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Unit 1 Topic 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.