as polyvinyl, synthetic resins etc. This paint is easy to apply and it dries within 2 hours. The surface of the paint is tough and it can be cleaned by washing with water. It is advisable to make the surface smooth before application of paint. A primary coat of cement paint is applied followed by two coats of emulsion paint.

16.14.3.6 Enamel paint

This paint is available in different colours. It contains white lead or zinc white, oil, spirit and resins. It dries slowly and forms hard durable surface which is not affected by acids, alkalis, fumes, etc.

16.14.4 Varnishes

It consists of resins dissolved in volatiles. It is made by dissolving the heated resins in hot oils and adding turpentine. Varnishes are available as transparent or translucent. The oil oxidizes to form a tough protective film. Depending on the solvent used, varnishes are classified as under.

- Oil varnishes
- Spirit varnishes
- Turpentine varnishes
- water varnishes

Linseed oil is used as solvent in oil varnishes while methylated spirit is used as solvent in spirit varnishes. Spirit varnishes dry quickly but it is not durable. It is used for furniture. In water varnishes, shellac is dissolved in hot water and required quantity of either ammonia or borax or potash or sods is added so that shellac is dissolved. Varnishes are applied by using smooth fine brush.

16.14.5 Painting for mold prevention

It is necessary to carry out painting on building and equipment by adopting recommended procedure in order to make the surface which is not suitable for mold growth. It is desirable to use paint containing a fungicide. The fungicide should be such that it is effective, non toxic, impart no odour or flavour to food products and be economical. Solubilized copper quinolinolate has been found to be an effective fungicide for paints, especially when combined with the paint during the manufacturing process. The surfaces containing mold growth may be treated with a hypochlorite solution containing 0.5 to 1.0% chlorine to prevent a general contamination of the area during the cleaning process. Many patented mold inhibitors are available to use as per the recommendation.

16.15 Painting Problems/ Failures:

The basic reasons for the defects in painting are due to (i) atmospheric conditions (ii) defective surfaces and (iii) Incorrect painting methods.

1. **Alligatoring:** It occurs due to application of relatively fast drying coat over one which is too soft. The reasons for soft under coat could be use of too much oil, use of unsuitable oil which dries to a soft film or due to insufficient drying time before another coat is applied.
2. **Blistering and peeling:** Blistering and peeling is caused by moisture penetration behind the film of paint on the wooden surface and plaster. The change in temperature causes vaporization of moisture which increases the volume. This causes a blister. This may also happen if the seasoning of wood is not done properly.

3. **Cracking and scaling:** This happens when paint becomes too brittle as it ages and then it begins to break. The wood expands and contracts due to moisture absorption which may break the film of colour. However, in the long run, the elasticity of the paint decreases. In order to overcome this, more elastic paints of higher grade should be used. In order to repaint the surface, first the old paint should be removed. This can be done by scrapping, using a sand paper or a wire brush, blow torch and scrapper or by using chemical solvents. (liquid paint removal).
4. **Running and sagging:** Use of too much oil results in sagging down and applying too much thick coat also results in sagging. Application of paint to very glossy a surface would also result in sagging. It is necessary to maintain proper viscosity and surface finish of the surface to be painted.
5. **Wrinkling:** Formation of wrinkles is due to improper drying of paints applied on the surface. This happens when surface dries quickly leaving undried paint below.