Passive Fire Protection

Lec 4: Designs to Prevent Fires and Explosions

Plant Layout, Preparation of the Layout, design features

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General overall design considerations

- The development of the overall design project involves many different design considerations.
- Failure to include these considerations in the overall design project may, in many instances, alter the entire economic situation so drastically as to make the venture unprofitable.
- Some of the factors involved in the development of a complete plant design include plant location, plant layout, materials of construction, structural design, utilities, buildings, storage, materials handling, safety, waste disposal, federal, state, and local laws or codes, and patents.

Plant Layout

- After the process flow diagrams are completed and before detailed piping, structural, and electrical design can begin, the layout of process units in a plant and the equipment within these process units must be planned.
- This layout can play an important part in determining construction and manufacturing costs, and thus must be planned carefully with attention being given to future problems that may arise.
- Since each plant differs in many ways and no two plant sites are exactly alike, there is no one ideal plant layout.
- However, proper layout in each case will include arrangement of processing areas, storage areas, and handling areas in efficient coordination and with regard to such factors as:

1. New site development or addition to previously developed site
2. Type and quantity of products to be produced
3. Type of process and product control
4. Operational convenience and accessibility
5. Economic distribution of utilities and services
6. Type of buildings and building-code requirements
7. Health and safety considerations
8. Waste-disposal requirements
9. Auxiliary equipment
10. Space available and space required
11. Roads and railroads
12. Possible future expansion

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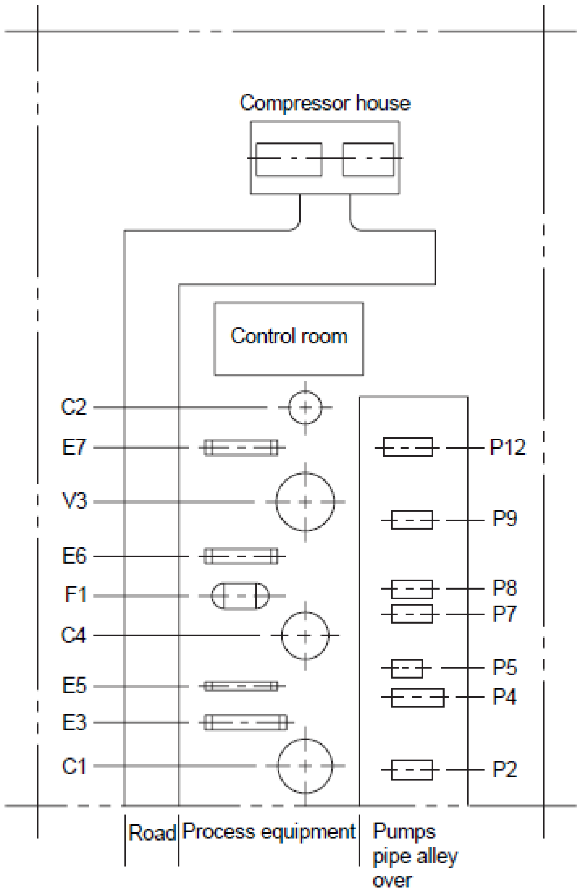
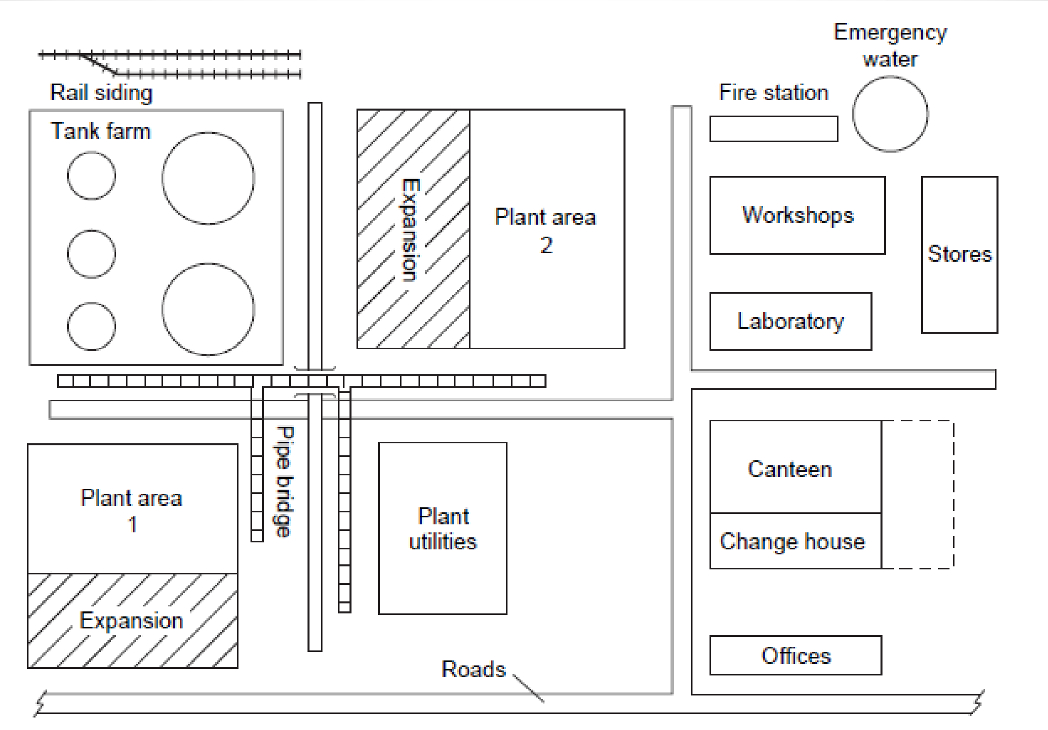
Preparation of the Layout

