

ENGINEERING DESIGN SEMINAR

SEPTEMBER 6, 1994 – NOVEMBER 11, 1994

PLOT PLANS

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INTRODUCTION

Plot is defined as a measured piece of land. Plan, in this context, is defined as an orderly arrangement of an overall design or objective. A plot plan, then, is an arrangement or layout, graphically represented, of the intended placement of the equipment that make up the refinery.

Many different plot plans are required throughout the course of refinery design, ranging from general to detailed, depending on requirements and available information. The delineation of plot plans is based ostensibly on the various stages of planning required to effect the final detailed layout of the entire plant.

Some of the plot plans to be discussed are:

- Refinery Plot Plan

- Process Area Unit Arrangement

- Individual Process Unit Plot Plans

- Offsite Plot Plans

- Piping Plans

REFINERY PLOT PLAN

The first plot plan to be developed is an overall layout of the refinery locating several, somewhat homogeneous, major groups of equipment. As a basis for this layout, following are considered major groups of equipment:

Process Area

Utility Area

Tankage

Waste Treatment

Flare

Buildings

Loading and Unloading Area

Future Requirements

Each of these groups requires significant space and cumulatively include most of the equipment within the refinery. Since the processes desired and the location of the site have been established, as is assumed here, it is necessary to approximate the area requirements for each of these groups. Reasonably accurate approximations of these areas is obtained from the process designers or previous layouts.

Even though it is early in the planning process, it is highly recommended that future process and supporting equipment needs to be considered at this time. With these future needs in mind, the estimates for the area required for each of these major groups should include the additional space for future requirements. It is not practical, as a rule, to provide one large area for future requirements since this will not allow for optimally expanding existing facilities that may be used for servicing future equipment.

As an example, it is often only necessary to add additional equipment to the utility area to service a whole new process area.

Along with the area estimates, information regarding the site must also be obtained before the layout is started. Valuable site information includes:

- Legal Boundaries

- Adjacent Land Usage

- Public Facilities Nearby

- Public Roads

- Public Utilities

- Railroads

- Waterways

- Meteorology

Another item that must be considered is the topography of the site. The topography is represented by a contour map showing the irregularities in elevation of the land. Once a topographic survey is made, the planning of its future shape can be started. If the site is relatively flat, a specific topographic plan is not usually required, but if hilly or abrupt changes in terrain are present, a definite plan should be developed. This planning may be coincidental with the development of the refinery plot plan for reasons that will be clear later in the discussion. Items to be considered in the topographic plan are natural drainage, soil conditions, accessibility, etc. The need to make large surface changes after the area is initially developed can be costly and dangerous. Certainly the whole refinery need not be located on flat land but, if possible, strong consideration should be given to locating the process units at one level for safer operation and easier construction and maintenance.

With the above information and data, preliminary planning of the refinery plot plan can begin. The main concerns in laying out any plot plan are safety and economy. Process requirements, for example, are really economic concerns. Personnel safety is of paramount concern and should be seriously considered in all phases of planning.

AREA LOCATIONS

Following are some guidelines in establishing the relative locations and actual placement of the major groups of equipment for the purpose of developing the refinery plot plan.

Process Area

Flat land

Good accessibility

Good load bearing soil

Higher elevation than tankage

Centralization

Prevailing wind

Utility Area

Locate adjacent to process area

Good accessibility

Higher elevation than tankage

Tankage

Locate adjacent to process and utility areas

Locate at lower elevation than process and utility areas

Waste Management

Locate at refinery low point

Locate remote from process and utility areas

Vehicle accessibility

Flare

Remote from all other equipment

Downwind from areas where personnel are required for continuous operation

Usually in corner of site

Higher elevation than tankage

Buildings

Locate at periphery

Near main road

High ground

Loading and Unloading Area

Locate at periphery

Near main road, railroad or docks

Usually adjacent to tankage

Single entrance

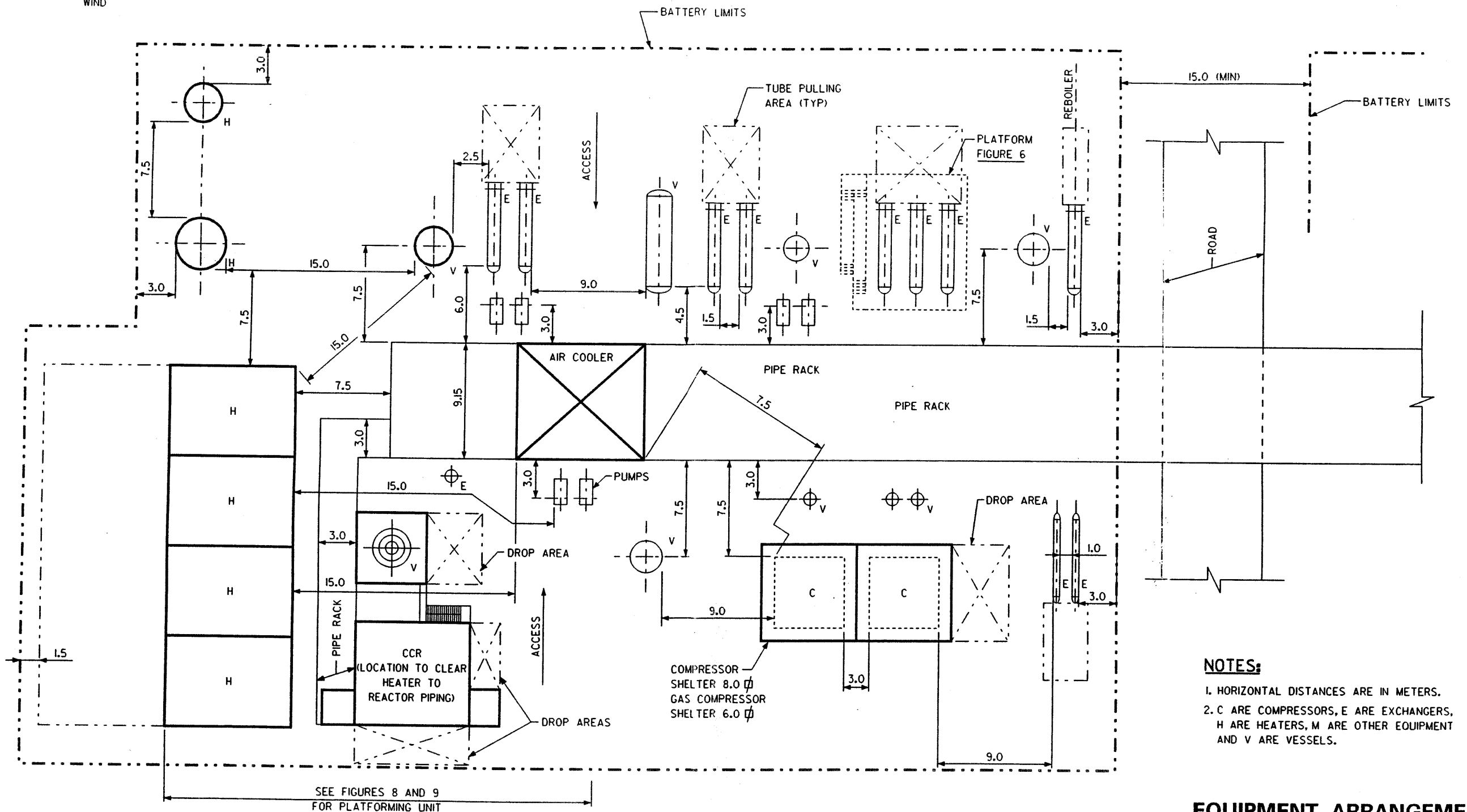
Future Requirements

Allocate areas for future expansion

Minimum clearances between these groups of equipment are required and used to facilitate the refinery layout. These minimums are based on process, safety and maintenance considerations. These minimum spacings may be further refined later in the planning process. Minimum spacing should also be kept in mind for locating and allocating areas for future equipment to assure sufficient space is apportioned. For minimum spacing of process units and equipment, see Figures 5-12 and Tables 1 and 2.

The refinery plot plan can now be arranged. At a later time, the refinery plan will be updated to reflect further planning and more detailed information as it develops. However, it is important that as many contingencies as possible are anticipated while planning the refinery plot plan so it will not be necessary to make major revisions later. Since the more detailed planning of the various areas proceeds independently, it may not be feasible to make major changes at a later date. This may result in greater expense and lost time as unforeseen problems are dealt with during detailed planning.

The need for optimum planning at each stage of the layout process is critical because of the dependency of each phase of the planning that has proceeded it.

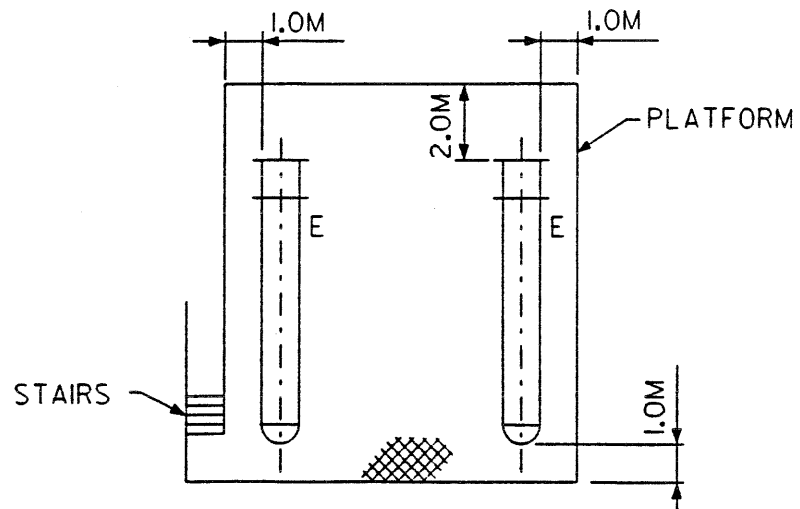


NOTES:

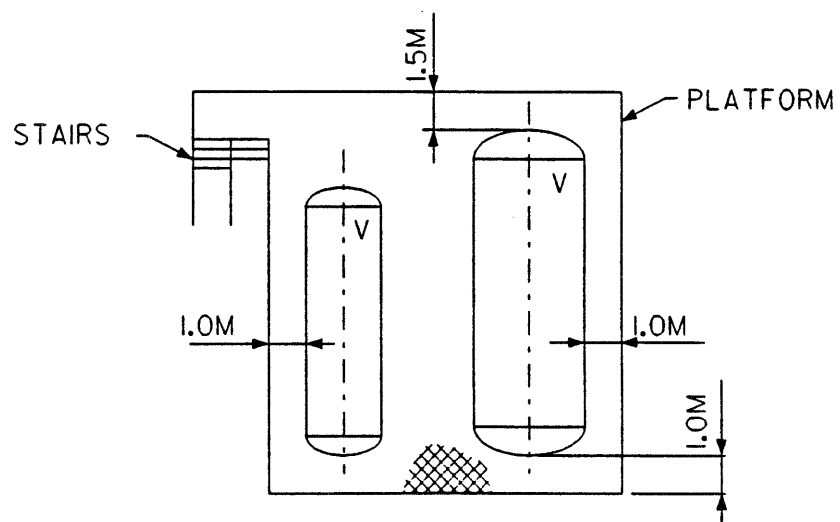
1. HORIZONTAL DISTANCES ARE IN METERS.
2. C ARE COMPRESSORS, E ARE EXCHANGERS, H ARE HEATERS, M ARE OTHER EQUIPMENT AND V ARE VESSELS.

EQUIPMENT ARRANGEMENT

FIGURE 5



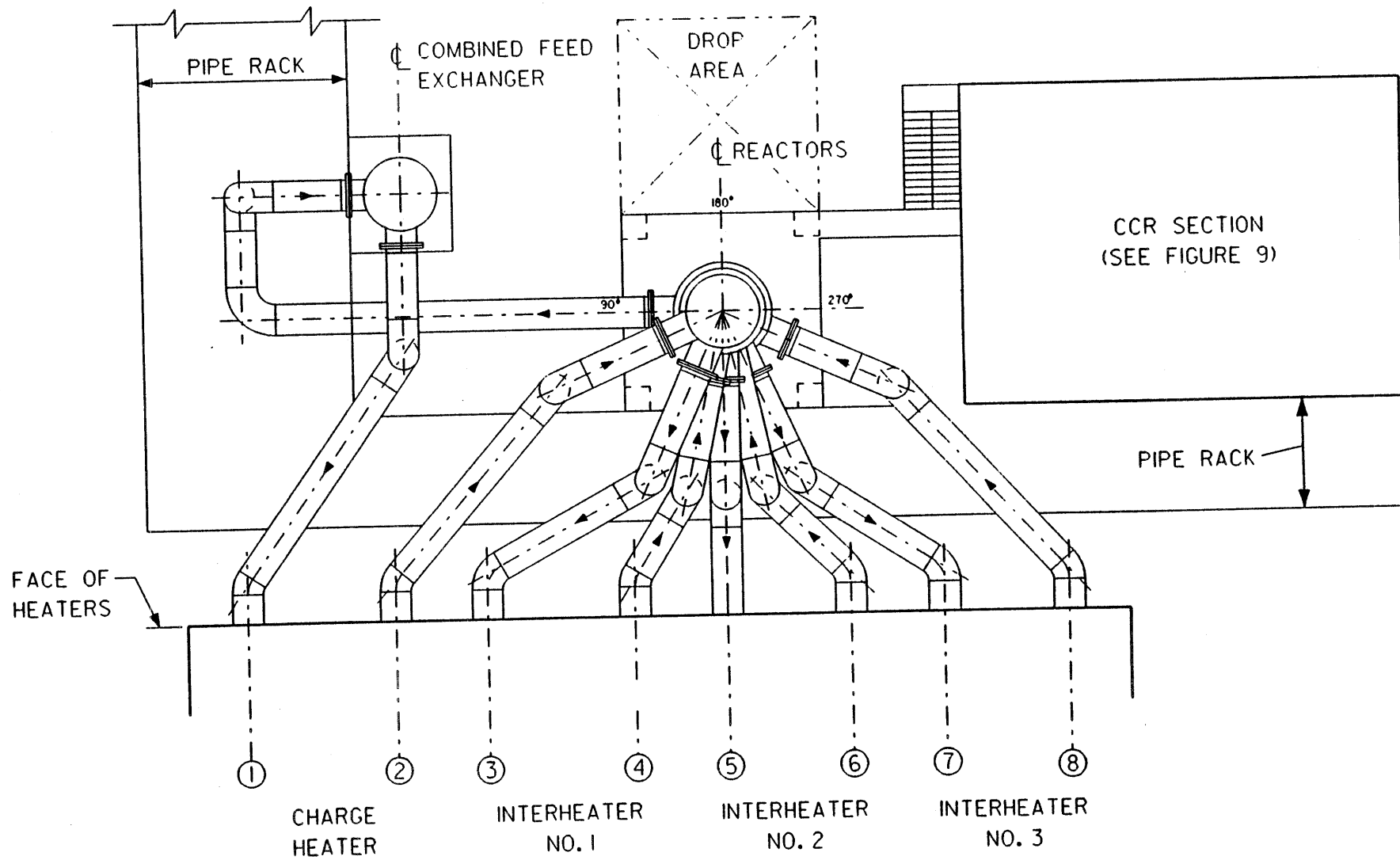
SECOND LEVEL



FIRST LEVEL

EQUIPMENT ARRANGEMENT

FIGURE 6

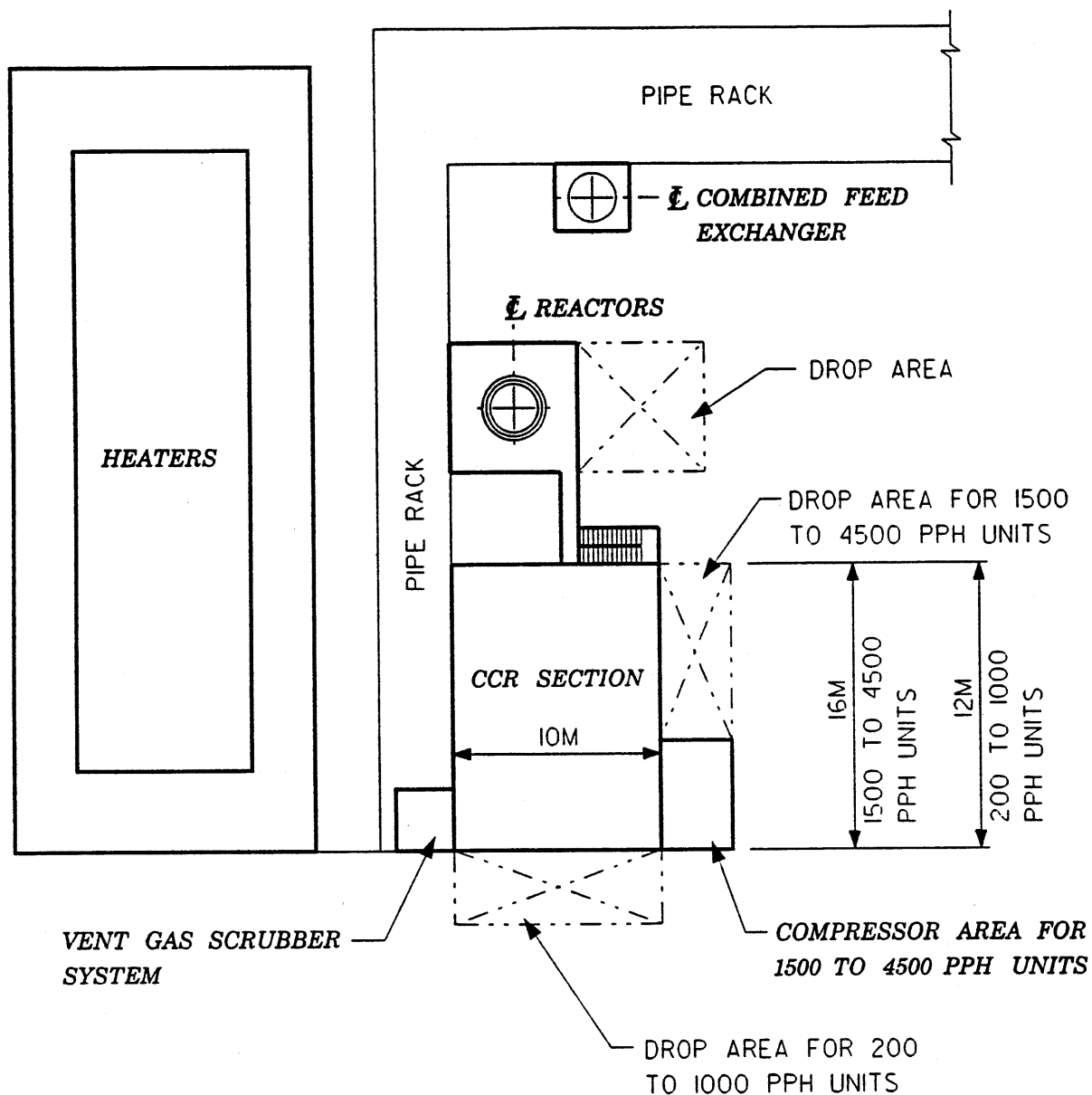


EQUIPMENT ARRANGEMENT

FIGURE 8

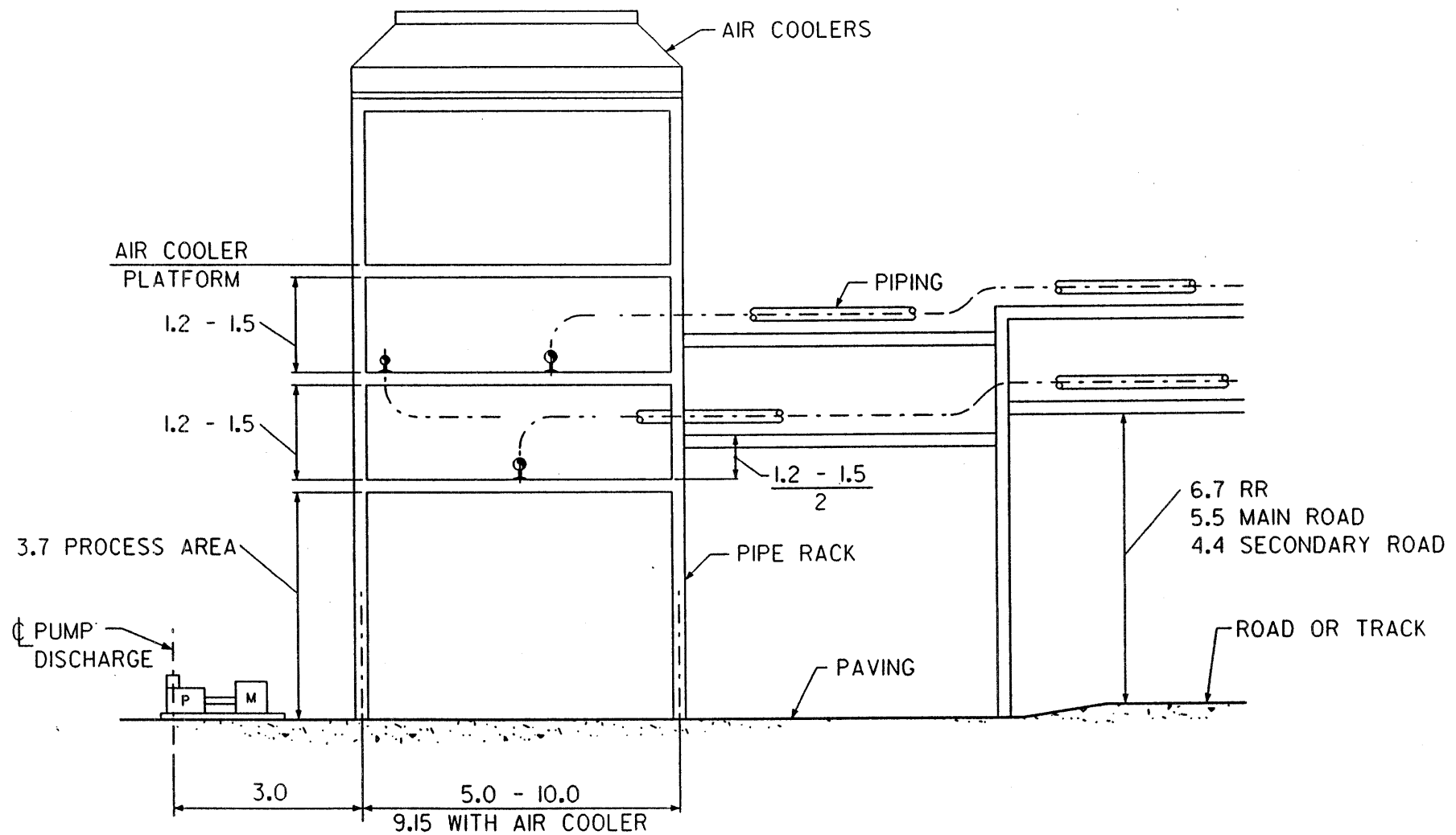
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CCR PLOT LAYOUTS