- Scale drawings, complete with elevation indications can be used for determining the best location for equipment and facilities.
- Elementary layouts are developed first.
- These show the fundamental relationships between storage space and operating equipment.
- The next step requires consideration of the safe operational sequence and gives a primary layout based on the flow of materials, unit operations, storage, and future expansion.
- Cardboard cutouts of the equipment outlines can be used to make trial plant layouts.
- Simple models, made up from rectangular and cylindrical blocks, can be used to study alternative layouts in plan and elevation.
- Cutouts and simple block models can also be used for site layout studies.

- By analyzing all the factors that are involved in plant layout, a detailed recommendation can be presented, and drawings and elevations, including isometric drawings of the piping systems, can be prepared.
- Once the layout of the major pieces of equipment has been decided, the plan and elevation drawings can be made and the design of the structural steelwork and foundations undertaken





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- Templates, or small cutouts constructed to a selected scale, are useful for making rapid and accurate layouts, and three-dimensional models are often made.
- A plant layout model is used as a design tool for arranging machinery, equipment, tool rooms, and the like in the best place to permit the quickest and smoothest production at the least cost.
- Plant layout models yield savings in construction and training, and they allow people with diverse expertise to collaborate on improvements.
- The use of such models for making certain a proposed plant layout is correct has found increasing favor in recent years
- Errors in a plant layout are easily located when three-dimensional models are used, since the operations and construction engineers can immediately see errors which might have escaped notice on two-dimensional templates or blueprints.

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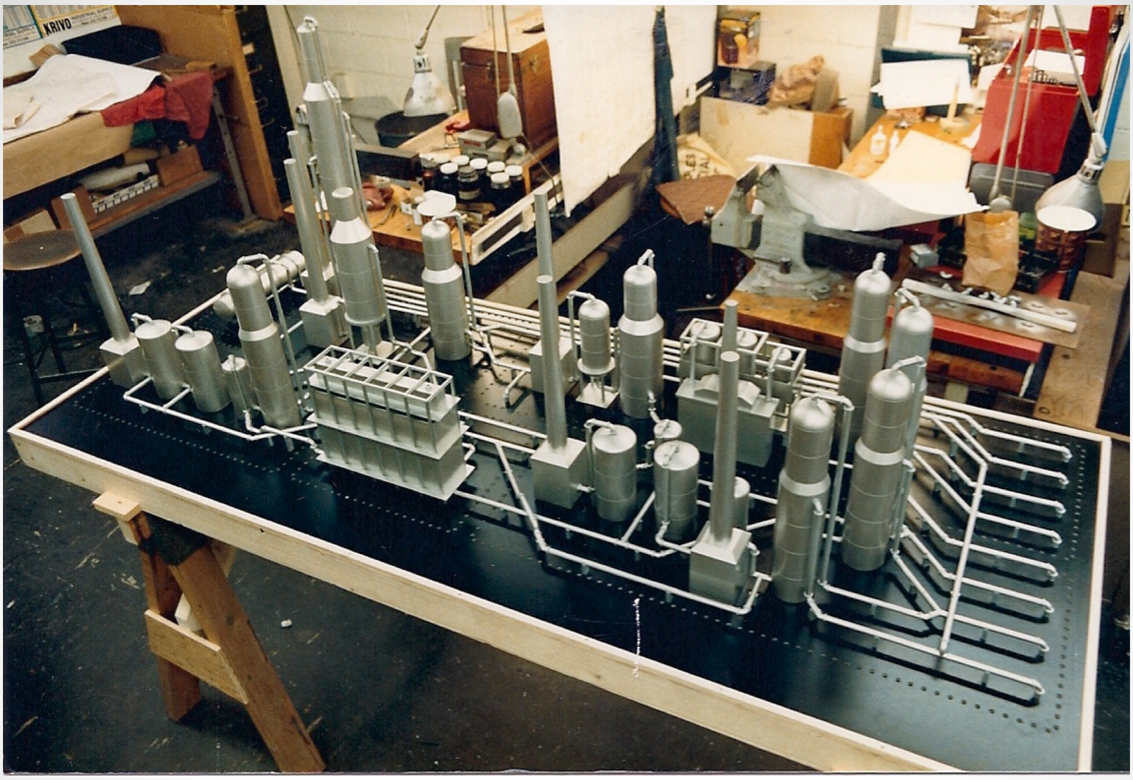
- In addition to increasing the efficiency of a plant layout, models are very useful during plant construction and for instruction and orientation purposes after the plant is completed.
- Many engineering/construction companies and their clients use plant layout models to optimize the design and construction of complex plants like an industrial manufacturing facility, a chemical plant, a pharmaceutical plant, an oil refinery (like the one shown below), a food processing plant, or a nuclear plant.
- For these types of companies a plant layout model often encompasses a series of buildings, tanks, major equipment, and pipes on the site.
- Large-scale models, to a scale of at least 1:30, are normally made for major projects
- The model may also have the roof removed from each building to display the machinery, equipment, and work flow inside.



ARAMCO oil refinery

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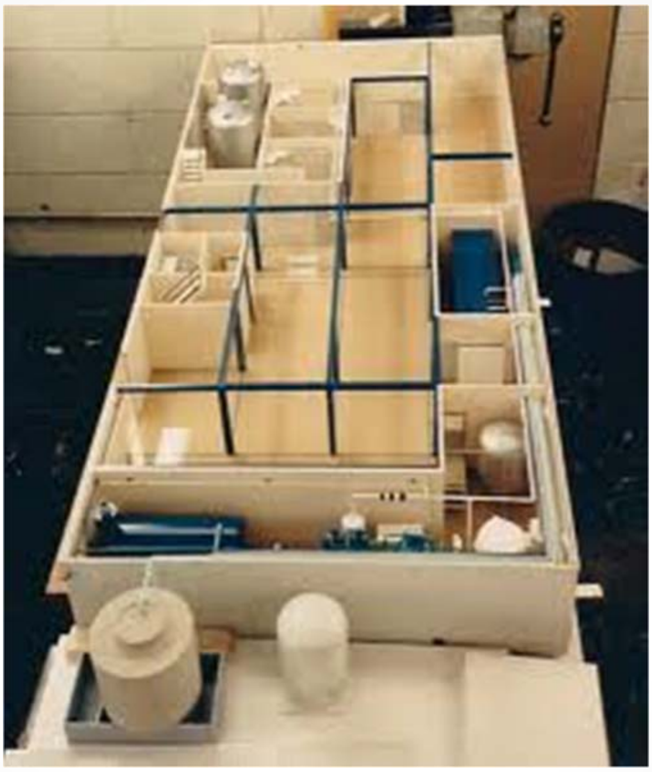