FIGURE 9

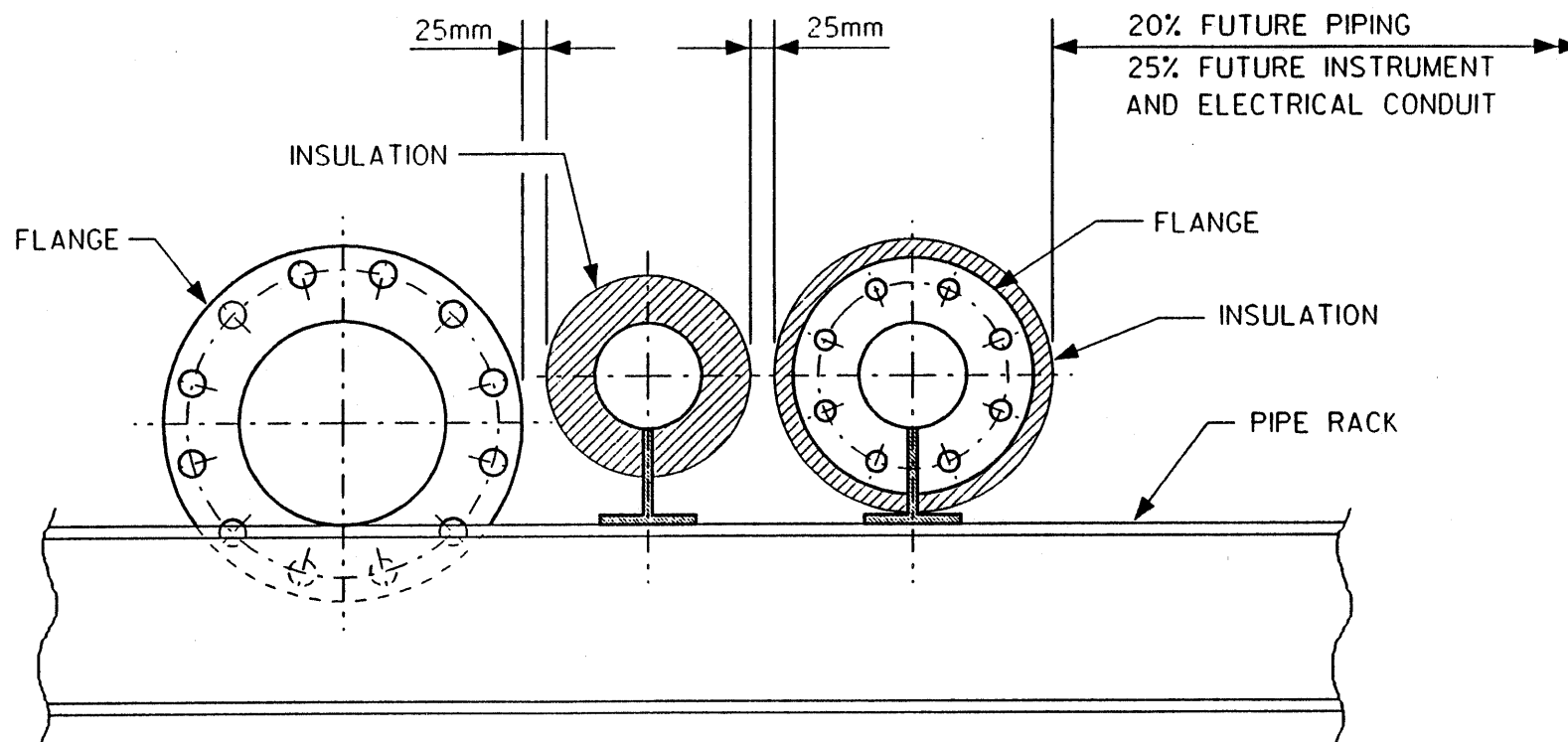


PIPE RACKS

FIGURE 10

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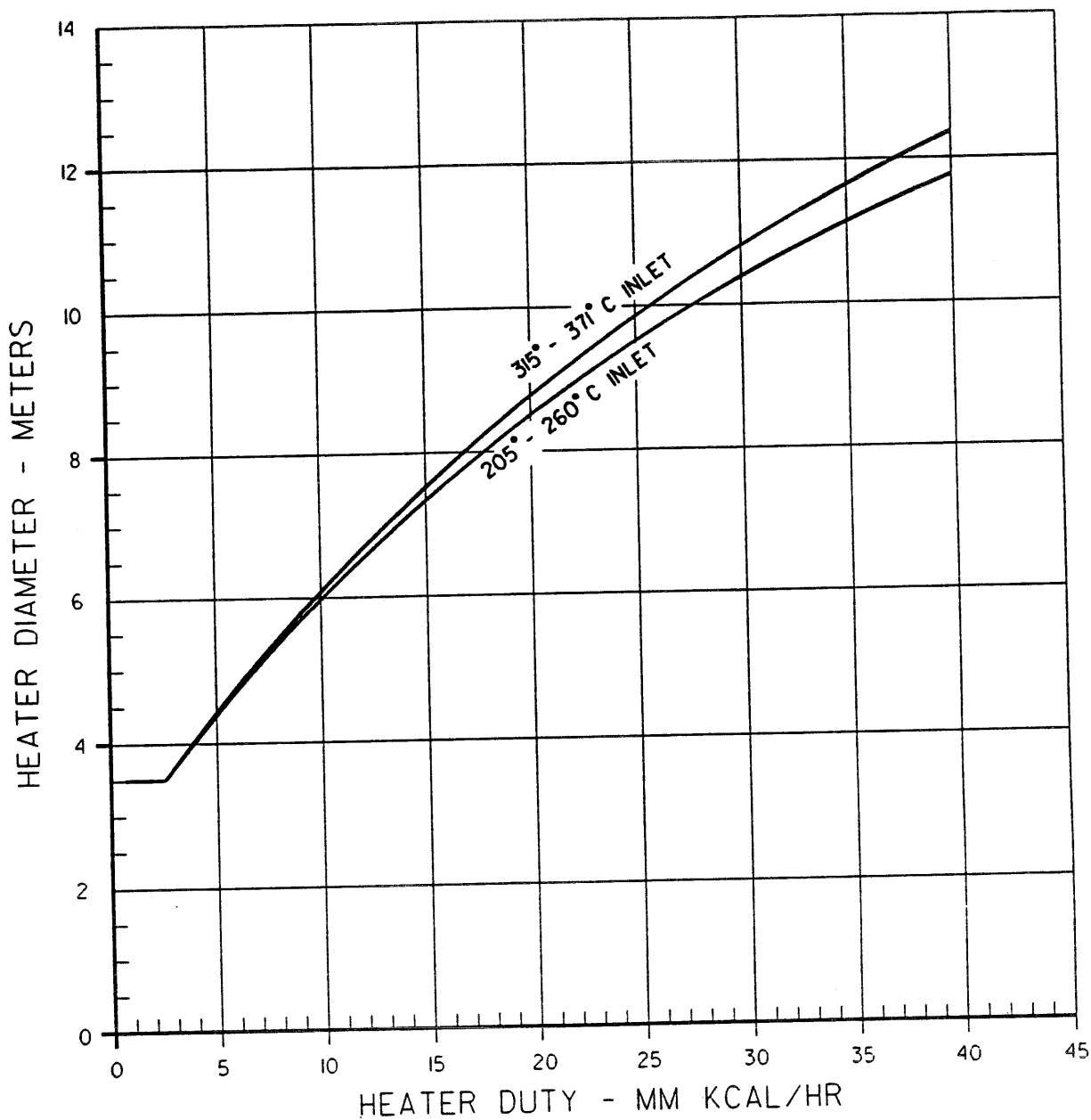


PIPE SPACING

FIGURE 1 1

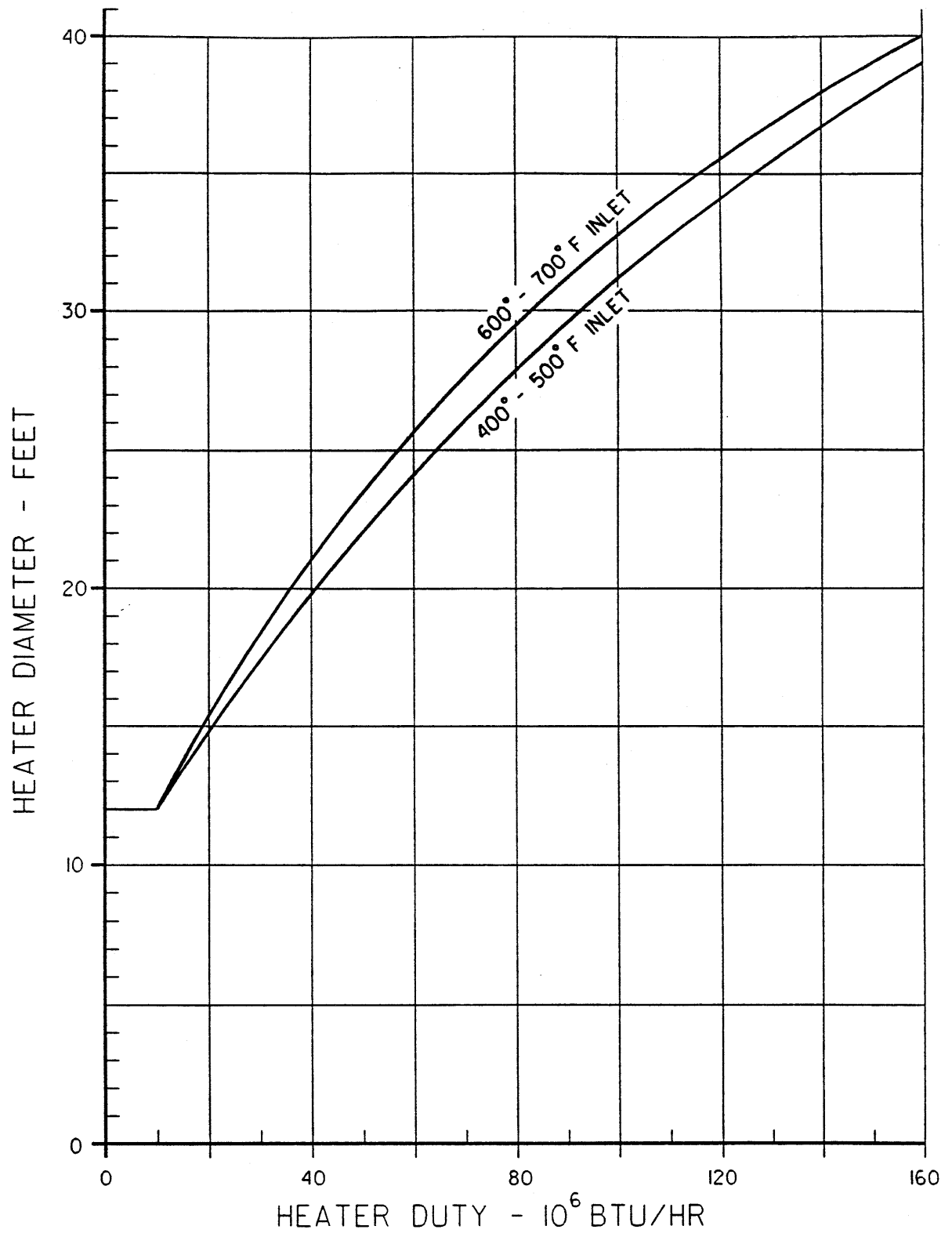
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CIRCULAR HEATING SIZING
(RADIANT - CONVECTION ONLY)

FIGURE 12A



CIRCULAR HEATING SIZING
(RADIANT - CONVECTION ONLY)

FIGURE 12B

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PROCESS AREA UNIT ARRANGEMENT

Once the preliminary overall refinery layout has been established, planning of the process area can begin. However, before layouts of individual pieces of equipment for individual process units can be started, an arrangement of the various units, along with pipe rack and roadway schemes, must be established. Estimates of space requirements for each process unit are obtained and, along with the relevant site information based on the location of the process area within the refinery already planned, the unit arrangement can be developed. A unit flow diagram, available early in the planning process, is used as an aid in locating units relative to one another within the process area. See Figures A and B for location of process units. Figures 1-4 show examples of unit block layouts.

It is also of paramount importance to obtain information regarding all heaters in all units. Heaters shall be located on the side of the process units from which the prevailing wind blows. Hydrocarbon gasses will be blown away from heaters instead of toward them. Heaters should be located in a line or clustered, if possible, at the periphery of the process area to isolate the fire hazard, save space, and allow for common ducting. Because of the practicality of adhering to these guidelines, heaters may actually determine the location of the process units over even process considerations.

Objectives of the Unit Arrangement

Set location and allot areas for individual units

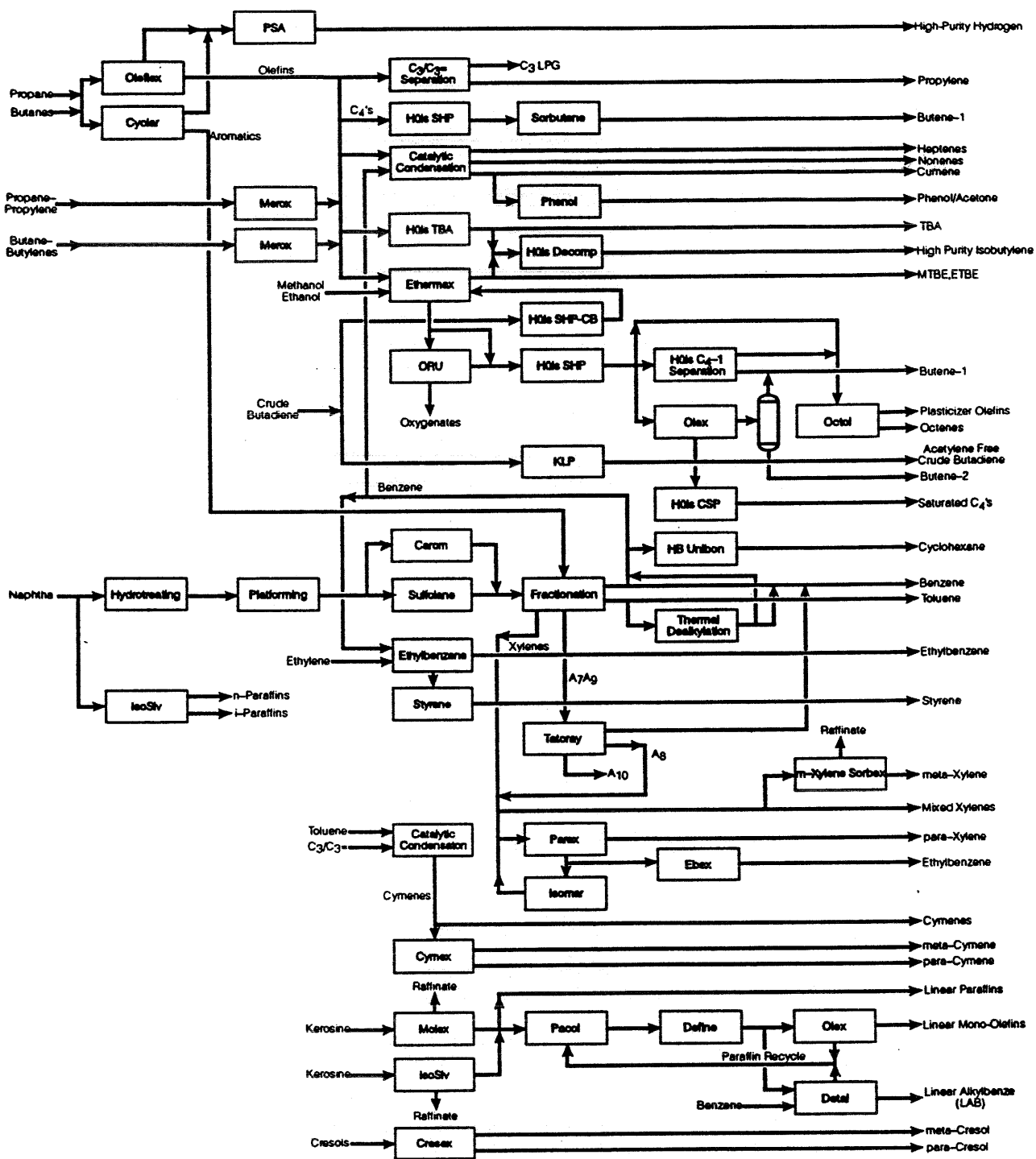
Develop roadway plan through and around process area

Develop pipe rack scheme for piping into, out of, and through process area

Allocate space for a control room, electrical substations, etc.

Set general location of heaters

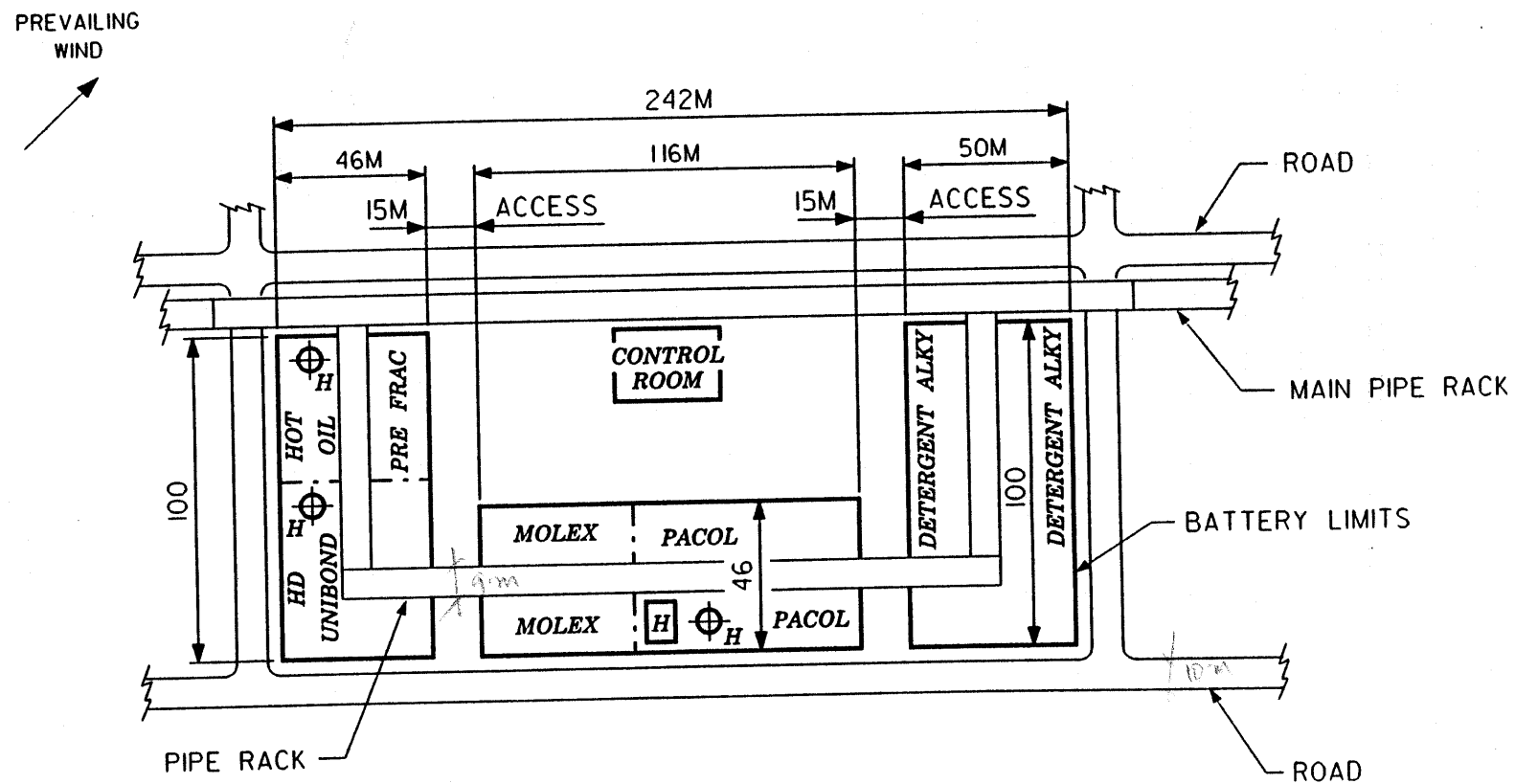
Define future process areas



PETROCHEMICAL PROCESSES
FIGURE B

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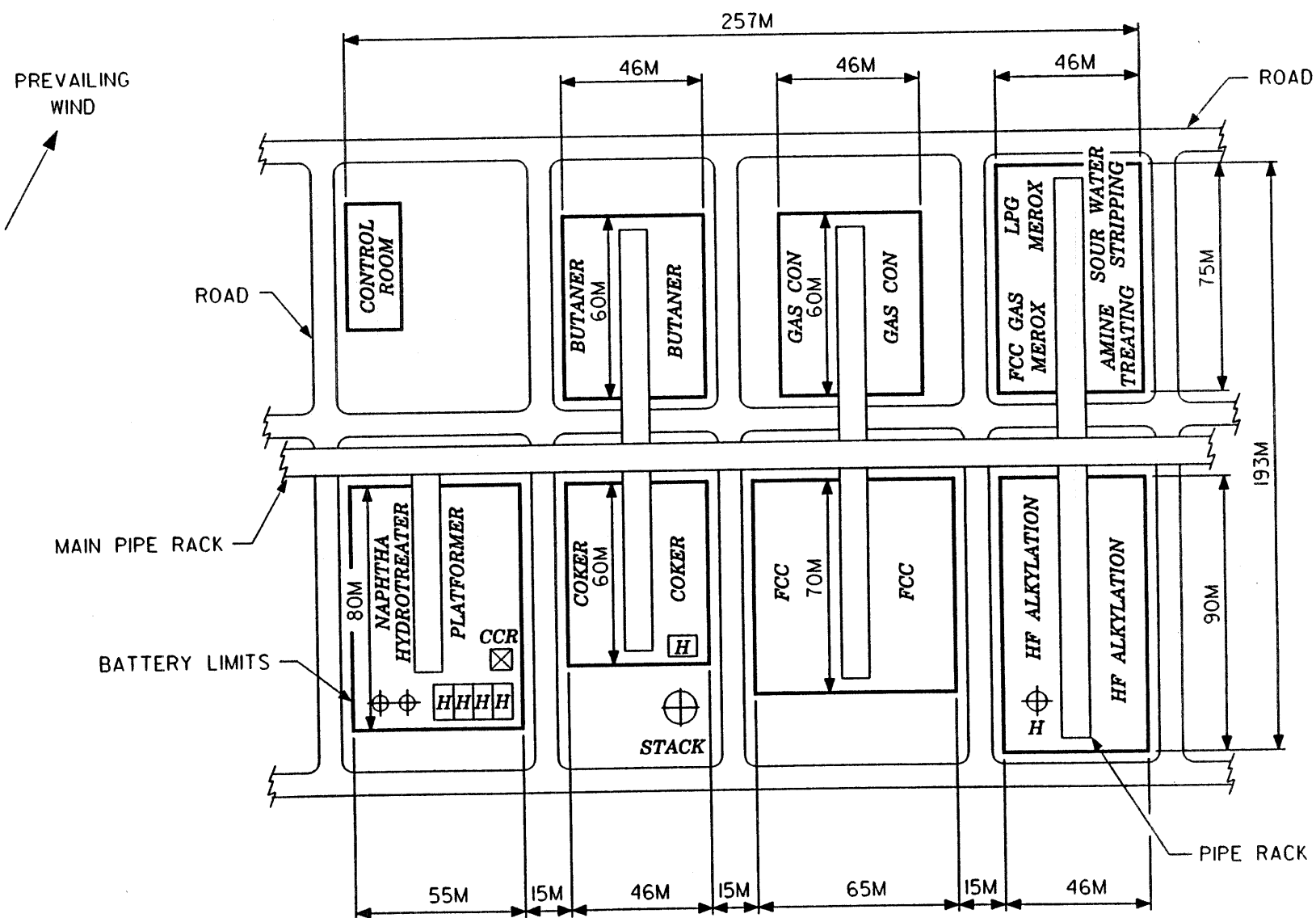


UNIT BLOCK LAYOUT

FIGURE 1

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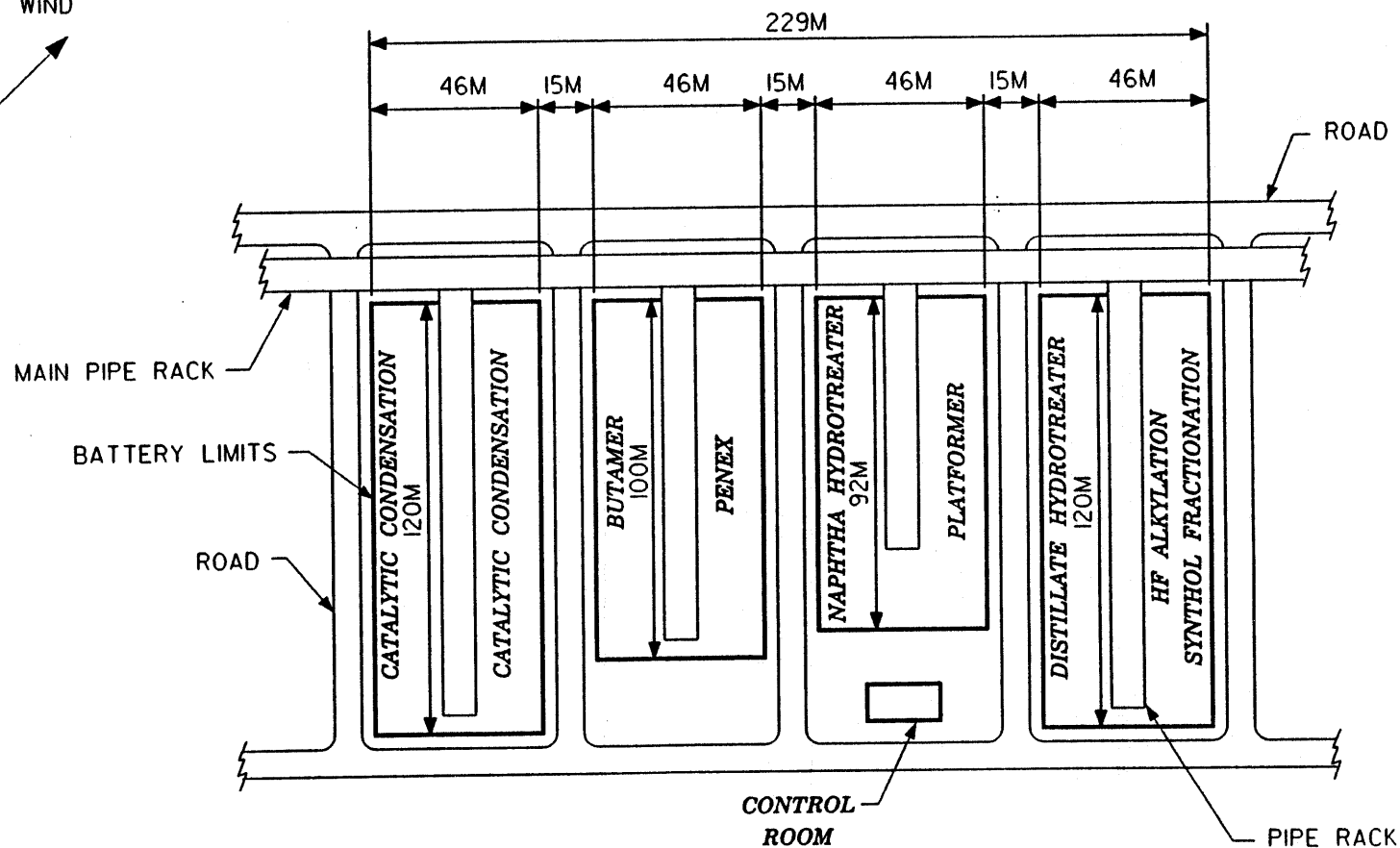


UNIT BLOCK LAYOUT
FIGURE 2

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PREVAILING
WIND

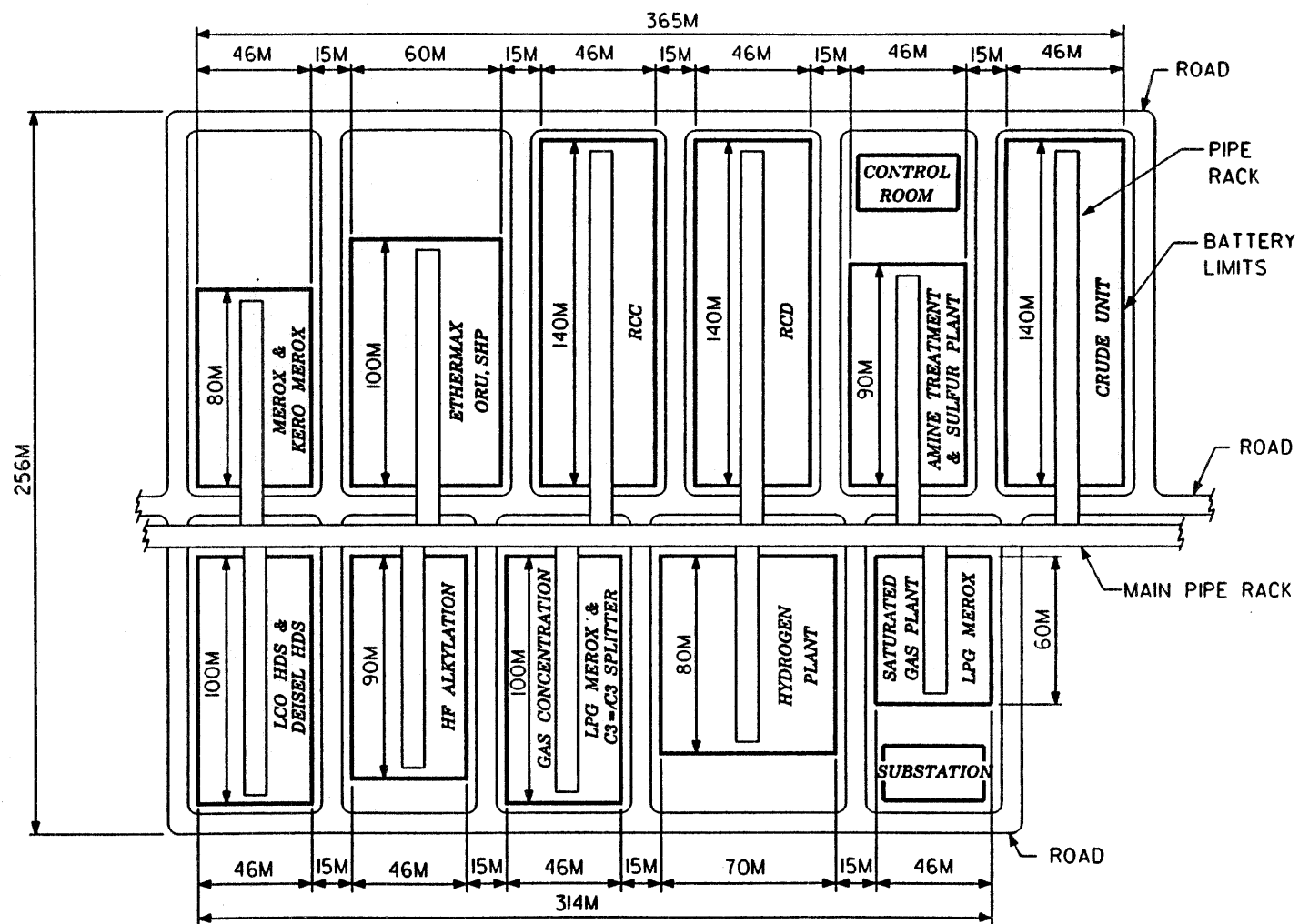


UNIT BLOCK LAYOUT

FIGURE 3

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UNIT BLOCK LAYOUT

FIGURE 4

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In order to develop an accurate and workable unit arrangement, it is useful to have standards for pipe racks and roadways. The following guidelines are recommended for a preliminary arrangement and can be adjusted once more detailed planning is contemplated. Some of the information is applicable to the rest of the areas within the refinery as well.

Battery Limits

Clearance between battery limits of process units shall be a minimum of 15 meters.

Plant Roadways

Roadways are located, usually in a symmetric manner, to service all areas requiring access for operation, maintenance, and fire protection. Roadways generally fall into three major categories.

Principle Roadways

Principle roadways are used primarily around process, utility, loading, and building areas. Roadways are from 7.3–9.15 meters wide with a shoulder width of up to 3.65 meters. Vertical clearance for these roads shall be a minimum of 5.5 meters.

Secondary Roadways

Secondary roadways are used in the tankage, waste treatment, and other offsite areas. These roadways should be 6 meters wide with a shoulder width of up to 3.65 meters. Vertical clearance for secondary roadways shall be a minimum of 4.4 meters.

Rail Roads

Rail roads are used in loading and offsite areas. Vertical clearance for railroads shall be a minimum of 6.75 meters above rail.

Pipe Racks

Overhead pipe racks are used to service process and utility areas. Main pipe racks are from 5–10 meters in width. The pipe rack shall be of sufficient width to provide space for instrument, pneumatic, electrical and other utility lines as well as process piping. For the unit arrangement, it is recommended to assume that the pipe racks will be 9.15 meters wide. This width can always be adjusted later. If air cooled exchangers are to be supported above the pipe rack, a 9.15 meter pipe rack will, in all probability, be used (see Figure 10).

Main utility headers or lines to and from the tank farm are not to be routed through any process units. Space for separate routing of these lines must be considered in the unit arrangement or refinery plot plan. Piping to and from tanks is normally arranged in groups at grade next to roadways supported by concrete piers or sleepers.

Pipe racks, concrete piers or sleepers shall be located a minimum distance of 3.65 meters from roadways.

INDIVIDUAL PROCESS UNIT PLOT PLANS

With the information obtained previously, along with the planning that has already taken place, independent layouts of individual pieces of equipment in various process units can begin. By this time, process requirements have been developed on the piping and instrument diagrams and project specifications. Even though shop drawings of equipment are not usually available at this time, there is sufficient information available to arrange the units with an acceptable degree of confidence. Items such as heaters, exchangers, and pumps must be sized by estimation, but this can be done within the range of accuracy required.

Once again, safety and economy are the predominant concerns in planning these equipment layouts. Safety is important from both the personnel standpoint and the economic hardship a catastrophe causes. By their very nature, refineries are all potentially hazardous. However, through good process and equipment design, many dangers are eliminated or reduced; through good layout, more potential problems can be reduced or their effects limited.

Following are guidelines based on safety considerations.

Keep all process equipment at least 15 meters from fired heaters. Exceptions are permitted for certain pieces of equipment where the heaters in question are being used to heat the process stream of the equipment, and where any leakage from the equipment would probably ignite instantly, thus creating no additional fire hazard. Such an exception is permitted when locating reactors for a hydrogen stream. Each exception must be individually investigated regarding its potential hazard and must not violate any refinery practices or governing codes. Sloping and curbing around fired heaters should also be considered.

Keep all pumps outside rather than under pipe racks with or without air coolers. Similarly, since pumps are one of the most common hazards in refinery, special considerations must be given to their location. Also, with the proliferation of air cooled exchangers which are usually located over the racks, a small pump fire can become a big one with extensive damage because of the updraft caused by the cooler fan. Pumps should not be located under overhead equipment because of the potential hazard to that equipment.

All process equipment, in general, should be installed in the open, as much as possible, for each of operation, certainly of ventilation, and to facilitate fire protection and extinguishment.

For recommended minimum spacings for some common process equipment, see Figures 5-10 and Tables 1 and 2.

Literature issued by the National Fire Protection Association provide further guidelines for spacing equipment to make refineries as safe as possible from fire and explosion. Also, UOP Standard Specification 9-32-1 provides for guidelines on spacing of tankage.

Other countries and companies have their own recommendations, and all codes and/or refinery standards must be followed. The most severe requirements must be met.

4. REQUIRED INFORMATION

4.1 From Owner or Contractor

- 4.1.a The plot space available for the unit.
- 4.1.b A wind "rose", indicating the percentage of time that the wind blows from each point on the compass.
- 4.1.c Other information that could influence the equipment layout. Examples are poor soil conditions in a portion of the available area, poor access to a part of the available space, heater locations in a neighboring unit, and the location of nearby tankage (both in plan and elevation).
- 4.1.d If the project is a revamp, some additional information is necessary -
 - Location of existing underground electrical, piping, and foundations that cannot be moved.
 - Existing equipment that will be reused in the revamp
 - Equipment in the area that will be operating during the installation of the revamp
 - Access restrictions that may prevent location of some equipment in an area (eg low pipe racks preclude bringing the equipment in or lack of an area to place a crane).
 - Location of unused equipment, or equipment that may be removed from the site prior to shutdown of the existing unit. Construction in these areas may begin in advance of the actual shutdown.
 - Is placing new equipment in front of the existing equipment (i.e. old items are between the new items and the rack) an acceptable option? This may allow time consuming operations, such as foundation construction and, possibly, erection of some large equipment, to proceed prior to the shutdown. At a minimum it allows construction to proceed prior to completion of demolition of the existing installations. Old equipment may be removed at a later, convenient time.

4.2 From Process Licensor

4.2.a Piping and Instrument Diagrams (P&ID's)

4.2.b Specifications for major equipment (eg, heaters, vessels and reactors, exchangers, pumps, and compressors).

4.3.c Miscellaneous equipment information such as; the number of shells required for each tubular exchanger, which air cooled exchangers share the same fan, and which pumps have common spares.

MINIMUM SPACING FOR REFINERY AND PETROCHEMICAL PLANTS (SI METRIC UNITS)

TABLE 1

NOTES:

1. Horizontal distances are in meters.
2. Minimum horizontal distances between buildings, process equipment and property lines are shown and apply to edge-to-edge dimensions.

LEGEND:

NA - Not applicable. No measurable distance can be determined.

NM = No minimum spacing requirement has been established. Use engineering judgement for spacing.

* = Equipment should not be located above heat exchangers containing flammable liquids above 260°C (500°F)

UOP STANDARD SPECIFICATION 9-32-1																			
NA	NM	NM	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NM	NM	NA																	
NM	15	30	1																
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60	60	60	60	60	60	30	30	30	15	NA	15	15	15	15	6	15	7.5	7.5	3
60	45	45	60	60	45	15	15	7.5	6	NA	NA	15	NA	7.5	NA	7.5	7.5	7.5	6
30	15	15	9	9	15	15	9	9	9	NM	NA	4.5	NA	4.5	NA	15	9	15	15
60	60	60	60	60	60	30	30	30	15	NA	9	15	NM	15	6	15	7.5	7.5	6
NM	NM	NM	NM	NM	15	NM	15	NM	NM	NA	NA	15	NA	4.5	7.5	7.5	NM	3	3

MINIMUM SPACING

REFINERY AND PETROCHEMICAL

(SI METRIC UNITS)

TABLE 1

NOTES:

- Horizontal distances are in meters.
- Minimum horizontal distances between buildings and property lines are shown and apply to edge of property.

LEGEND:

NA = Not applicable. No measurable distance.

NM = No minimum spacing requirement. Engineering judgement for spacing is required.

* = Equipment should not be located within 15 m (50 ft) of flammable liquids or gases.

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UOP STANDARD SPECIFICATION 9-32-1

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TABLE 2

1. Horizontal distances are in feet.

2. Minimum horizontal distances between buildings, process equipment and property lines are shown and apply to edge-to-edge dimensions.

NA = Not applicable. No measurable distance can be determined.

- NM - No minimum spacing requirement has been established. Use engineering judgement for spacing.

- * - Equipment should not be located above heat exchangers containing flammable liquids above 260°C (500°F)

MINIMUM SPACING REQUIREMENTS REFINERY AND PETROCHEMICAL PLANTS (Customary Units) TABLE 2

NOTES:

- Horizontal distances are in feet.
- Minimum horizontal distances between buildings, process units, etc., where property lines are shown and apply to edge-to-edge.

LEGEND:

NA = Not applicable. No measurable distance

NM = No minimum spacing requirement has been determined by engineering judgement for spacing.

* = Equipment should not be located above ground level when containing flammable liquids above 20 ft.

Administration Building	Shops, Warehouse, Shipping Bldgs., etc.	Main Substation	Fire Pumps - Fire Station	Property Boundary	Tank Truck & Tank Car Loading Racks except LPG Racks	Boilers & Power Generation	Instrument Air Compressors	Cooling Towers	Main Process Control House	Process Unit Control House	Process Unit Battery Limits	Unit Isolation, Depressuring, Control & Snuffing Steam Valves	Hydrants & Fire Monitors	Water Spray Control Valves & Emergency Shutdowns	Process Unit Substation	Explosionproof Electrical Switch Racks	Process Unit Fired Heaters	Gas Compressors-Expanders	Desalters	Vessels	Exchangers *	Pumps	Process Area Pipeway	Main Pipeway	Air Coolers	Equipment Handling Nonflammables	Atmospheric Storage Tanks	Low Pressure Storage (Spheroids or Tanks not over 15 psig)	High-Pressure Storage (Spheres-Bullets)	FLARES
NA																														
NM	NA																													
NM	NM	NA																												
NM	50	100	3																											
NM	NM	NM	NM	NA																										
200	200	200	150	100																										
100	100	NM	NM	100	200	NA																								
100	100	200	100	100	150	100	25																							
NA	NA	100	NA	100	200	100	100	NA																						
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200	200	200	200	200	150	100	100	NA	NM	50																				
NA	NA	NA	NA	NA	30	NM	NA	NM	NM	NM	NA																			
50	50	50	NM	NM	50	50	50	50	80	NM	NA	NA																		
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250	250	200	200	200	200	100	100	100	50	NA	50	50	50	50	50	25														
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200	200	200	200	200	200	100	100	100	50	NA	30	50	50	50	50	30	3													
200	200	200	200	200	200	100	100	100	50	NA	30	50	50	50	50	30	50	8												
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200	200	200	200	200	200	100	100	100	50	NA	30	50	NM	50	20	50	25	25	20	15	10	NM	NM	NM						
NM	NM	NM	NM	NM	50	NM	50	NM	NM	NA	50	NA	NA	15	25	25	NM	10	10	10	10	NM	NM	NM						

UQP STANDARD SPECIFICATION 9-32-1

UQP PROJECT SPECIFICATION-935

UOP STANDARD SPECIFICATION 9-32-1

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Process Division

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STANDARD SPECIFICATION

9-32-1

PAGE 1 OF 4

HYDROCARBON STORAGE TANK LOCATION, SPACING, AND DIKE REQUIREMENTS

I GENERAL

A. Scope

1. This specification covers the basic requirements for storage tank location, spacing, and diking requirements.
2. Exceptions or variations shown in the Project Specification take precedence over the requirements shown herein.
3. Depending on location or when revamping existing facilities, it may be necessary to deviate from the specific requirements because of surrounding conditions, land value and shape, ground contours, local regulations, or other factors. Any variation from the Project Specification and this specification shall be subject to agreement with the Refiner.

B. Classification of Hydrocarbons

1. Hydrocarbons shall be classified into the following groups:

a. Crude Oils

Defined as crude oil or stock having boil over tendencies.

b. Low Flash Hydrocarbons

Defined as hydrocarbons having a flash point at or under 100° F such as naphtha, platformate, light straight run and gasoline.

c. Medium Flash Hydrocarbon

Defined as hydrocarbons having a flash point above 100° F and below 150° F such as kerosene, diesel, jet fuels, and light fuel oil.

d. High Flash Hydrocarbons

Defined as hydrocarbons having a flash point of 150° F and higher such as heavy fuel oil and asphalt.

e. Liquefied Petroleum Gas (LPG)

Defined as any material which is composed predominantly of propane, propylene, butane, or any mixture thereof.

2. If more than one tank is located in a single diked area, the hydrocarbon contained in each tank should have the same classification.

II TANKAGE LOCATION

A. Minimum clearance as shown in the following table shall be provided.

DISTANCE IN FEET OF NEAREST TANK SHELL TO:	CRUDE TANKAGE	LOW FLASH TANKAGE	MEDIUM FLASH TANKAGE	HIGH FLASH TANKAGE	LPG
PROPERTY LINES, PUBLIC HIGHWAYS AND MAIN LINE RAILROADS	250	250	250	250	250 NOTE 3
BUILDINGS OF HIGH OCCUPANCY, SUCH AS MAIN OFFICES, SHOPS, LABORATORIES, CHANGE HOUSES, CONTROL HOUSES, WAREHOUSES, ETC.	250	200	200	200	200 NOTE 3
REFINERY PROCESS EQUIPMENT, UTILITY AREA EQUIPMENT, COMPRESSOR HOUSE, COOLING TOWERS, BOILERS, ELECTRICAL GENERATING EQUIPMENT, ETC.	250	200 NOTE 1	200 NOTE 1	200 NOTE 1	200 NOTE 3
HAZARDOUS LOADING AND UNLOADING FACILITIES INCLUDING DOCKS	300	250 NOTE 2	250 NOTE 2	250 NOTE 2	250 NOTE 3

HYDROCARBON STORAGE TANK LOCATION, SPACING, AND DIKE REQUIREMENTS

Note 1: This spacing may be reduced to 100 feet where tanks are an integral part of a given process or utility operation, and when each tank is less than 10,000 barrels capacity or the total capacity of all tanks does not exceed 50,000 barrels.

Note 2: This spacing may be reduced to 150 feet when each tank is less than 10,000 barrels capacity.

Note 3: High pressure spheres and bullets should be isolated to remote areas of the refinery whenever possible.

B. Where possible, process, utility and flare areas should be located on higher ground elevation than storage tanks. Where this is not possible, drainage should be arranged such that storage tank areas will drain away from process, utility and flare areas.

III DIKE CONSTRUCTION

- A.** Earthen dikes shall be used. Where land availability may restrict the use of earthen dikes or at Refiner's option, dikes may be constructed of concrete. Concrete diked enclosures shall be provided with entrance and exit stairways.
- B.** All diked enclosures shall be liquid tight and shall withstand a full hydrostatic head with a flooded diked enclosure.
1. Soil stabilization may be required to provide a liquid tight enclosure, depending on the type of soil used for earthen dike construction.
- C.** The total height of a dike including freeboard shall not exceed an average of 6 feet measured from the interior grade of the diked enclosure.
1. A 6 inch minimum freeboard shall be provided. The dike height below freeboard is the effective height of the dike and shall be used in calculating the volume of hydrocarbon retained in the diked enclosure.
 2. Where special circumstances may require a dike height in excess of 6 feet, stairways shall be provided for normal access and necessary emergency access to piping, tanks and valves; and for safe egress from the diked enclosure.
- D.** The top of an earthen dike shall have a flat section no less than 3 feet wide.
- E.** The area to be occupied by a diked enclosure shall be cleared of all brush, trees, stumps, sod, and top soil.
- F.** The slope of an earthen dike shall be consistent with the construction requirements of the material used but shall not exceed a slope of 1 ¼ horizontal to 1 vertical.

IV ATMOSPHERIC AND LOW PRESSURE STORAGE TANKS

A. Dike Arrangement

1. Crude Oils

- a. Fixed roof tanks of any capacity containing crude oils shall be retained in a diked enclosure with no more than one tank per enclosure.
- b. Open or internal floating roof tanks of any capacity containing crude oils shall be retained in a diked enclosure with no more than two tanks per enclosure.
- c. The volume within the diked enclosure containing one tank shall be 100 per cent of the nominal tank capacity.
- d. The volume within the diked enclosure containing two tanks shall be 100 per cent of the nominal capacity of the largest tank plus the volume of the second tank below the effective height of the dike plus the volume of the intermediate wall.
- e. Where two tanks are located within a single diked enclosure, the tanks shall be separated by an intermediate wall with a height 12 inches below the effective height of the dike. The intermediate wall may be constructed of earth or concrete.