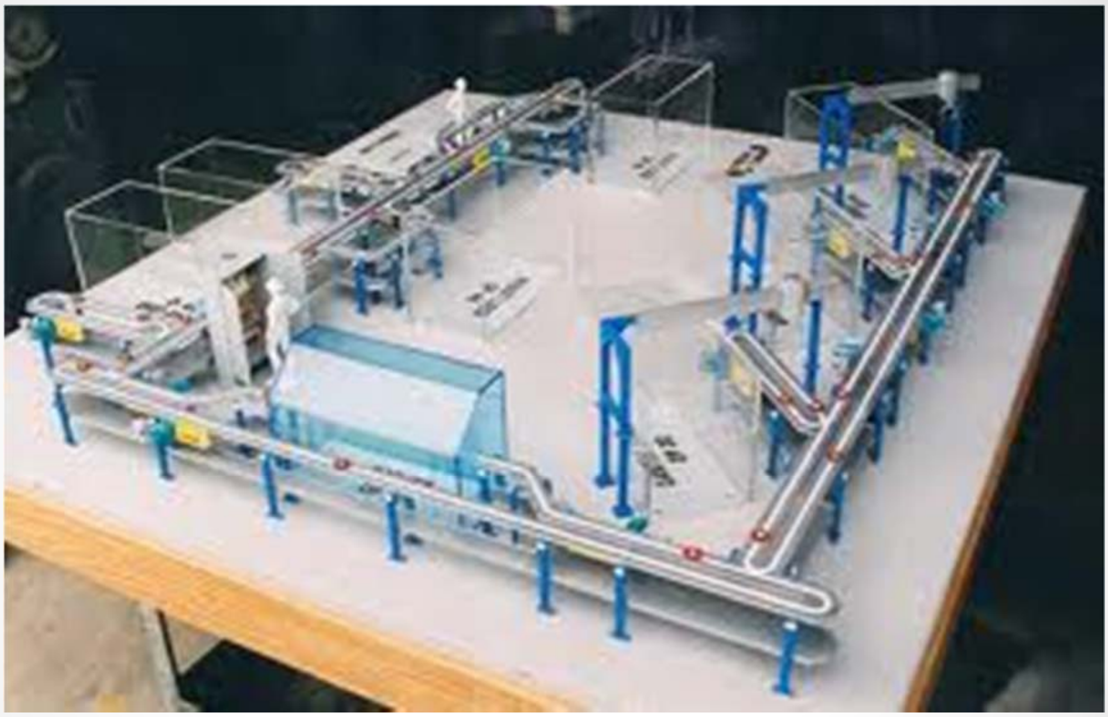

- The first real engineering process design model was fabricated in 1951 with all of the equipment, piping, and vessels in exact scale.
- However, building the model was time-consuming since many parts had to be hand formed.
- By the 1960's many of the parts needed for plant layout and process models (as well as many parts for architectural models) were being produced as precision-injected plastic molded parts available off the shelf in quantity and in a variety of scales.
- This greatly cut the time and cost of fabricating a plant layout model.
- Computer-aided design (CAD) tools are being increasingly used for plant layout studies, and computer models are complementing, if not yet replacing, physical models.