2. Low, Medium, and High Flash Hydrocarbon

- a. Fixed roof and open or internal floating roof tanks containing low, medium, or high flash hydrocarbons shall be retained in a diked enclosure with one or more tanks per enclosure.
- b. Where three or more tanks are retained in a single diked enclosure, the total nominal capacity of all tanks shall not exceed 600,000 barrels.
- c. The volume within the diked enclosure containing one tank of any capacity shall be 100 per cent of the nominal tank capacity.
- d. The volume within the diked enclosure containing two or more tanks of any capacity shall be 100 per cent of the nominal capacity of the largest tank plus the volume of all other tanks below the effective height of the dike.

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HYDROCARBON STORAGE TANK LOCATION, SPACING, AND DIKE REQUIREMENTS

e. Each diked area containing two or more tanks shall be subdivided by intermediate curbs in order to prevent spills from endangering adjacent tanks within the diked area as follows:

1. One subdivision for each tank in excess of 10,000 barrels and one subdivision for each group of tanks having an aggregate capacity not exceeding 15,000 barrels.
2. Whenever two or more tanks storing low flash material are located within the same diked area, the capacity of the subdivision for any tank over 150 feet in diameter shall be sized to contain at least 10 percent of the capacity of the tank so enclosed not to include the volume displaced by the tank.
3. The intermediate curbs shall be a minimum of 18 inches in height and constructed of earth or concrete.

3. Refrigerated LPG

- a. Tanks of any capacity containing refrigerated LPG shall be retained in a diked enclosure with no more than two tanks per enclosure.
- b. The volume within the diked enclosure containing one tank shall be 100 per cent of the nominal tank capacity.
- c. The volume within the diked enclosure containing two tanks shall be 100 per cent of the nominal capacity of the largest tank plus the volume of the second tank below the effective height of the dike.
- d. Where two tanks are located within a single diked enclosure, the tanks shall be separated by an intermediate curb of sufficient height to contain 10 per cent of the nominal capacity of the enclosed tank. The curb may be constructed of earth or concrete.

B. Tank Arrangement and Spacing Within the Diked Enclosure

1. Tanks contained in a single diked enclosure shall be so arranged that a side wall of any tank is directly adjacent to the inside wall of the diked enclosure.
2. A roadway shall be located on the outside of a diked enclosure such that any tank within the enclosure is adjacent to the roadway.
3. The minimum distance between tanks less than 150 feet diameter located within a single diked enclosure shall be one-half the diameter of the largest adjacent tank.
4. The minimum distance between tanks 150 feet diameter and larger located within a single diked enclosure shall be one third the sum of the adjacent tank diameters.
5. The minimum distance between a tank sidewall and the inside toe of the dike wall shall be no less than one half the height of the tank, or 25 feet whichever is larger.

C. Tank Piping and Equipment

1. Pumps and equipment not directly connected to a tank shall be located outside of a diked enclosure.
2. Piping for any tank or tanks contained in a single diked enclosure shall not pass through any other diked enclosure.
3. Piping from tanks shall run as directly as practicable to the outside of the diked enclosure to minimize piping within the enclosure.
4. Piping that passes through the dike wall shall be sealed liquid tight to withstand a full hydrostatic head with a flooded dike enclosure.
5. Piping that passes through the dike wall or is attached to a tank shall be designed to prevent excessive stress that may result from dike or tank settlement.

D. Grading and Drainage Within the Diked Enclosure

1. The surface on which each tank bottom will rest shall be a minimum of 12 inches above the ground surface at the periphery of the tank.
2. The surface area within the diked enclosure shall be liquid tight and shall have a uniform slope from the ground surface at the periphery of the tank to a drain sump or sumps located at the inside toe of the dike. The slope shall be not less than one percent for 50 feet of this distance or to the drain sump if less than 50 feet. A drain pipe shall extend from the sump through the dike wall with a normally closed valve located outside the dike wall for a controlled drainage of the diked enclosure.
3. When two or more tanks are located in a single diked enclosure and the tanks are separated by intermediate curbs each curbed section shall be graded and drained as stated in paragraph IV-D-2.



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HYDROCARBON STORAGE TANK LOCATION, SPACING, AND DIKE REQUIREMENTS

V HIGH PRESSURE STORAGE TANKS

A. Location and Curbing

1. Site selection for high pressure storage tanks containing LPG shall consider prevailing winds, terrain, and available space to maximize the distance from process and utility areas, loading areas, buildings and tanks containing hydrocarbons classified other than LPG.
2. It is preferred that all horizontal bullets be arranged such that vessel heads are directed away from process and utility areas, buildings, and property lines.
3. Non-Refrigerated Storage
 - a. Spheres or horizontal bullets of any capacity containing LPG shall be retained in a liquid tight curbed enclosure containing one or more storage tanks.
 - b. The curb shall be no more than 24 inches high and may be constructed of earth or concrete.
 - c. There is no specific curbed enclosure volume requirement, except when specified in the project specification where there may be prolonged periods of ambient temperatures below the boiling point of the material stored. In such case, the minimum volume within the curbed enclosure shall be 100 per cent of the largest sphere or horizontal bullet.
4. Refrigerated Storage
 - a. Spheres of any capacity containing LPG shall be retained in a liquid tight curbed enclosure containing no more than two spheres.
 - b. The minimum volume within the curbed enclosure shall be 100 per cent of the capacity of the largest sphere.
 - c. The curb shall be no more than 24 inches high and shall be constructed of earth or concrete.

B. Tank Arrangement and Spacing Within the Curbed Area

1. Spheres or horizontal bullets contained in a single curbed enclosure shall be so arranged that an outermost projection of any sphere or bullet is directly adjacent to an inside wall of the curbed enclosure.
2. A roadway shall be located on the outside of a curbed enclosure such that any sphere or bullet within the enclosure is adjacent to the roadway.
3. The minimum horizontal distance between the outermost projection of any sphere located within a single curbed enclosure shall be 25 feet or the diameter of the largest adjacent sphere whichever is greater.
4. The minimum horizontal distance between the outermost projection of any horizontal bullet located within a single curbed enclosure shall be one-half the diameter of the largest adjacent bullet.
5. The minimum horizontal distance between the outermost projection of any sphere or horizontal bullet and the inside toe of the curb shall be 25 feet or one-half the diameter of the sphere or bullet, whichever is greater.

C. Tank Piping and Equipment

1. Pumps and equipment not directly connected to a tank shall be located outside the curbed enclosure.
2. Piping for any sphere or horizontal bullet contained in a single curbed enclosure shall not pass through any other curbed enclosure.
3. Piping from spheres or horizontal bullets shall run as directly as practicable to the outside of the curbed enclosure to minimize piping within the enclosure.
4. Any piping that passes through the curb shall be sealed liquid tight.

D. Grading and Drainage Within the Curbed Enclosure

1. The surface area within the curbed enclosure shall be liquid tight and shall be graded to slope away from each sphere or horizontal bullet to a drain sump or sumps located at the inside toe of the curb. The surface area slope shall be such that drainage from any sphere or bullet within the curbed area shall not pass under any other sphere or bullet.
2. A drain pipe shall extend from the sump to a point outside the curbed area with a normally closed valve located outside of the curb for controlled drainage of the curbed enclosure.

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The following information should be available from the unit arrangement or, as in the case of revamps and expansions, from existing layouts, and should be kept in mind while planning the individual process units.

Source and location of all lines entering the unit

Destination of all product lines

Adjacent units

Equipment common to more than one unit

Access available and required

Location of control room, service and utility buildings, electrical equipment, etc.

Future equipment areas

Below are recommendations based on economic considerations such as process requirements and maintenance.

Keep piping runs as short as possible. This is especially important for alloy lines and large diameter lines. Saving pipe and fittings not only saves on material costs, but also saves on pressure losses which represents an ongoing savings in utility costs. In some cases, pipe runs must be kept to a certain minimum for the process specifications to be valid. Where required, these minimums will be indicated on the piping and instrument diagrams.

Hot and heavy wall pipe must be reviewed for expansion so that it can be made workable without the use of expansion compensators. If possible, critical areas around some heater and reactor systems may require a more detailed study before the plot plan can be finalized. Reactor circuits for units such as Platforming, Pacol, and THDA will require additional study.

Although it is not usually governing, foundation type and size should be considered. This is usually something that can be adjusted once design begins, but good foresight can reduce design problems and costs.

Overhead receivers can usually be placed over exchangers. Where condensers or trim coolers must be free draining, a combined structure with the receiver should be investigated. If a structure is decided upon, it is recommended that it be combined with other receivers, if possible. This kind of arrangement will reduce structure and foundation costs and optimize piping runs. For an example of this kind of arrangement, see Figures 5–7.

Space around equipment must be left for items such as pipe supports, control valve manifolds, hose stations, etc., although these items are not usually shown on the plot plan.

Much of the equipment within a process unit falls into one of several general categories. Following are recommendations for locating each of these categories of equipment.

Heaters

The locations of heaters has been anticipated during the planning of the unit arrangement. The same considerations, as entertained for the unit arrangement, are pursued here in greater detail for better defining heater locations. Safety guidelines, as previously discussed, must also be met.

Heater tube pulling areas, if required, shall not encroach on roadways or other process areas.

Heaters should be placed a minimum of 7.5 meters apart, 7.5 meters from process unit pipe rack, 15 meters from main pipe rack and equipment. A clear aisle 2 meters wide is minimum for operation.

For heater sizing of non-UOP heaters, see Figure 12; for UOP heaters, see project specifications.

Vessels

Vertical vessels with trays shall have an access area for installing or removing trays.

Vessels containing catalyst, clay, sieves, etc., shall be located to allow for easy loading and unloading of the contents.

Some vessels may have to be elevated more than the minimum amount required for pump head. This is necessary to keep the suction piping from blocking access ways and must be considered in the plot plan layout.

Locate vertical vessels 7.5 meters from the centerline to the edge of the pipe rack, except for pots, fill tanks, etc. For large vessels, adjust vessel location to maintain a 3 meter clearance from pump discharge and 6 meter clearance to pipe racks.

Locate vessels less than 3 meters in diameter, 2.5 meters from adjacent pieces of equipment or structures.

Locate vessels 3 meters and greater in diameter, 3 meters from adjacent pieces of equipment or structures.

Locate horizontal vessels perpendicular to the pipe rack with the tangent line 4.5 meters from the edge of the pipe rack. With adjoining pumps, locate the vessel tangent line 6 meters from edge of pipe rack. If platform is required with adjoining pumps, locate vessel tangent line 7.5 meters from edge of pipe rack.

Heat Exchangers

Exchangers should be located close to the vessels or equipment they service.

Access and tube pulling space must be provided for all exchangers. This space should not encroach on plant roadways.

Clearance between shell and tube exchanger shells should be 1.5 meters, and the clearance between hairpin exchanger shells should be 1 meter.

Thermosyphon reboilers must be located next to the vessels they service with a clearance of 1.5 meters.

Locate shell, tube and hairpin exchangers perpendicular to the pipe rack.

Locate tangent line of exchangers 4.5 meters from the pipe rack and group exchangers where possible. With adjoining pumps, locate tangent line of exchangers 6 meters from pipe rack.

Stacking exchangers two (2) high is a commonly accepted practice if consistent with process considerations. Stacking exchangers three (3) or more high is not recommended.

For spacing between exchangers and vessels, use vessel spacing recommendations.

Air Cooled Heat Exchangers

All exchangers should be located in groups at the same level within a unit unless they are so widely separated that other exchangers will not discharge air into them.

Exchangers should be located as close as possible to the equipment they service. Often, there will be free draining requirements which will be noted on the piping and instrument diagram.

Provide a minimum of 9 meters clearance for crane access between equipment and structures for maintenance of exchangers.

Pumps

Pumps shall be located so that the suction lines are short.

Pump aisles shall be 1 meter between pump foundations.

Show centrifugal pump foundations 1 by 2 meters and proportioning pump foundations 1 by 1 meters.

Pump discharge shall be located in a row or rows 2 meters from pipe rack. The driver shall be located toward the pipe rack.

The location of small chemical, in line and injection pumps are not governed by the above minimum.

Clearance between pumps should be 1.5 meters.

Compressors

Gas compressors are usually located in a shelter. If more than one compressor is required for a particular process unit, they should be combined in a common shelter.

Compressors shall be located adjacent to a roadway for ease of maintenance.

Space shall be provided at grade, next to the compressors for the manifold piping and compressor auxiliary equipment, such as suction drums and intercoolers. Lube oil coolers shall be within shelter area.

Allow 8 meters square of shelter space for each gas compressor. Adjust area for multi-stage compressors.

Locate compressors 7.5 meters from the edge of the pipe rack. Provide 9 meters horizontal clearance between compressor and other equipment, except for suction drums and intercoolers.

Allow 3 meters between compressors.

Miscellaneous Equipment

All other equipment for the process unit to be spaced with the best engineering judgment similar to the above.

Storage Tanks

No storage tanks shall be permitted in process area.

If storage tanks are required for process reasons, they shall be enclosed by a concrete dike. The storage tank shall be 7.5 meters from equipment and pipe rack, except for storage tank pumps.

It is important to note that there is probably no perfect plot plan because almost all plot plans require some compromises be made. Adherence to all guidelines cannot generally be encompassed. The safest layout might locate each piece of equipment at least 15 meters from every other piece of equipment. This kind of arrangement would be ideal, not only for safety, but also for maintenance. This same layout, however, would be extremely unrealistic from an economic standpoint.

OFFSITE PLOT PLAN

As soon as the general locations and area allotments for the major groups of equipment have been established, more detailed planning of the offsite areas can begin. Guidelines considered for development of the refinery plot plan, along with some specific guidelines given below, will be used to arrange the equipment for the following offsite areas.

Utility Area

Tankage

Loading and Unloading Area

Flare

Waste Treatment

Future Areas

As in the case of the process area planning, the planning of the offsite areas shall provide for safety and economy. In addition, many of the items to be considered in making these arrangements are the same ones contemplated when making the unit arrangement and individual process unit plot plans. Items to be considered include site, topography, location and destination of lines, maintenance and operating requirements, insurance rules, future requirements, etc.

Because of the similarity between equipment in the utility and process areas, many of the recommendations and guidelines given for process area equipment are applicable to the arrangement of equipment in the utility. For equipment spacing, see Tables 1 and 2 and UOP Standard Specification 9-32-1.

Some specific guidelines for the offsite areas are as follows:

Utility Area

The cooling tower should be located to provide the least possible restriction to the free flow of air and away from areas where drift or fogging might create a problem.

The circulating fuel oil system that supplies oil for process heaters and boilers is usually located in one corner of the utility area including tanks and circulating pumps. Tanks are to be diked.

All boilers are grouped together with space provided for at least one future boiler. All boiler auxiliaries including deaerator, feed pumps, flash drums, and chemical feed systems are located in close proximity to the boiler. Consideration must be given to single stacks for each boiler or one common stack.

Plant and instrument air compressors, including dryers, are located in the utility area.

Switchgear for the electrical system is usually placed in an enclosed building and located within the utility area. Substations serving process units and offsite facilities are usually located in the refinery area dependent upon the areas served.

A utility control building is usually provided to house all board mounted instruments used for operation and control of the utility equipment. If weather is a factor, pumps, compressors, dryers, and chemical feed systems may be housed in a building which can be a part of the utility control building.

Tankage

Tanks within the tank farm should be grouped as follows:

Crude

Intermediate or charge tanks that will feed process units

Gasoline product and component or rundown tanks used in blending gasoline

Kerosine, diesel, and light fuel oil

Heavy fuel oil

Asphalt

Slop tanks

LPG

All tanks, with the exception of LPG, should be diked. The number of tanks within a dike, spacing within the dike and volume of dikes should be in accordance with UOP Standard Specification 9-32-1.

Dikes are not usually required for LPG storage. The LPG storage area should be graded to drain to a safe area.

Roadways and access around all diked areas should be provided for fire fighting, maintenance, and required pumps and pipeways.

Transfer pumps should be grouped in one or more locations, located outside a tank dike and provided with a minimum of a roof shelter. The number of pump locations should be a minimum.

Loading and Unloading Area

The truck loading entrance should be separate from any other entrance area to the refinery and easily accessible to a public roadway.

The truck loading area should be fenced from the rest of the refinery to prevent unauthorized persons from entering the refinery area.

Care must be taken to provide sufficient access area for trucks to enter and leave each loading station without interference.

An adequate parking area for trucks waiting to load must be provided out of the path of moving trucks.

If weigh scales are required for truck loading, they should be located near the entrance for ease in weighing trucks as they enter and just prior to their leaving. Weight scales may be incorporated with a gate house.

The preferred rail loading area is the outer edge of the refinery plot; however, this depends on the location of the incoming rail spur.

Flare

There should be a totally clear area surrounding the flare stack. The size of this area is dependent on heat intensity requirements which depend upon the height of the flare and relieving quantity.

The flare knockout drum, pumpout drum, and flare ignition system should be located at the periphery of the clear area.

Layout of area must include vehicle accessibility for maintenance.

Waste Treatment

The preferred location of the waste treatment area is at a refinery low point to insure gravity flow from all areas in the refinery. Where this is not possible, lift stations must be provided as required.

The waste treatment area should be remote from the process and utility areas and arranged to permit future expansion of the system.

Layout of the area must include vehicle accessibility for maintenance.

Future Offsite Areas

Allocate areas for future expansion.

PIPING PLANS

With completion of the planning, the general locations of most equipment is set. At this point, piping layouts can be started.

Piping plans are done to a larger scale than other plans, approximately 30 to 1, and show all piping, valves, platforms, access ways, etc. These plans are the vehicle from which detailed piping drawings (isometrics) are made. This stage of planning requires that final dimensions be established. A scale model may be developed coincidentally and represents the ultimate layout tool in that it can be seen in three dimensions.

Reference material to be obtained before starting piping layout are:

Project Specifications

Piping and Instrument Diagrams

Petroleum Refinery Piping Code (ANSI B31.3)

Plot Plans

Equipment Suppliers Drawings

UOP or Customer Standards

In preparing piping plans, there are certain requirements to be fulfilled. Even though process designers do not usually get directly involved, it is valuable to be aware of these requisites. Basic requirements for piping layouts are as follows:

All equipment and piping shall be indicated or accounted for on the layout. The layout shall be made to scale.

Piping shall be routed in accordance with the piping and instrument diagrams, project specifications, codes and insurance regulations.

Piping shall be routed to provide convenience in operation, ease of erection and maintenance, and consistency in appearance. These requirements shall be met with consideration given to economy.

Equipment locations for fired heaters, heat exchangers, vessels, pumps, compressors, and pipe racks shall be in general agreement with the plot plan.

All equipment platforms, ladders, structures, davits, and trolley beams shall be indicated.

All instruments shall be located and identified.

All valving and handwheel orientations shall be indicated.

All access, lifting, tube pulling and maintenance areas shall be indicated. These areas must remain clear.

All sample systems shall be indicated.

Guidelines and recommendations to be followed when preparing the piping layouts are:

Piping shall be routed in groups, overhead, wherever possible. Firewater and sewer systems shall be buried. All piping shall be arranged to avoid gas and liquid traps except when noted otherwise on the piping and instrument diagram.

Piping shall be routed to permit normal bends and offsets to take thermal expansion. Where this is not sufficient, provide expansion loops or other means to accommodate thermal expansion.

Do not use trenches.

All branch lines off the instrument air, steam, and cooling water supply headers are taken off the top of the header.

Design steam piping for complete continuous condensate removal.

Steam trap piping in uninterruptible service shall be arranged to provide continuous operation of equipment while steam trap maintenance is being performed.

Utility stations at grade shall include steam, water, air, and permanent hose rack. They shall be located such that any working area at grade can be reached with a 15.0 meter length of hose. Utility stations above grade shall include steam and air connections. Vertical vessels shall have utility stations located at all manway levels.

Structures shall have at least one utility station located at each maintenance area.

Utility stations at grade and first platform level only shall include nitrogen when required. Nitrogen shall be clearly marked and shall have non-interchangeable connectors.

Short radius elbows are not to be used unless space limitations require their use.

Provide overhead clearance above access areas of 2.2 meters minimum.

Operating drains shall be arranged that the discharge is visible from the drain valve.

Uninsulated lines lie directly on the pipe support member. Heat insulated lines set on "T"-Bar supports (shoes).

Pipe Racks

Pipe rack runs oriented in the same direction shall be at consistent elevations. Pipe rack runs oriented opposite (perpendicular) to these runs shall be at other elevations to accommodate crossing of lines at pipe rack junctions and to accommodate branch line intersections.

Single level pipe racks are preferred; however, if more than one level is required, the vertical distance between levels oriented in the same direction shall be adequate for maintenance from 1.2–1.5 meters.

Minimum spacing between pipe centerlines in the rack shall be as indicated in Figure 11 and the following guidelines:

For non-insulated lines:

Outer diameter of largest flange multiplied by 0.5, plus adjacent pipe outer diameter multiplied by 0.5, plus 25 millimeters clear.

For insulated lines:

Outer diameter of largest flange, or insulation outer diameter if greater, multiplied by 0.5, plus adjacent pipe outer diameter or insulation outer diameter multiplied by 0.5, plus 25 millimeters clear.

Avoid flat turns. When changing directions, change elevation.

Allow ample space for routing instrument lines and electric conduit adjacent to that required.

Provide 20 percent additional space on the pipe rack for future piping. This space shall be continuous and clear on each level for the full length of the rack. The width allocations may be split in two sections, but no more than two.

Heaters

Arrange piping to permit burner removal.

Locate burner valves as close to burners as possible.

Design each fuel gas or fuel oil distribution header for uniform distribution to all burners. Branch takeoffs for fuel oil at burners are from the bottom or side of horizontal headers.

Block valves for emergency snuffing steam injection are to be located at grade 9 meters minimum from the heater, preferably on the upwind side of the heater.

Distribution and collection manifolds on multi-pass heaters shall be designed to give equal flow distribution.

Vessels

Elevations shown on piping and instrument diagrams reflect minimum process requirements. Piping layouts may require elevation adjustments. If the adjustment results in any decrease in elevation or any increase of more than 600 millimeters in elevation, both the process requirements and hydraulics design must be reviewed.

Establish nozzle orientation with respect to process requirements, vessel internals, maintenance, and adjacent structures.

Do not locate valves inside vessel skirts.

Manways, hand holes, level controllers, liner blinds, and valves larger than 50 millimeters require platform access if located more than 2.2 meters above grade.

Platform accessways require 750 millimeters minimum clear space.

For servicing manways, the preferred distance from manway center line to the platform below is 750 millimeters.

Traffic patterns of vessel platforms shall not require persons to cross over ladder openings.

Maximum uninterrupted caged ladder length shall be 9.0 meters.

Exchangers

Exchangers at grade shall be kept as low as possible. Shell and tube exchangers shall have a minimum tube bundle centerline elevation of 750 millimeters above high point of finished surface. Hairpin exchangers shall have a minimum foundation height of 300 millimeters above high point of finished surface.

Arrange piping to provide clear area for tube bundle pulling. Clearance shall be provided around flanges to facilitate removal.

Arrange piping to clear permanent tube handling facilities.

Provide platforms for removal of cover, channel and bonnet where exchanger centerline is more than 3.7 meters above high point of finished surface.

When accessway is required between exchangers and piping, provide 750 millimeters minimum clear aisle.

Pumps

Arrange the suction lines of pumps to be as short as practical and to be sufficiently flexible to permit pipe expansion without imposing excessive forces on the pump.

Top of foundation shall be 300 millimeters above high point of finished surface.

When accessway is required between pump foundation and piping, provide 750 millimeters minimum clear aisle.

Arrange piping to provide access to permit removal or replacement.

Compressors

Compressors shall be located at minimum elevation consistent with foundation, piping layout, safety and maintenance requirements.

When accessway is required between piping and compressor, provide 1.5 meters minimum clear aisle.

All operating valves in compressor piping shall be accessible from the compressor operating area and shall be grouped together where possible for ease of operation.

Piping shall be arranged to permit the removal of compressor components for maintenance.

Fire Protection

The fire water system layout shall be in accordance with National Fire Protection Association Code. The fire water line should be looped around a process block and storage tank area, consisting of fixed monitors, sprinklers, hose stations, and hydrants. The monitor should not be installed closer than 15 meters to hazardous process equipment or tankage.

Hydrants should be spaced no more than 60 meters apart around process block or storage tank area. In general, monitors, hose stations, and hydrants should be located on the perimeter of process and storage areas. Sprinklers should be located at buildings and equipment. Only extra protection is required for buildings in hazardous service with the unit such as pump or compressor buildings. In such a case, hydrant and/or hose stations should be located 15 meters from the building. In any case, hydrants and hose stations should be located and spaced to keep hose lines short, preferably not over 45 meters.

Fire pumps should be located 60 meters from process area and 90 meters from storage tanks.

In conclusion, the intent of this lecture is to create an awareness of the items that must be considered to design the safest and most economic plant possible. A good layout can eliminate problems and save costs over the entire life of the refinery.

STORAGE TANKS

Guidelines for arriving at nominal capacity, diameter and height for atmospheric and low pressure storage tanks. Working capacity is obtained from bpsd of product and total days of storage required.

Tank Working Capacity	Working Capacity as a Percent of Nominal
2000–10,000 bbls	85 percent
10,000 bbls and up	90 percent
Less than 2000 bbls	Calculate nominal on individual basis assuming 4 foot (1 meter) of tank height is not usable.

Round-off the calculated nominal tank capacity upwards as follows:

an even 50 for tanks under 1000 barrels

an even 100 for tanks 1000 to under 10,000 barrels

an even 1000 for 10,000 barrels and up

Establish tank height using increments of 8 foot plate. Calculate tank diameter to nearest tenth of a foot.

The following guideline can be used in establishing tank height. This is subject to customer preference.

15,000 bbls up to 100,000 bbls	48 feet high
100,000 bbl up to 250,000 bbl	56 feet high
250,000 bbl up to 350,000 bbl	64 feet high
350,000 bbl and up	72 feet high

For tanks less than 14,000 barrels, use a tank height that will give an approximate diameter to height ratio of one. For tanks 2000 barrels and less, consideration may be given to using 6 foot plate.

Typical sizes and corresponding nominal and working capacities for storage tanks.

Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
50	30		6.0	10		
75	52		7.3	10		
100	60		8.5	10		
125	83		8.6	12		
150	90		9.5	12		
175	116		10.2	12		
200	136		11.0	12		
250	161		12.2	12		
300	226	201	11.6	16	13.4	12
350	262	233	12.5	16	14.4	12
400	301	266	13.4	16	15.4	12
450	337	300	14.2	16	16.4	12
500	373	335	14.9	16	17.3	12
550	412	367	15.7	16	18.1	12
600	450	400	16.4	16	18.9	12
650	520	485	15.2	20	17.0	16
700	560	526	15.8	20	17.7	16
750	602	563	16.4	20	18.3	16
800	640	600	16.9	20	18.9	16
850	680	638	17.4	20	19.5	16
900	720	675	17.9	20	20.0	16
950	760	713	18.4	20	20.6	16
1,000	800	748	18.9	20	21.1	16
1,100	896	813	20.0	20	22.0	16
1,200	1,011	896	19.0	24	23.1	16
1,300	1,087	1035	19.7	24	21.5	20
1,400	1,167	1124	20.4	24	22.4	20
1,500	1,250	1195	21.1	24	23.1	20
1,600	1,333	1280	21.8	24	23.9	20
1,700	1,417	1356	22.5	24	24.6	20
1,800	1,500	1445	23.1	24	25.4	20

Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
1,900	1,583	1514	23.8	24	26.0	20
2,000	1,700		24.4	24	26.7	20
2,500	2,188		23.6	32	27.3	24
3,000	2,550		25.9	32	29.9	24
3,500	2,975		27.9	32	32.3	24
4,000	3,400		30.0	32	34.5	24
4,500	3,825		31.7	32	36.3	24
5,000	4,250		33.4	32	38.6	24
5,500	4,675		35.0	32		
6,000	5,100		36.6	32		
6,500	5,525		38.0	32		
7,000	5,950		35.6	40	39.5	32
7,500	6,375		36.6	40	40.9	32
8,000	6,800		37.8	40	42.3	32
8,500	7,225		38.9	40	43.6	32
9,000	7,650		40.0	40	44.8	32
9,500	8,075	Same as cone roof	41.2	40	46.0	32
10,000	9,000		42.2	40		
11,000	9,900		44.3	40		
12,000	10,800		46.3	40		
13,000	11,700		48.2	40		
14,000	12,600		50.0	40		
15,000	13,500		47.2	48	51.8	40
16,000	14,400		48.8	48	53.4	40
17,000	15,300				50.3	48
18,000	16,200				51.8	48
19,000	17,100				53.2	48
20,000	18,000				54.6	48
21,000	18,900				55.9	48
22,000	19,800				57.2	48
23,000	20,700				58.5	48
24,000	21,600				59.8	48
25,000	22,500				61.0	48

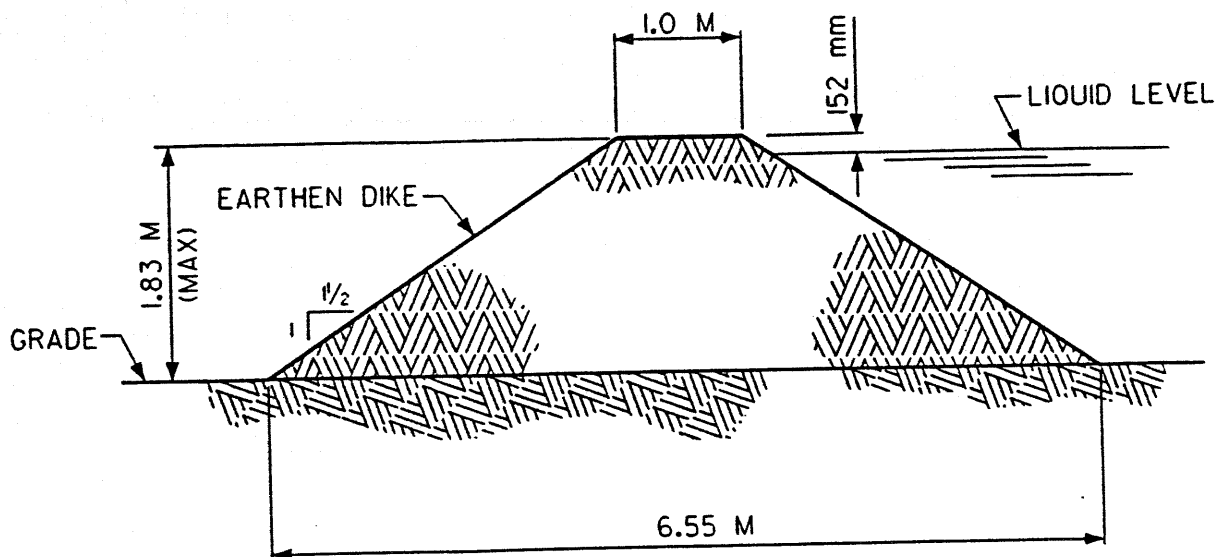
Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
26,000	23,400	Same as cone roof			62.2	48
27,000	24,300				63.4	48
28,000	25,200				64.5	48
29,000	26,100				65.7	48
30,000	27,000				66.8	48
31,000	27,900				67.9	48
32,000	28,800				69.0	48
33,000	29,700				70.0	48
34,000	30,600				71.1	48
35,000	31,500				72.2	48
36,000	32,400				73.2	48
37,000	33,300				74.2	48
38,000	34,200				75.2	48
39,000	35,100				76.2	48
40,000	36,000				77.2	48
41,000	36,900				78.1	48
42,000	37,800				79.0	48
43,000	38,700				80.0	48
44,000	39,600				81.0	48
45,000	40,500				81.8	48
46,000	41,400				82.7	48
47,000	42,300				83.6	48
48,000	43,200				84.5	48
49,000	44,100				85.4	48
50,000	45,000				86.3	48
51,000	45,900				87.1	48
52,000	46,800				88.0	48
53,000	47,700				88.8	48
54,000	48,600				89.6	48
55,000	49,500		Same as floating roof		90.5	48
56,000	50,400				91.3	48
57,000	51,300				92.1	48
58,000	52,200				92.9	48

Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
59,000	53,100	Same as cone roof	Same as floating roof		93.7	48
60,000	54,000				94.5	48
61,000	64,900				95.3	48
62,000	55,800				96.0	48
63,000	56,700				96.8	48
64,000	57,600				97.6	48
65,000	58,500				98.3	48
66,000	59,400				99.1	48
67,000	60,300				99.8	48
68,000	61,200				100.6	48
69,000	62,100				101.3	48
70,000	63,000				102.1	48
71,000	63,900				102.8	48
72,000	64,800				103.5	48
73,000	65,700				104.2	48
74,000	66,600				105.0	48
75,000	67,500				105.6	48
76,000	68,400				106.3	48
77,000	69,300				107.0	48
78,000	70,200				107.7	48
79,000	71,100				108.4	48
80,000	72,000				109.1	48
81,000	72,900				109.8	48
82,000	73,800				110.5	48
83,000	74,700				111.1	48
84,000	75,600				111.8	48
85,000	76,500				112.5	48
86,000	77,400				113.1	48
87,000	78,300				113.8	48
88,000	79,200				114.4	48
89,000	80,100				115.1	48
90,000	81,000				115.7	48
91,000	81,900				116.4	48

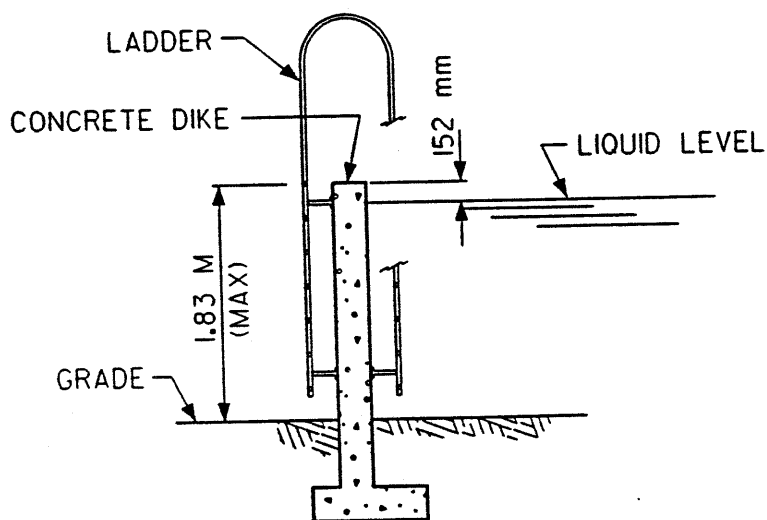
Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
92,000	82,800	Same as cone roof	Same as floating roof		117.0	48
93,000	83,700				117.6	48
94,000	84,600				118.3	48
95,000	85,500				118.9	48
96,000	86,400				119.5	48
97,000	87,300				120.2	48
98,000	88,200				120.8	48
99,000	89,100				121.4	48
100,000	90,000				122.0	48
100,000	90,000				112.9	56
105,000	94,500				115.7	56
110,000	99,000				118.5	56
115,000	103,500				121.1	56
120,000	108,000				123.7	56
125,000	112,500				126.3	56
130,000	117,000				128.8	56
135,000	121,500				131.2	56
140,000	126,000				133.6	56
145,000	130,500				136.0	56
150,000	135,000				138.3	56
155,000	139,500				140.6	56
160,000	144,500				142.9	56
165,000	148,500				145.0	56
170,000	153,500				147.3	56
175,000	157,500				149.4	56
180,000	162,000				151.5	56
185,000	166,500				153.6	56
190,000	171,000				155.7	56
195,000	175,000				157.7	56
200,000	180,000				159.7	56
205,000	184,500				161.7	56
210,000	189,000				163.7	56
215,000	193,500				165.6	56

Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
220,000	198,000	Same as cone roof	Same as floating roof		167.5	56
225,000	202,500				169.4	56
230,000	207,000				171.3	56
235,000	211,500				173.1	56
240,000	216,000				175.0	56
245,000	220,500				176.8	56
250,000	225,000				178.6	56
250,000	225,000				167.0	64
255,000	229,500				168.7	64
260,000	234,000				170.3	64
265,000	238,500				180.0	64
270,000	243,000				173.6	64
275,000	247,500				175.2	64
280,000	252,000				176.8	64
285,000	256,500				171.3	64
290,000	261,000				179.9	64
295,000	265,500				181.5	64
300,000	270,000				183.0	64
305,000	274,500				184.5	64
310,000	279,000				186.0	64
315,000	283,500				187.5	64
320,000	288,000				189.0	64
325,000	292,500				190.5	64
330,000	297,000				191.9	64
335,000	301,500				193.4	64
340,000	306,000				194.8	64
345,000	310,500				196.2	64
350,000	315,000				197.6	64
350,000	315,000				186.3	64
355,000	319,500				187.7	72
360,000	324,000				189.0	72
365,000	328,500				190.3	72
370,000	333,000				191.6	72

Nominal	Working Capacity Cone Roof	Working Capacity Floating Roof	Cone Roof Size in Feet		Floating Roof Size in Feet	
			Diameter	Height	Diameter	Height
375,000	337,500	Same as cone roof	Same as floating roof		192.9	72
380,000	342,000				194.2	72
385,000	346,500				195.4	72
390,000	351,000				196.7	72
395,000	355,500				198.0	72
400,000	360,000				199.2	72
405,000	364,500				200.4	72
410,000	369,000				201.7	72
415,000	373,500				202.9	72
420,000	378,000				204.1	72
425,000	382,500				205.3	72
430,000	387,000				206.5	72
435,000	391,500				207.7	72
440,000	396,000				208.9	72
445,000	400,500				210.1	72
450,000	405,000				211.3	72
455,000	409,500				212.5	72
460,000	414,000				213.6	72
465,000	418,500				214.8	72
470,000	423,000				215.9	72
475,000	427,500				217.0	72
480,000	432,000				218.2	72
485,000	436,500				219.4	72
490,000	441,000				229.5	72
495,000	445,500				221.6	72
500,000	450,000				222.7	72