Some of the advantages of computer graphics modeling compared with actual scale models are

1. The ease of electronic transfer of information. Piping drawings can be generated directly from the layout model. Bills of quantities: materials, valves, instruments, etc. are generated automatically.
2. The computer model can be part of an integrated project information system, covering all aspects of the project from conception to operation.
3. It is easy to detect interference between pipe runs and pipes and structural steel that occupy the same space.
4. A physical model of a major plant construction can occupy several square meters. The computer model is contained on a single CD.
5. The physical model has to be transported to the plant site for use in the plant construction and operator training. A computer model can be instantly available in the design office, the customer's offices, and at the plant site.
6. Expert systems and optimization programs can be incorporated in the package to assist the designer to find the best practical layout; see Madden et al. (1990).

The principal factors to be considered

Costs

The cost of construction can be minimized by adopting a layout that gives the shortest run of connecting pipe between equipment and the least amount of structural steel work; however, this will not necessarily be the best arrangement for operation and maintenance.

Process Requirements

An example of the need to take into account process considerations is the need to elevate the base of columns to provide the necessary net positive suction head to a pump

Operation

Equipment that needs to have frequent operator attention should be located convenient to the control room. Valves, sample points, and instruments should be located at convenient positions and heights. Sufficient working space and headroom must be provided to allow easy access to equipment. If it is anticipated that equipment will need replacement, then sufficient space must be allowed to permit access for lifting equipment.

Maintenance

Heat exchangers need to be sited so that the tube bundles can be easily withdrawn for cleaning and tube replacement. Vessels that require frequent replacement of catalyst or packing should be located on the outside of buildings. Equipment that requires dismantling for maintenance, such as compressors and large pumps, should be placed under cover.

Safety

Blast walls may be needed to isolate potentially hazardous equipment and confine the effects of an explosion.

At least two escape routes for operators must be provided from each level in process buildings.

Plant Expansion

Equipment should be located so that it can be conveniently tied in with any future expansion of the process.

Space should be left on pipe racks for future needs, and service pipes should be oversized to allow for future requirements.

Modular Construction

In recent years there has been a move to assemble sections of a plant at the plant manufacturer's site. These modules include the equipment, structural steel, piping, and instrumentation. The modules are then transported to the plant site, by road or sea.

The advantages of modular construction are

1. Improved quality control;
2. Reduced construction cost;
3. Less need for skilled labor on site;
4. Less need for skilled personnel on overseas sites.

Some of the disadvantages are

1. Higher design costs;
2. More structural steel work;
3. More flanged connections;
4. Possible problems with assembly, on site;

- In general, the layout of the plot plan can take one of two basic configurations: the grade-level, horizontal, in-line arrangement and the structure mounted vertical arrangement
- The minimum spacing between equipment should be set early on in the design. These distances are set for safety purposes and should be set with both local and national codes in mind

Table 1.11 Recommended Minimum Spacing (in feet) between Process Equipment for Refinery, Chemical, and Petrochemical Plants

	Pumps	Compressors	Reactors	Towers and Vessels	Exchangers
Pumps	M	25	M	M	M
Compressors		M	30	M	M
Reactors			M	15	M
Towers				M	M
Exchangers					M

M = minimum for maintenance access

Source: Process Plant Layout and Piping Design, by E. Bausbacher and R. Hunt, © 1994, reprinted by permission of Pearson Education, Inc. Upper Saddle River, NJ.

Reasons for Elevating Equipment

Equipment to Be Elevated	Reason for Elevation
Columns or vessels	When the NPSH available is too low to avoid cavitation in the discharge pump, equipment must be elevated.
Columns	To provide driving head for thermosiphon reboilers.
Any equipment containing suspended solids or slurries	To provide gravity flow of liquids containing solids that avoids the use of problematic slurry pumps.
Contact barometric condensers	This equipment is used to produce vacuum by expanding high-pressure steam through an ejector. The condensables in the vapor are removed by direct contact with a cold-water spray. The tail pipe of such a condenser is sealed with a 34-foot leg of water.
Critical fire-water tank (or cooling water holding tank)	In some instances, flow of water is absolutely critical, for example, in firefighting or critical cooling operations, the main water supply tank for these operations may be elevated to provide enough water pressure to eliminate the need for feed pumps.