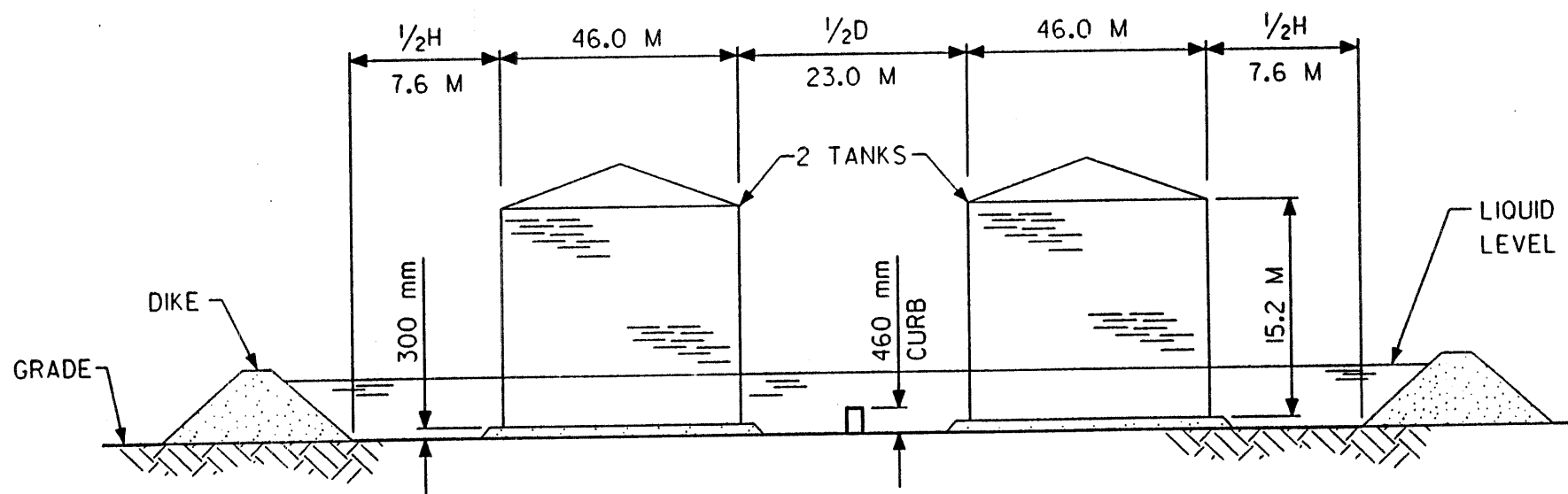


EARTHEN DIKE



CONCRETE DIKE

FIGURE 13



**LOW, MEDIUM AND HIGH
HYDROCARBON TANK ARRANGEMENT**

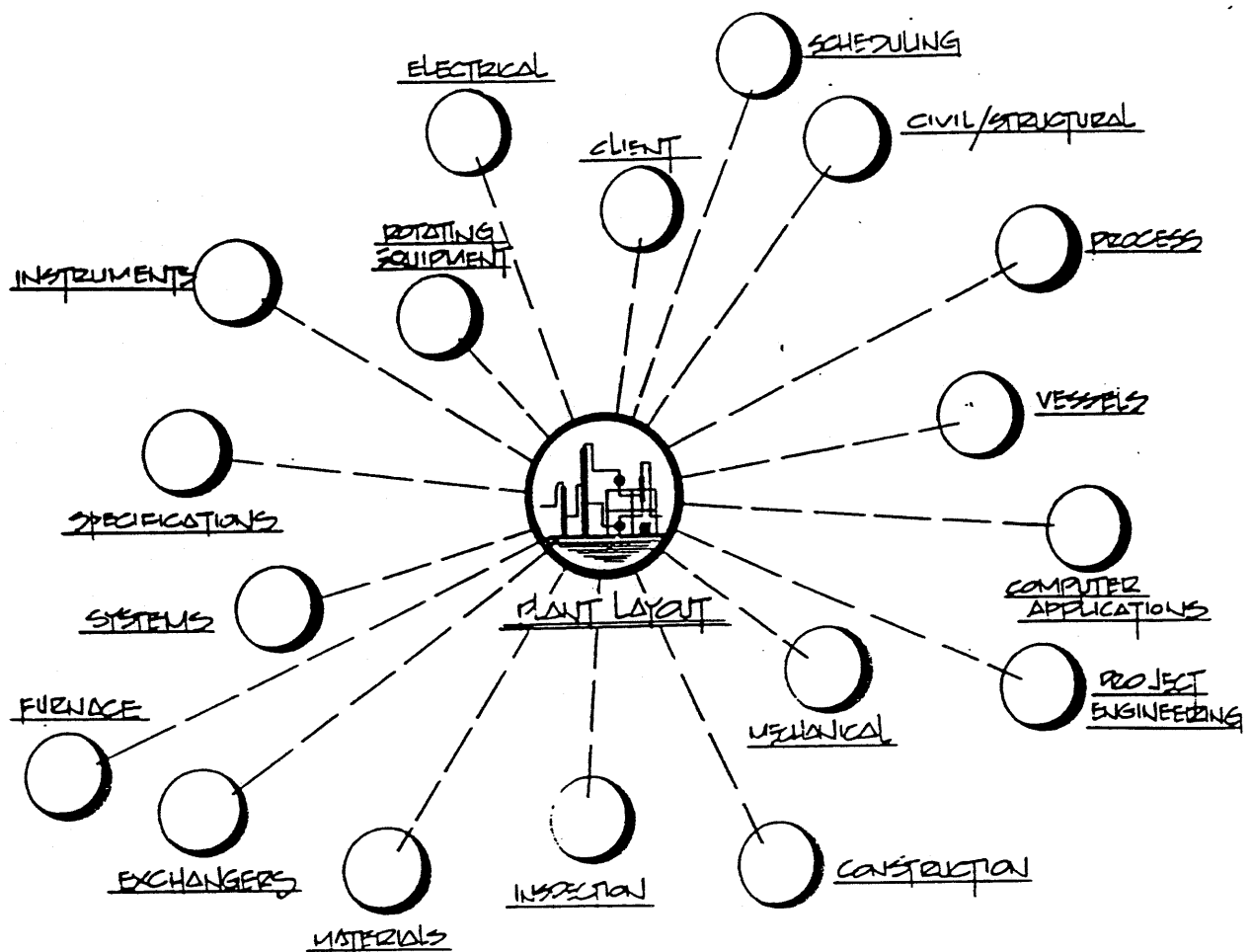
FIGURE 14

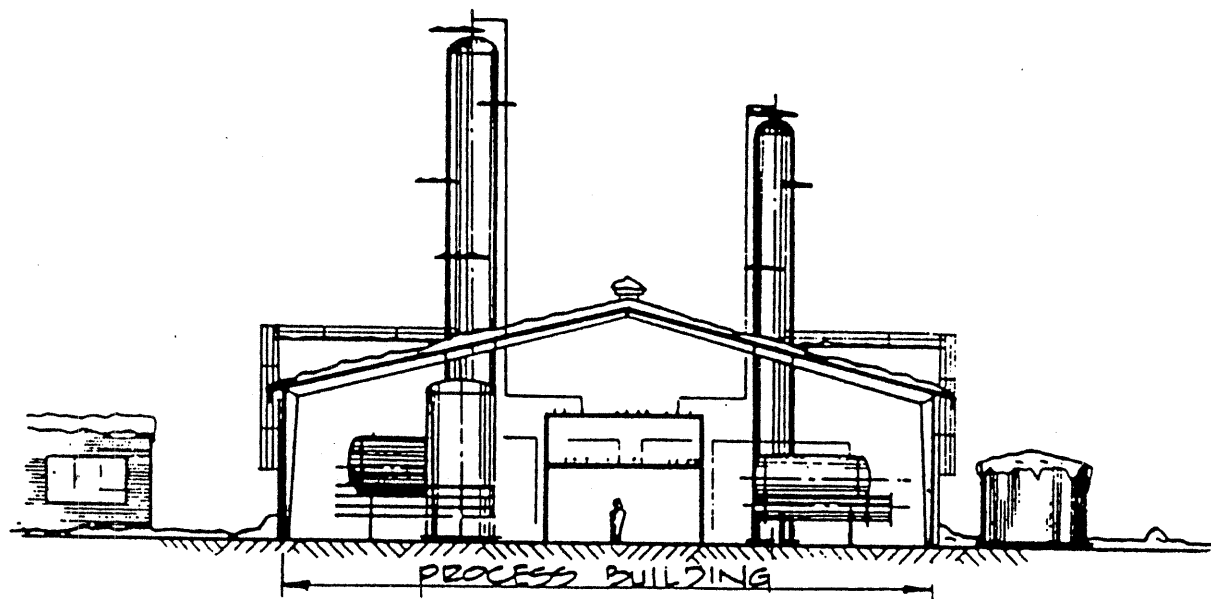
Uop

25 East Algonquin Road
Des Plaines, Illinois 60017-5017 USA

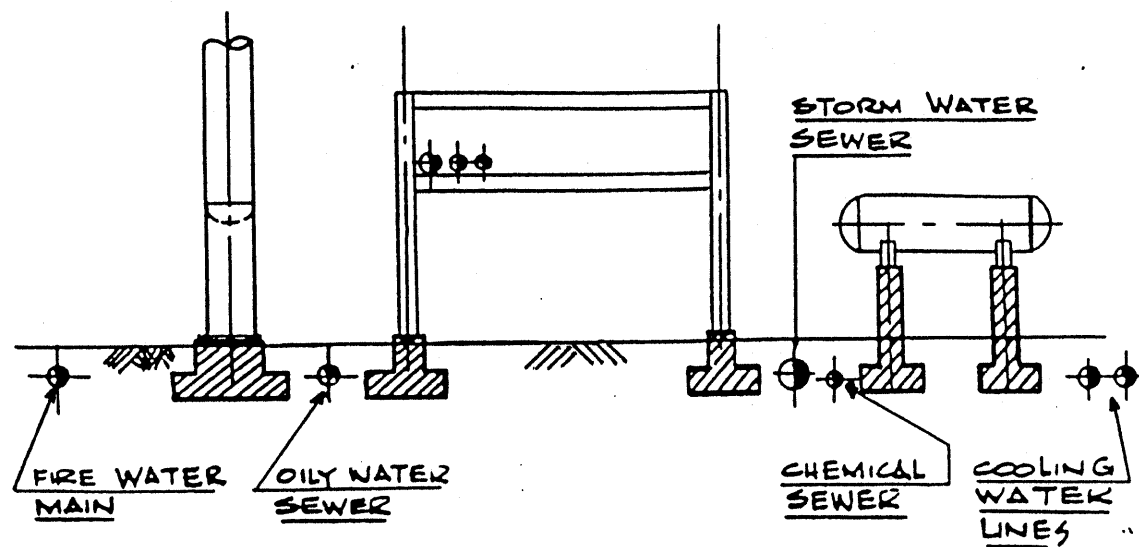
GENERAL EQUIPMENT INFORMATION

Plant Layout Interface



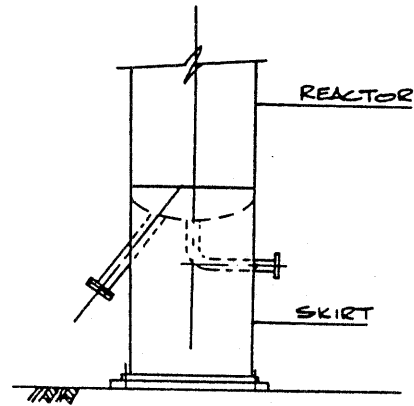


Total Unit Encasement

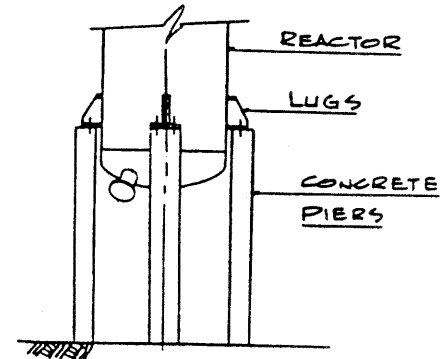


Typical Underground
Elevations

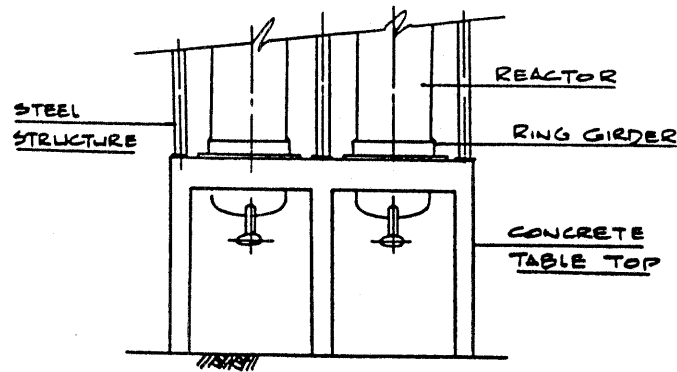
Methods for Reactor Support



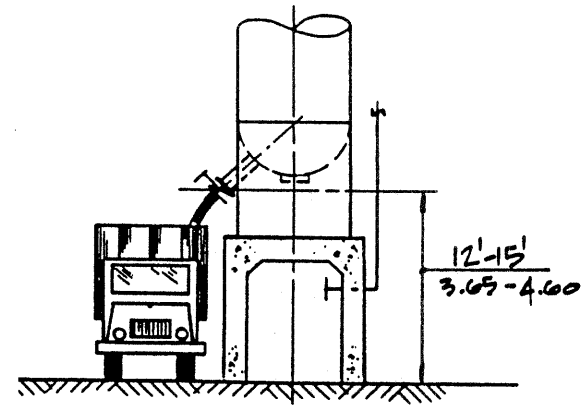
a. Skirt Supported (foundation)



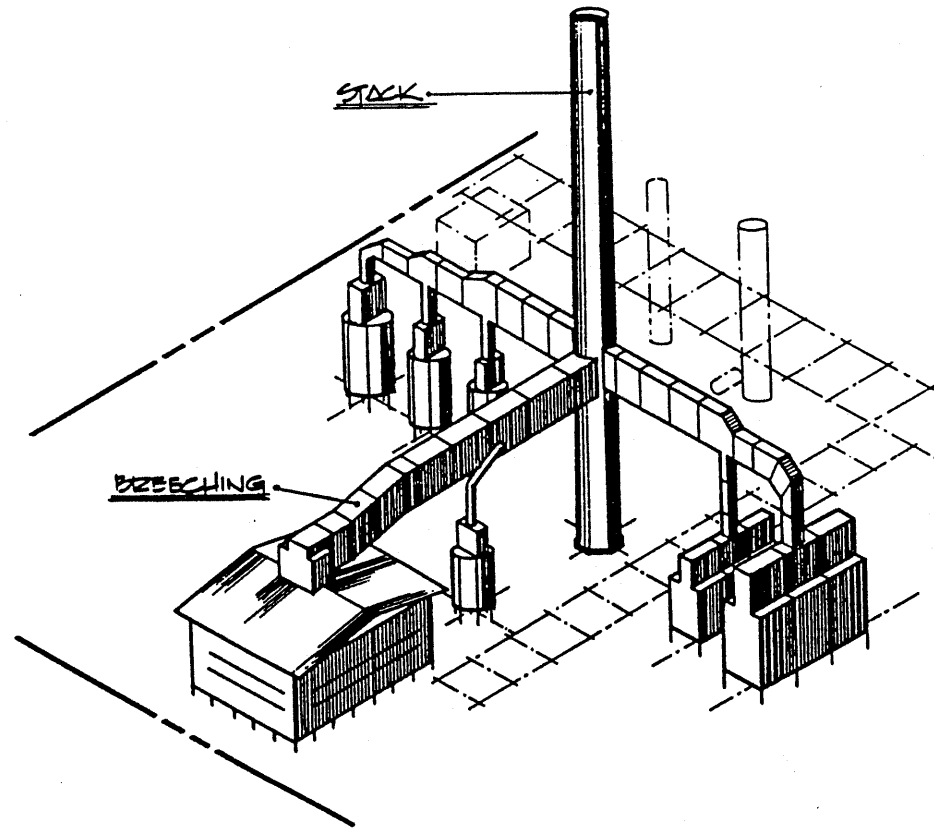
b. Lug Supported



c. Ring Girder Supported

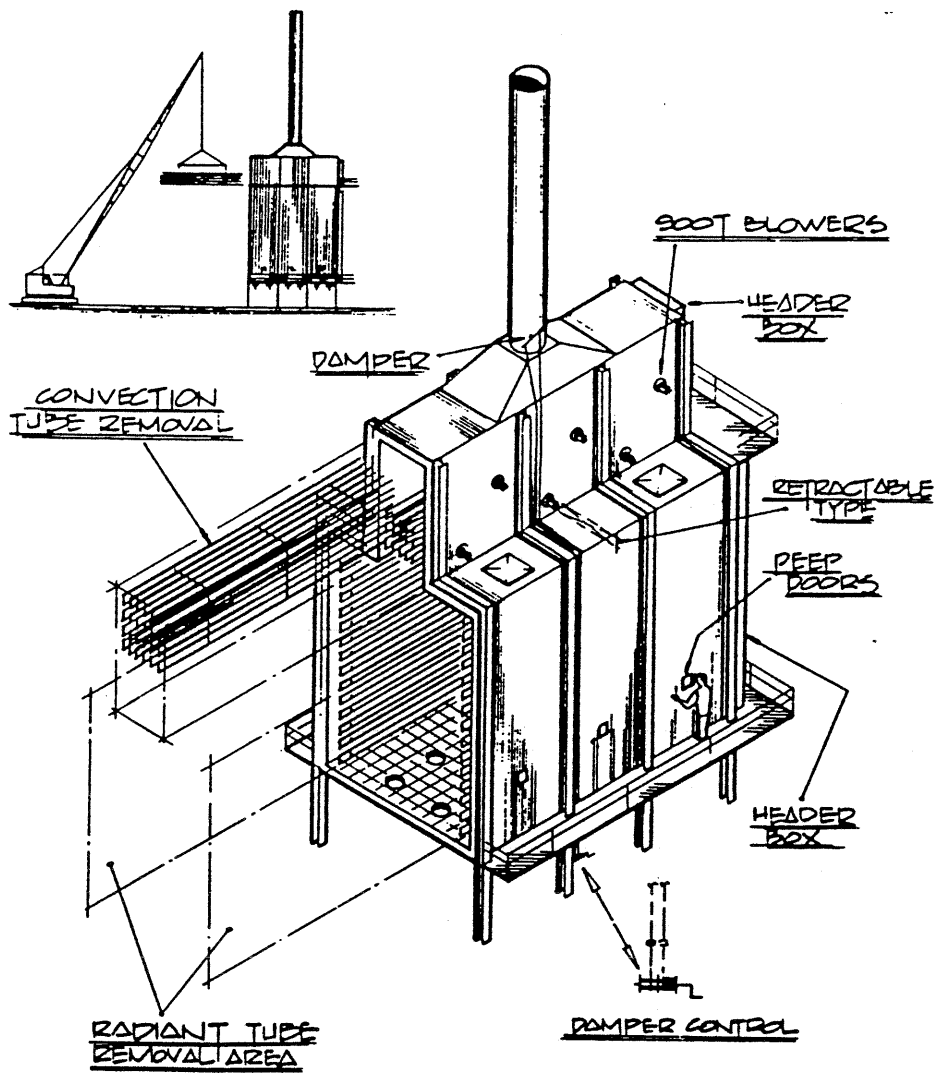


d. Skirt Supported (table top)

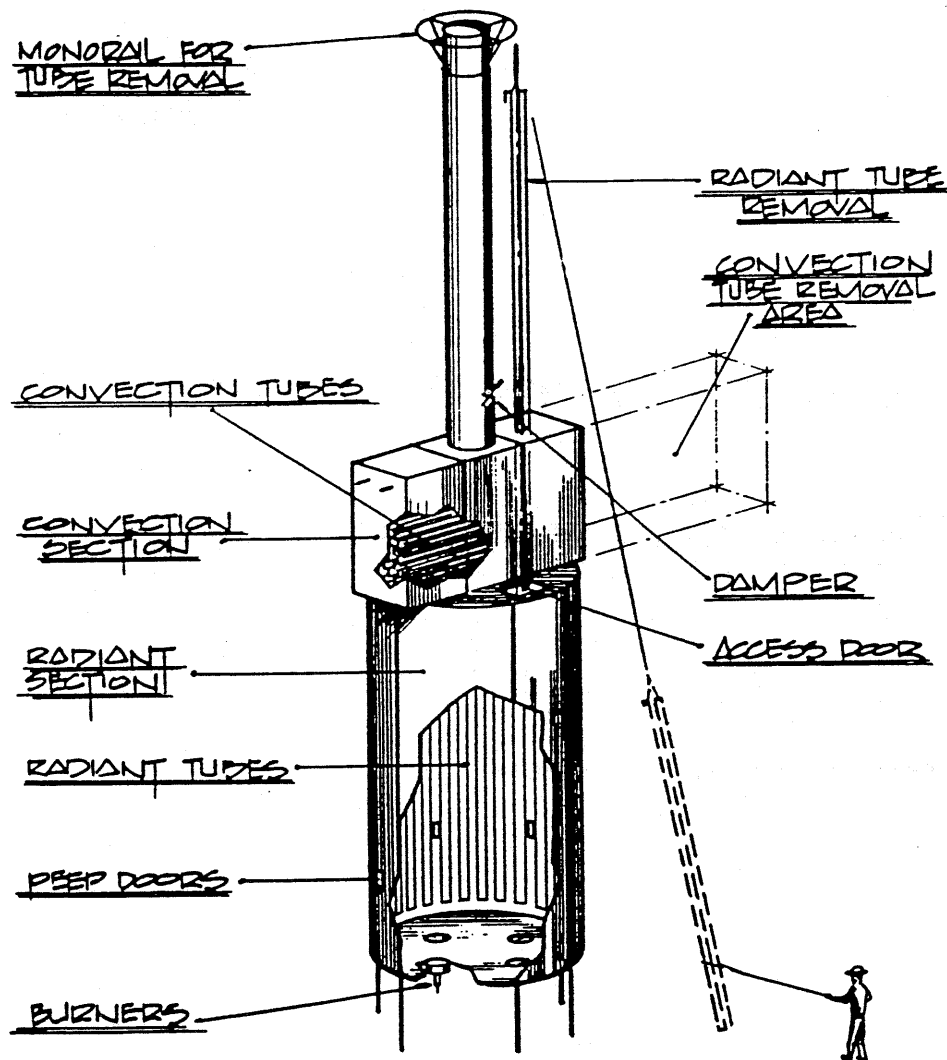


Common Stack for
Multiple Furnaces

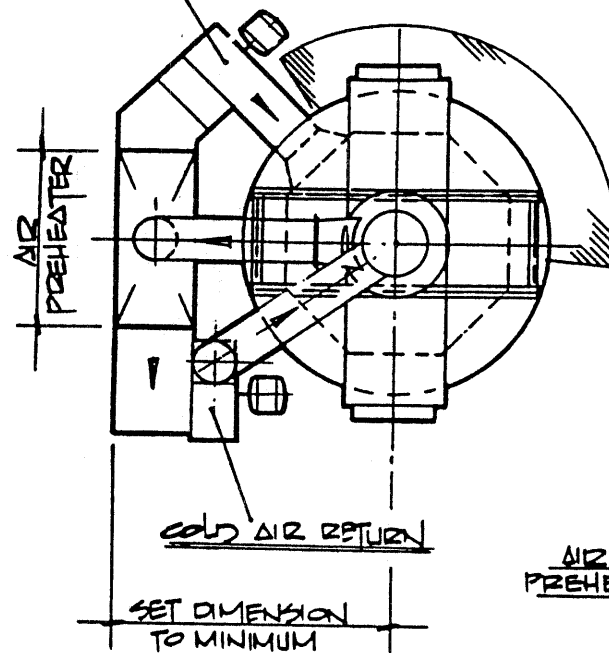
Convection Section Tube
Removal in a Box-Type
Furnace



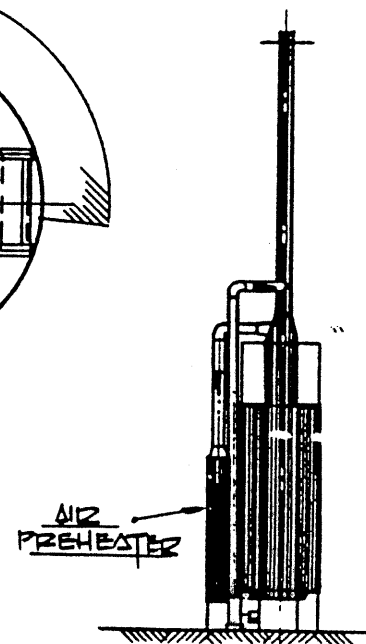
Radiant Tube Removal in
a Circular Furnace



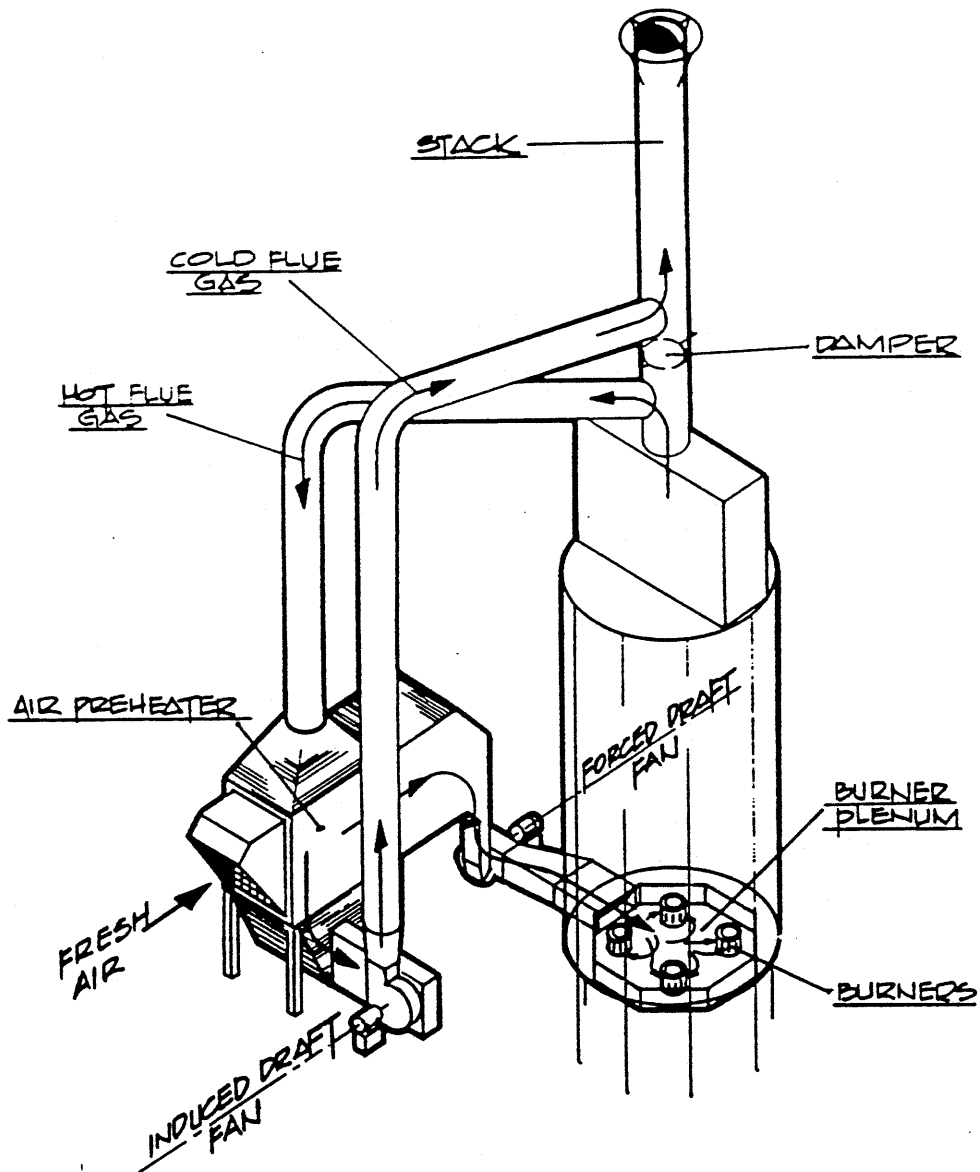
HEATED AIR TO FLENUM

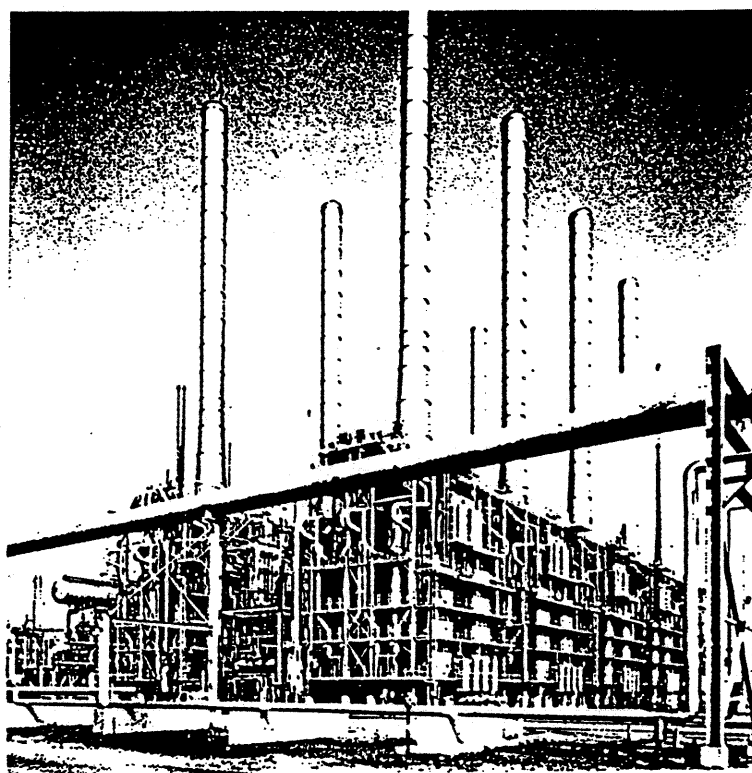


Combustion Air
Preheating System

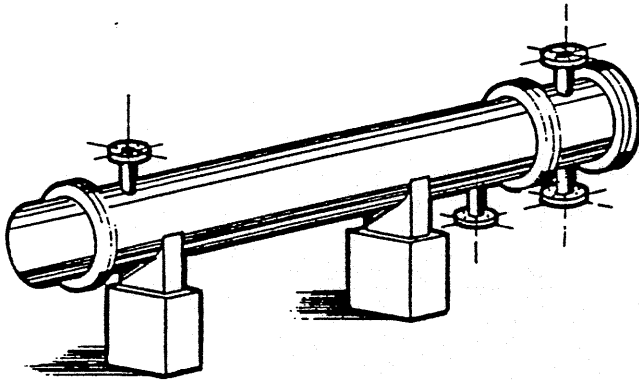


Typical Regenerative System

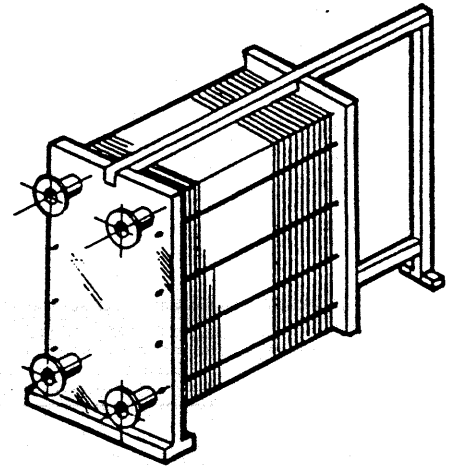




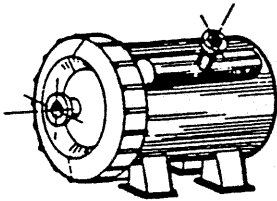
Common Heat Exchangers



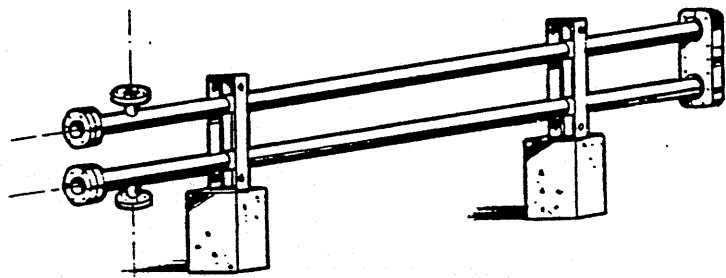
a. Shell and Tube Exchanger



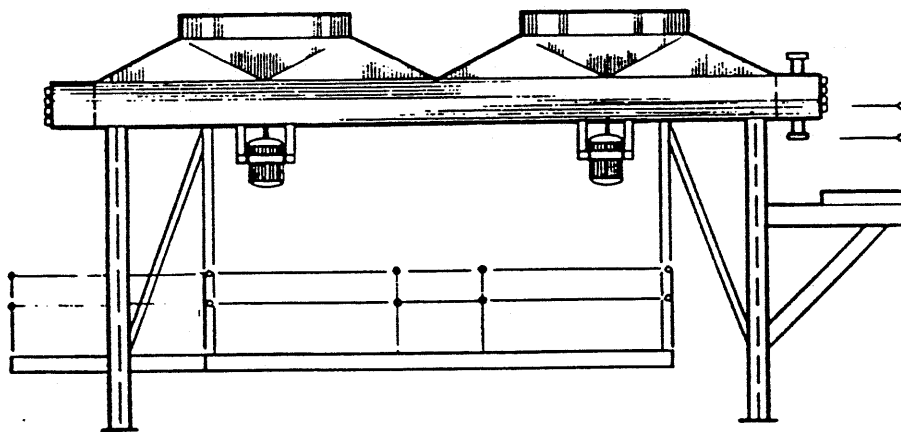
b. Plate Exchanger



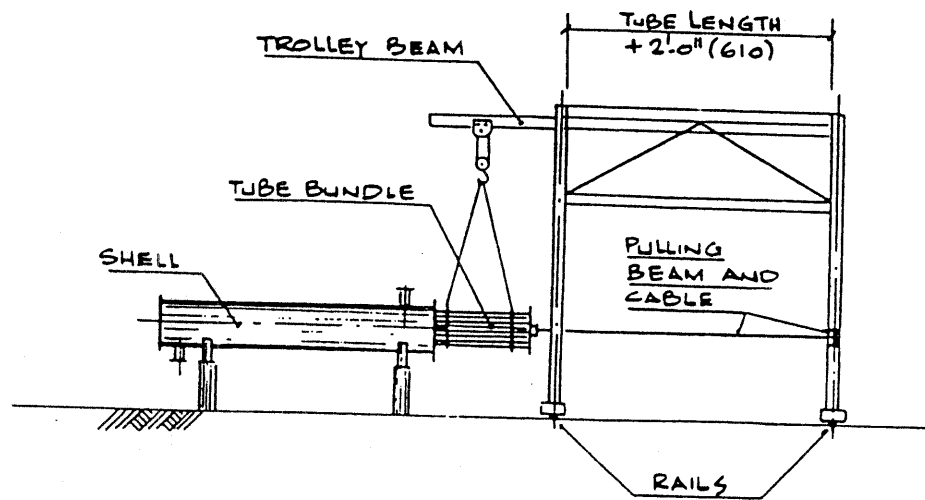
c. Spiral Exchanger



d. Double Pipe Exchanger

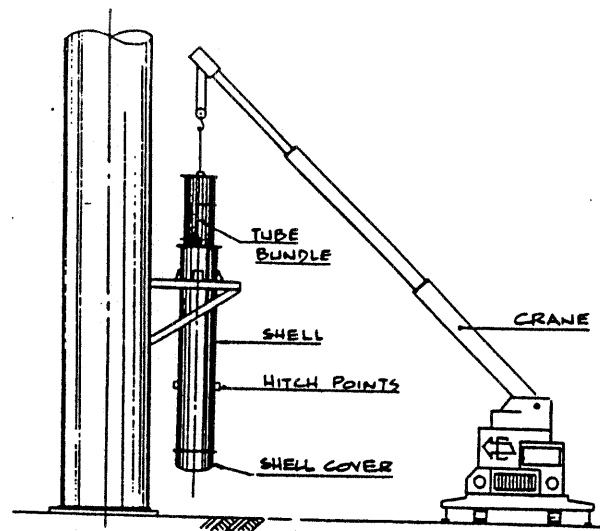


e. Air Cooler Exchanger

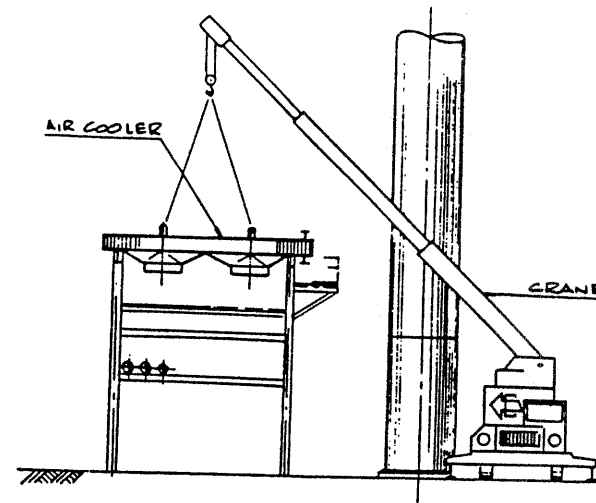


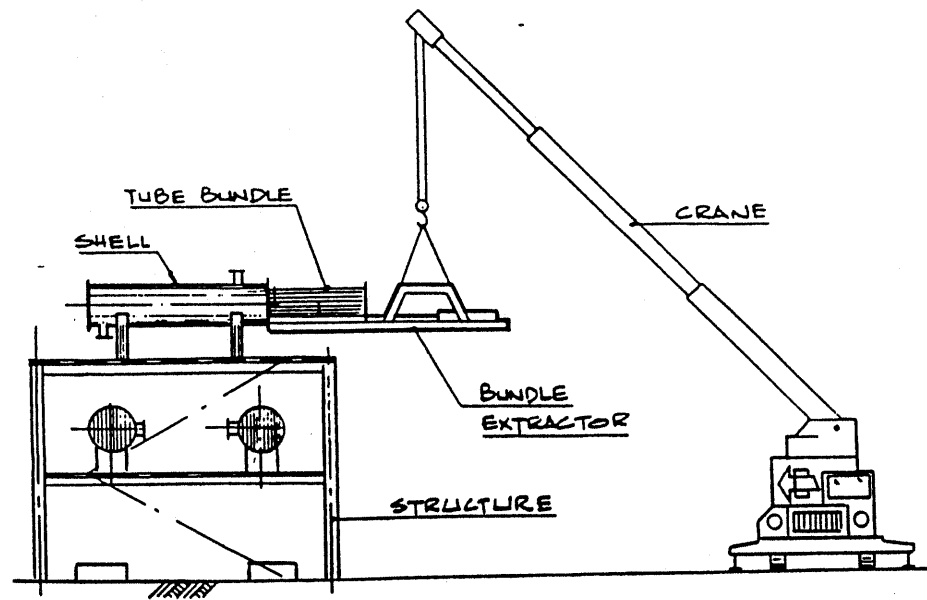
Fixed Structure with a
Traveling Gantry

Removal of a Tube Bundle by Crane

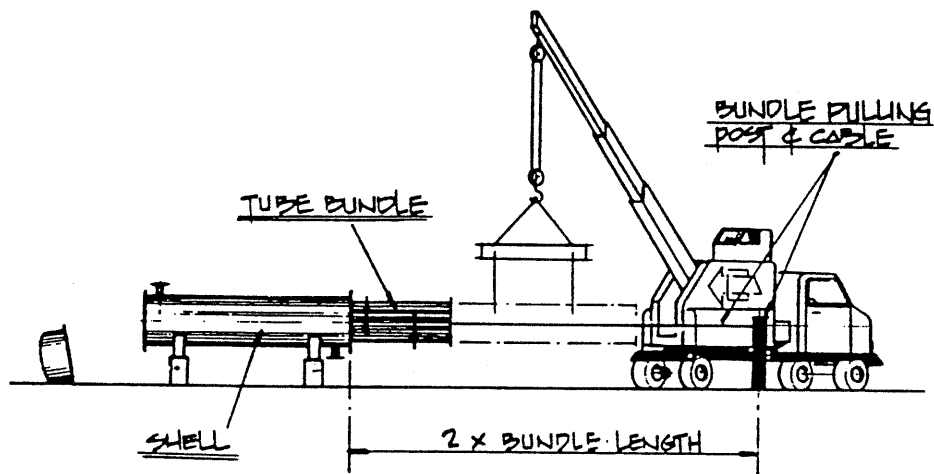


Removal of Air Cooler Sections with a
Mobile Crane

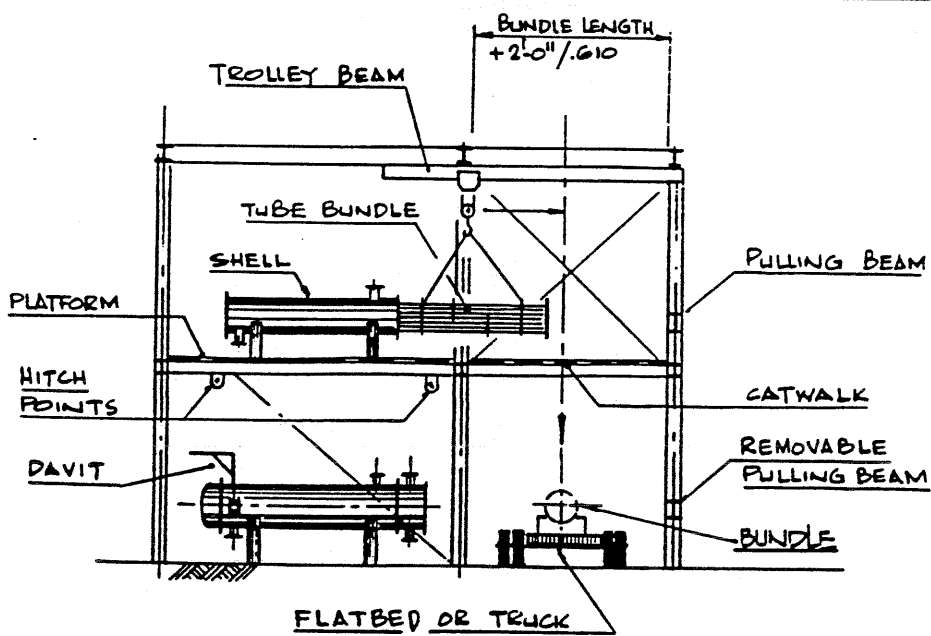




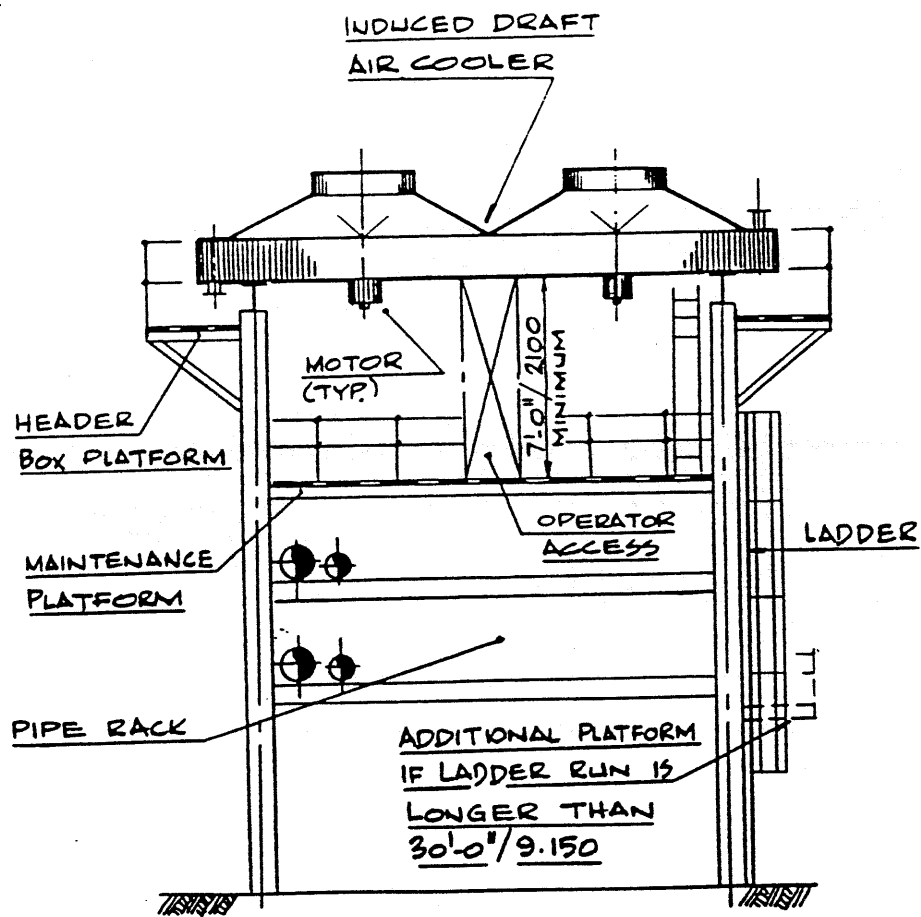
Bundle Removal Using an
Extractor and a Mobile
Crane



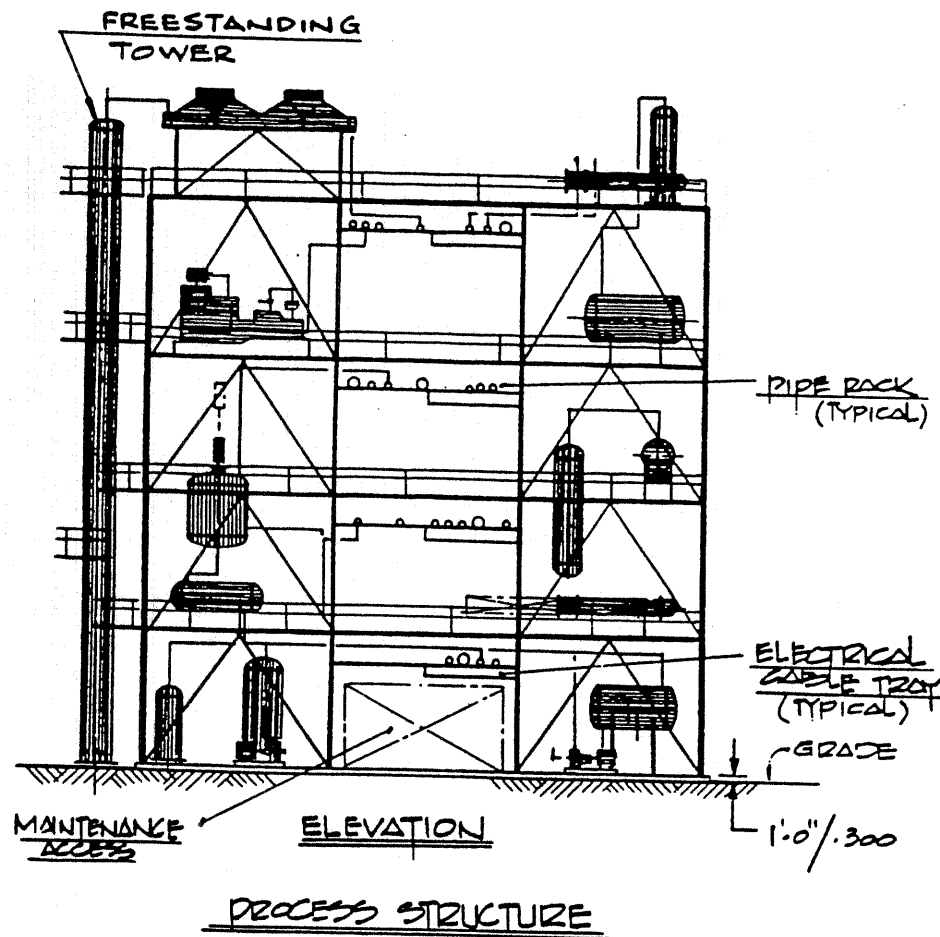
Bundle Pulling Post



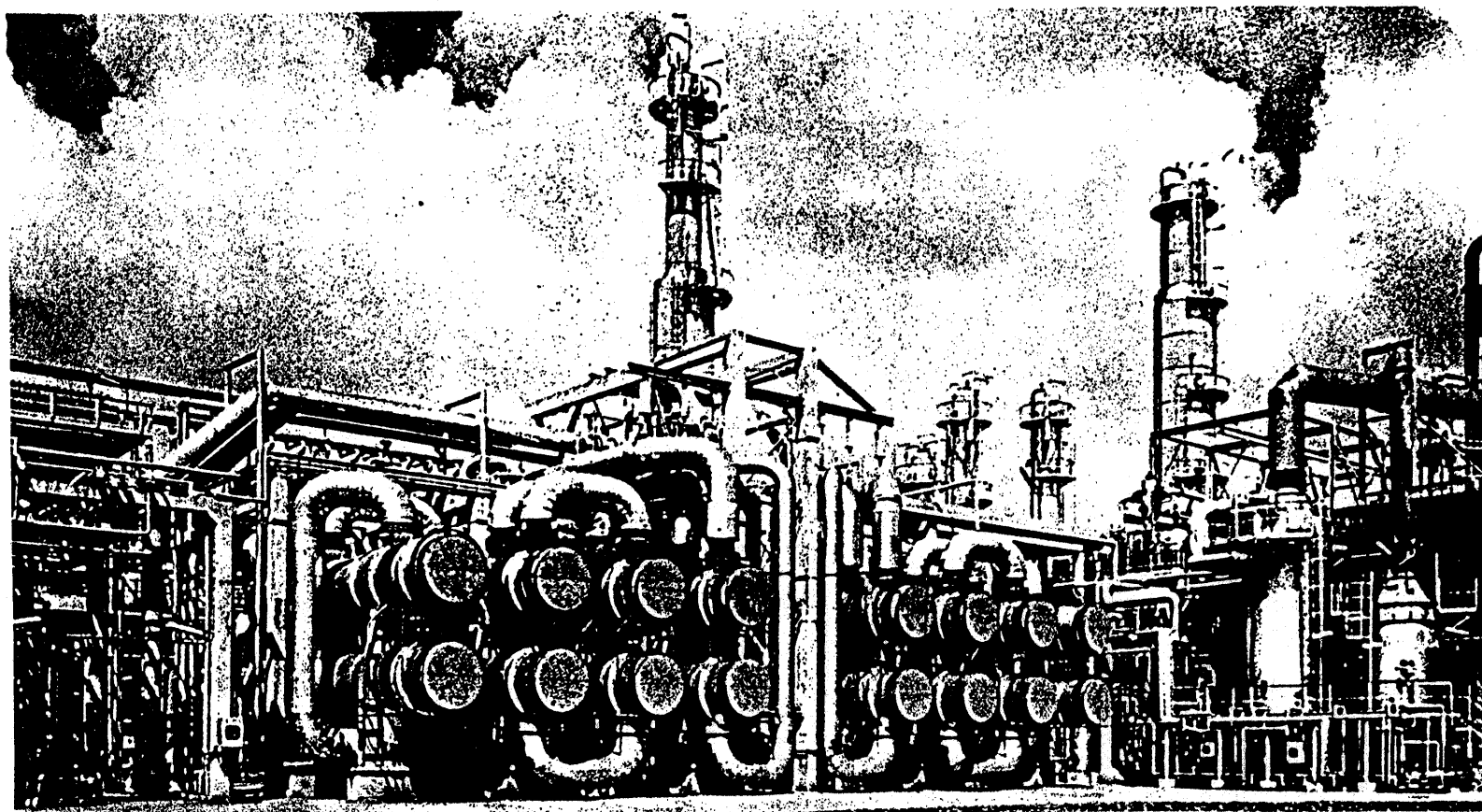
Fixed Structure with a Trolley Beam

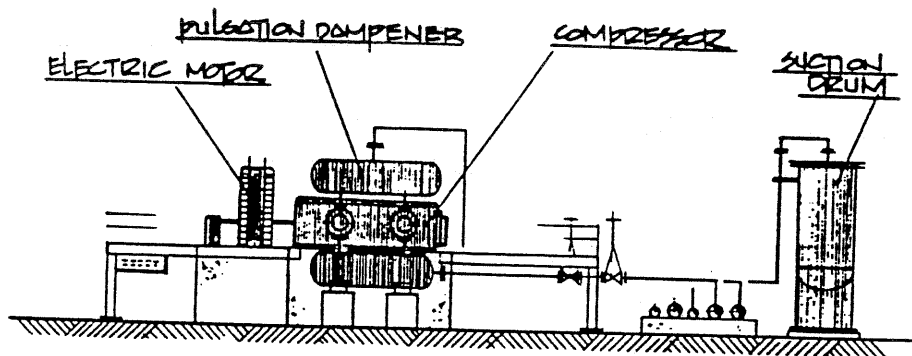


Typical
Column-Supported Air
Cooler Arrangement

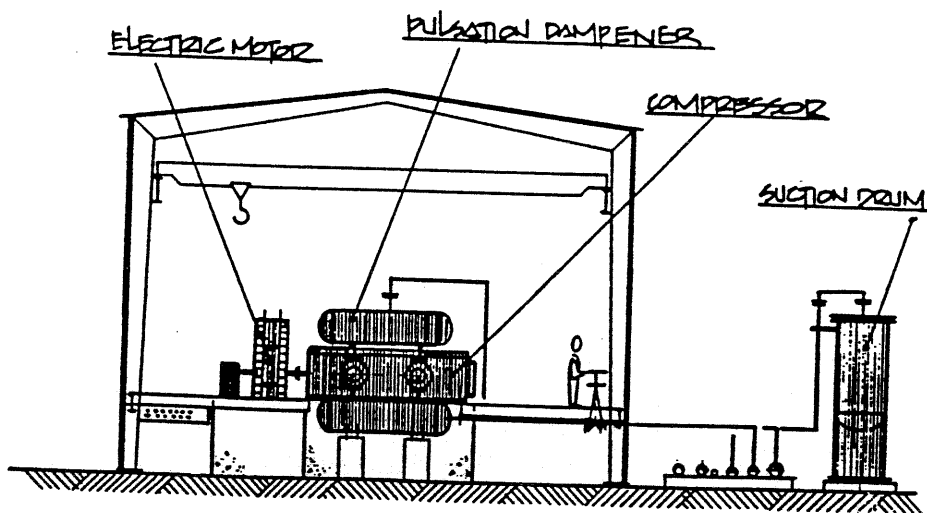


Drum Locations in an
Enclosed Chemical Plant
Structure

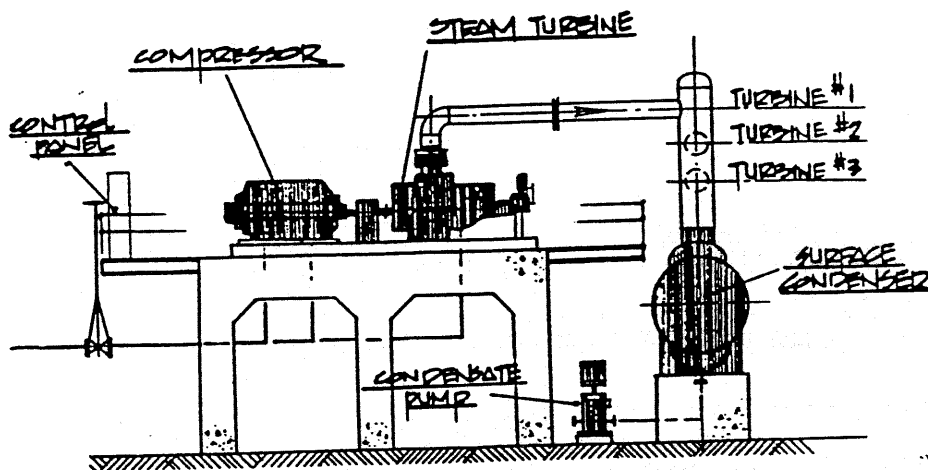




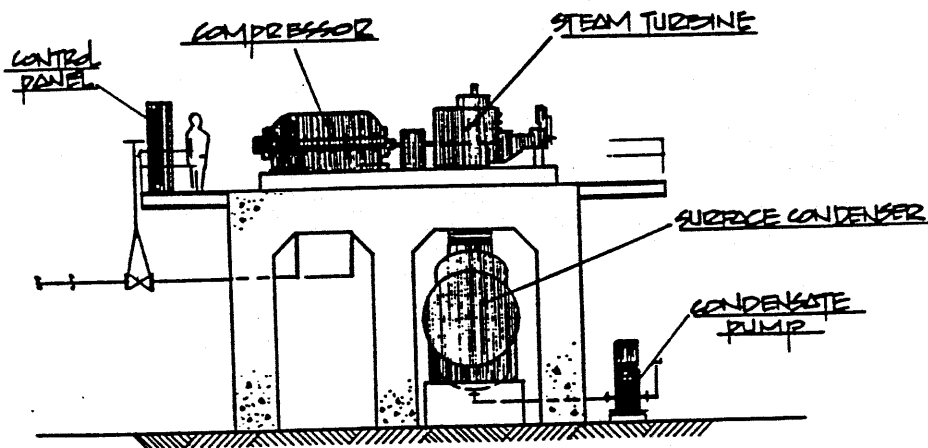
**Reciprocating Compressor with Electric Motor Drive:
Outdoor Installation**



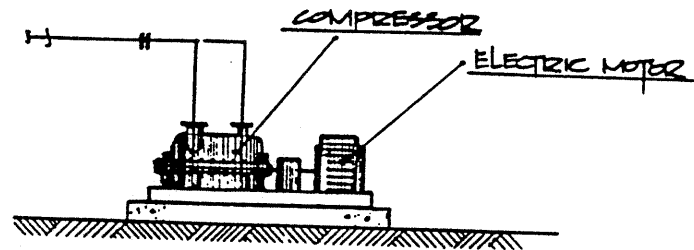
**Reciprocating Compressor with Electric Motor Drive:
Indoor Installation**



Elevated Centrifugal
Compressor with
Multiple Condensing
Steam Turbine Drives

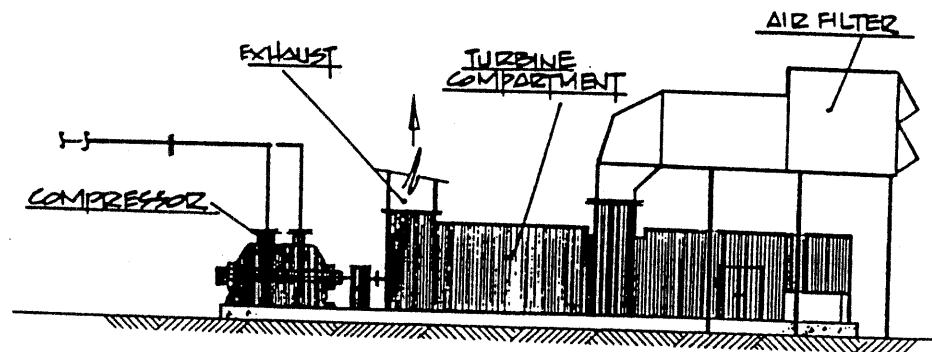


Elevated Centrifugal
Compressor with a Single
Condensing Steam
Turbine Drive

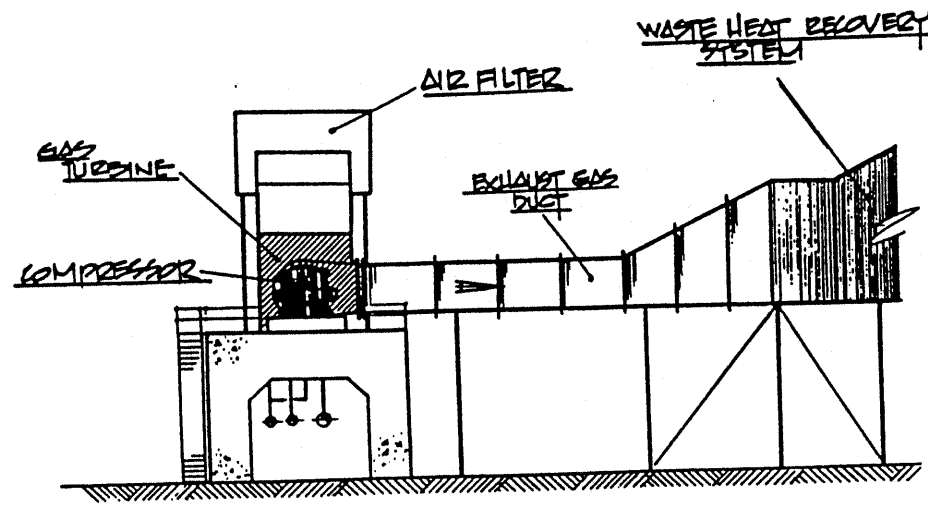


**Grade-Mounted Centrifugal Compressor
with Electric Motor Drive**

Types of Compressor
Systems



**Grade-Mounted Centrifugal Compressor
with Gas Turbine Drive**



Types of Compressor
Systems

Elevated Centrifugal Compressor with Gas Turbine Drive
and Waste Heat Recovery System

Graphs Speed Spread Footing Design

When designing square or octagonal footings, these graphs will cut the calculation time to a minimum. No trial and error sizing is required

F. B. van Hamme, Chief Structural Engineer,
Fluor-Schuytlot N. V., Haarlem, Holland*

TRIAL-AND-ERROR SIZING of spread footings can be supplanted by a better method. A graph can be used to size footings with a minimum of calculations. Use Figure 1. to determine the size of square footings, Figure 2 for octagonal footings.

Stability and soil bearing are the main considerations in designing spread footings. Equipment must be supported by the foundation so it will not be overturned by maximum forces acting upon it. The load on the soil

below the foundation must not exceed the maximum allowable soil pressure. The most severe stability conditions are realized when the vertical load is minimum and the lateral loads (winds or earthquake) are maximum. Severe soil bearing conditions are realized when the vertical and lateral loads are maximum.

Both graphs were scheduled for an allowable soil pressure of 1000 lbs. per sq. ft. However, these graphs can be used for any allowable soil pressure if the vertical load (including the weight of the footing and backfill) and the overturning moment about the base of the footing are divided by the soil pressure coefficient N .

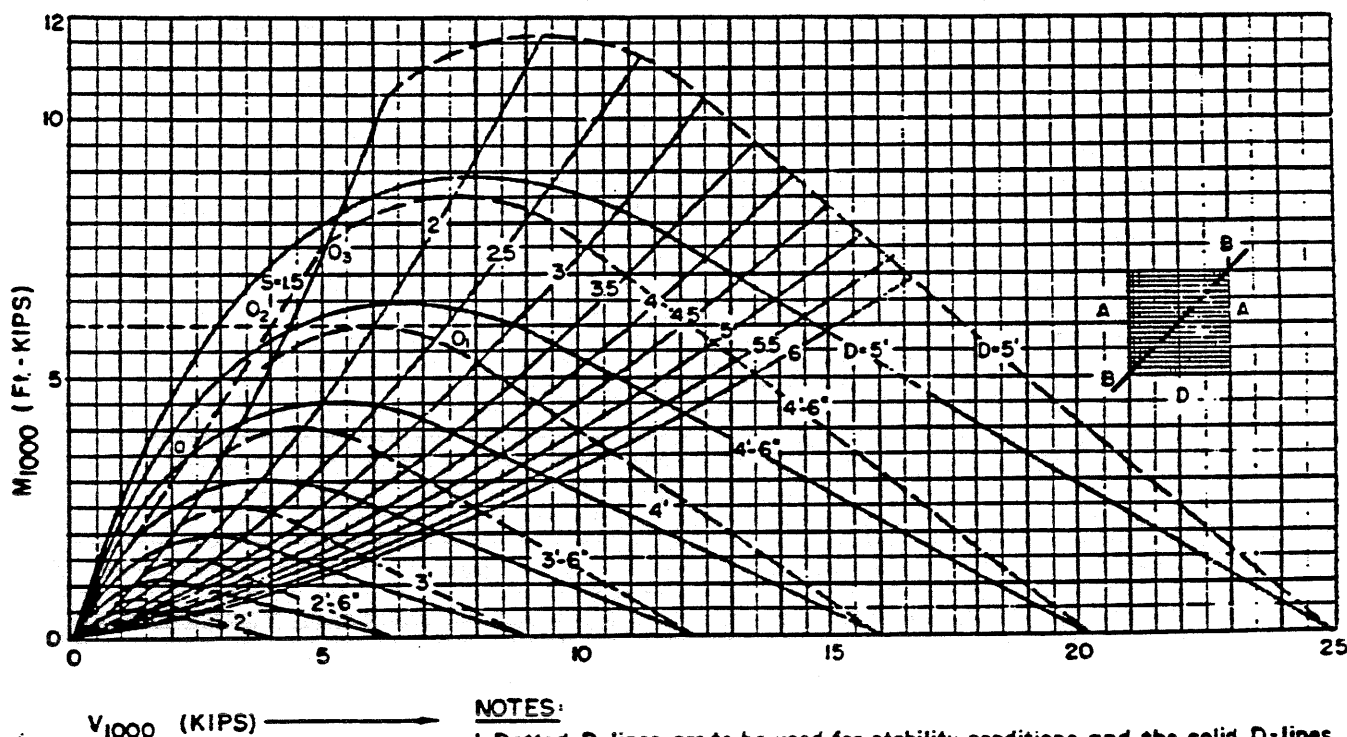
$$N = \frac{\text{allowable soil pressure in lbs. per sq. ft.}}{1000 \text{ lbs. per sq. ft.}}$$

$$V/1000 = \frac{\text{total vertical load in kips}}{N}$$

$$M/1000 = \frac{\text{overturning moment in ft.-kips}}{N}$$

Square Footings. When the footing can turn on the A-A-axis only (Figure 1) (pipe-rack footings, for ex-

* Subsidiary of The Fluor Corp., Ltd., Los Angeles, Calif.

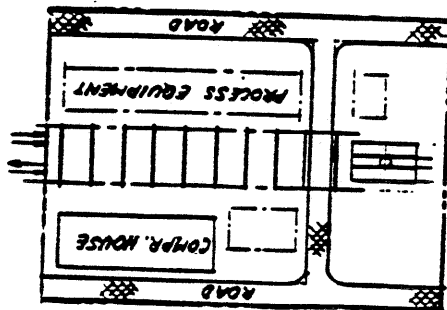


NOTES:

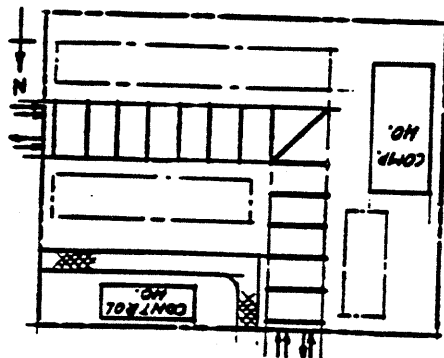
- 1 Dotted D-lines are to be used for stability conditions and the solid D-lines for soil bearing conditions when footing can turn as well on A-A-axis as B-B
2. When footing can turn on A-A-axis only the dotted D-lines are to be used for stability as well as soil bearing conditions.

FIGURE 1—Use this graph to design square footings.

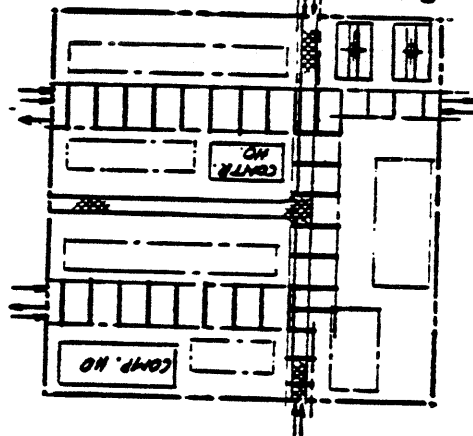
Various yard piping arrangements



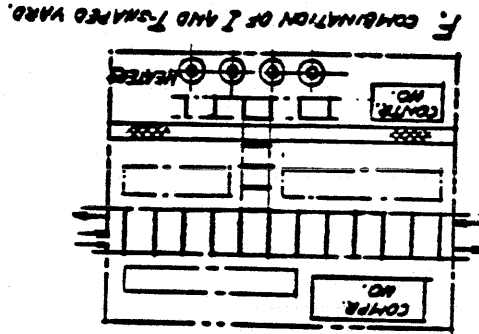
A. DEAD END YARD. LINES ENTER AND LEAVE ONE END OF YARD.



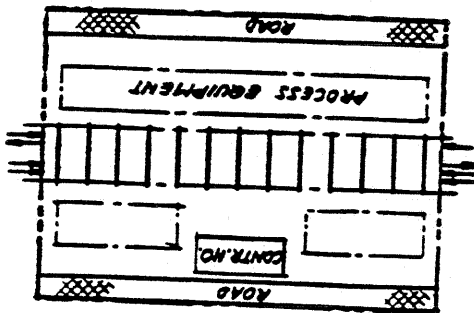
C. L-SHAPED YARD. LINES CAN ENTER AND LEAVE NORTH AND EAST OF THE PLOT.



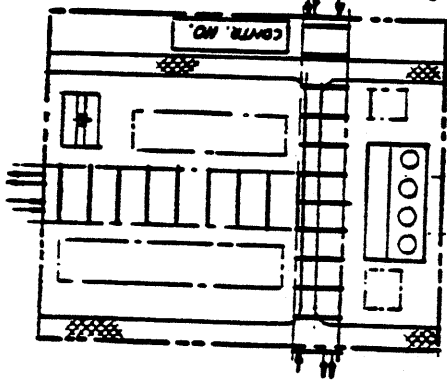
E. U-SHAPED YARD. LINES CAN ENTER AND LEAVE ALL FOUR SIDES OF THE PLOT.



F. COMBINATION OF I AND T-SHAPED YARD.



B. STRAIGHT THROUGH YARD. LINES CAN ENTER AND LEAVE BOTH ENDS OF THE YARD.



D. T-SHAPED YARD. LINES CAN ENTER AND LEAVE ON THREE SIDES OF THE PLOT.

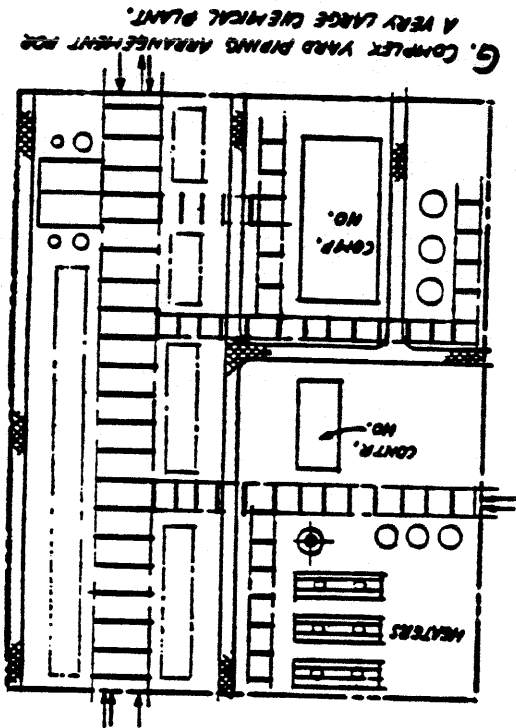


FIGURE 2—In these typical yard piping arrangements, notice how a complex piping arrangement can be broken down into a combination of several of the more simple arrangements.

General pipe line arrangement on a one-level yard

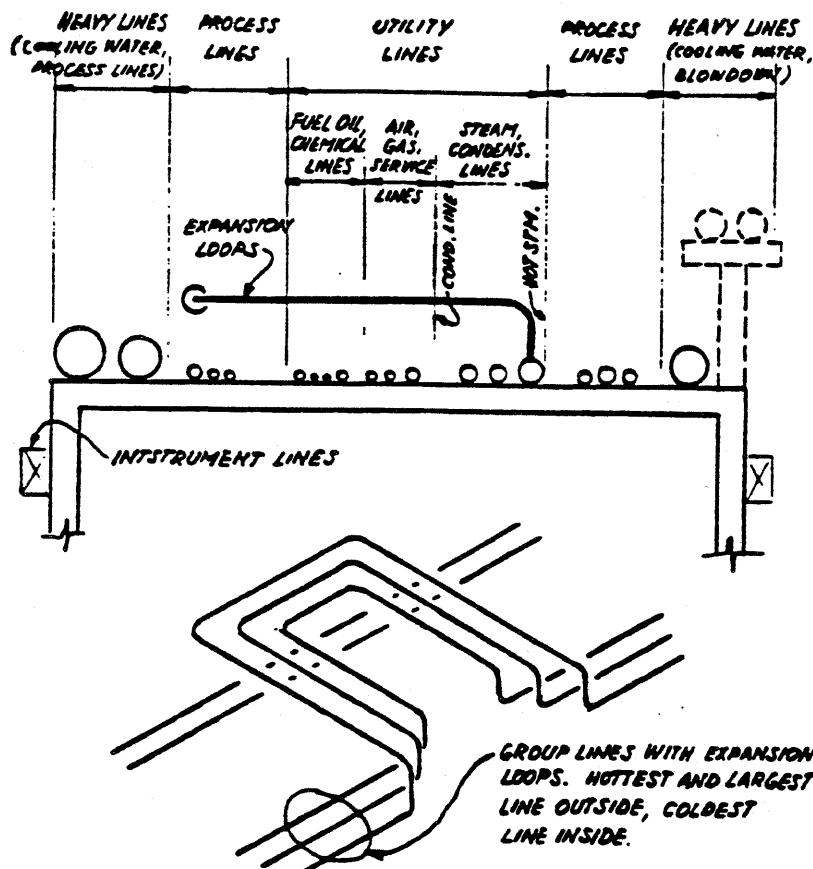


FIGURE 3—Important points in this typical line position arrangement of yard piping are: heavy lines over columns, utility lines near the center, and horizontal expansion loops with hot lines on the outside of the loops.

lines should also be taken into account for estimating additional space requirement.

How to Analyze Yard Piping. The plant layout determines the main yard piping runs. Figure 2 shows yard piping layouts resulting from various plant arrangements. Smaller plants have usually the simplest yard piping as shown on sketch A and B. On sketch A process and utility lines enter and leave the same end of the plot. Sketch B is a frequently adopted layout often with utility lines entering at one end and process lines at the opposite end of the yard. Layout conditions sometimes result in an L shaped yard as shown on sketch C. Larger plants will have a more involved yard piping as shown on sketch D, E, and F. Sketch G shows yard piping arrangement of a very large plant. This layout can be considered as the combination of several simpler yard piping arrangements.

Of course, the shape of yard is not chosen when doing plant layout. The yard is the result of over-all

plant arrangement, site conditions, customer's requirement and above all plant economy.

Some pipe lines arranged in the yard need special consideration. Consequently, the designer must also know what type of lines are arranged in the yard. These lines are classified as follows:

Process lines: (a) which interconnect nozzles on process equipment more than 20 feet apart (closer process equipment can be directly interconnected with pipe lines); (b) product lines which run from vessels, exchangers or more often from pumps to the unit limits, to storage or header arrangement outside the plant; (c) crude or other charge lines which enter the unit and usually run in the yard before connecting to exchangers, furnaces or to other process equipment, e.g., holding drums or booster pumps.

Relief line headers, individual relief lines, blow down lines and flare lines should be self-draining from all relief valve outlets to the knock-out drum, flare stack

Spacing of yard piping

Table 1- Pipe lines without flanges...

NOTE: 1. THIS TABULATION IS BASED ON THE FOLLOWING RELATIONSHIP:

$$A = \frac{D_1}{2} + \frac{D_2}{2} + 3"$$
 = TABULATED VALUES

2. FOR INSULATED LINES ADD INSULATION THICKNESSES TO TABULATED VALUES:

$$B = A + x + y$$

3. REMEMBER THE 3" GAP BETWEEN LINES WHEN CHECKING LATERAL THERMAL MOVEMENTS OF ADJECENT PIPES. FOR EXCESSIVE LATERAL MOVEMENTS INCREASE GAP ACCORDINGLY.

PIPE SIZE	1	1½	2	2½	3	4	6	8	10	12	14	16	18	20	24		PIPE SIZE
24	15½	16	16	16½	17	17½	18½	19½	20½	21½	22	23	24	25	27	6	1
20	13½	14	14	14½	15	15½	16½	17½	18½	19½	20	21	22	23	7	7	1½
18	12½	13	13	13½	14	14½	15½	16½	17½	18½	19	20	21	7½	7	7	2
16	11½	12	12	12½	13	13½	14½	15½	16½	17½	18	19	8	8	7½	7½	2½
14	10½	11	11	11½	12	12½	13½	14½	15½	16½	17	9	8½	8½	8	8	3
12	10	10½	10½	11	11	11½	12½	13½	14½	15½	16	10	10	9½	9	9	4
10	9	9½	9½	10	10	10½	11½	12½	14	12½	11½	11	10½	10½	10	10	6
8	8	8	8½	9	9	9½	9½	9½	15	14	13	12	12	11½	11½	11	8
6	7	7	7½	8	8	8½	8½	17	16	15	14	13½	13	13	12½	12½	10
4	6	6	6½	6½	7	7½	19½	18½	17½	16½	15½	15	14½	14½	14	14	12
3	5½	6	6	6	6½	21½	21	20	19	18	17	16	15½	15½	15½	15½	14
2½	5	5½	5½	6	24	23	22	21	20	19	18	17	16	15	14	14	16
2	5	5	5½	26	25	24	23½	22½	21½	20½	19	18	17	16	15	14	18
1½	4½	5	28	27	26	25	24½	23½	22½	21½	20½	19	18	17	16	15	20
1	4½	33	31	30	29	28	27½	26½	25½	24½	23½	22½	21	20	19	18	24
PIPE SIZE		24	20	18	16	14	12	10	8	6	4	3	2½	2	1½	1	PIPE SIZE

IF FLANGES ARE IN LINES LISTED HERE USE TOP FIGURES

IF FLANGES ARE IN LINES LISTED HERE USE BOTTOM FIGURES

IF FLANGES ARE IN LINES LISTED HERE USE BOTTOM FIGURES

IF FLANGES ARE IN LINES LISTED HERE USE TOP FIGURES

Table 2- Pipe lines with flanges or line size valves (up to 400 lbs rating)...

NOTE: 1. THIS TABULATION IS BASED ON THE FOLLOWING RELATIONSHIP:

$$C = \frac{D_1}{2} + \frac{D_2}{2} + 3"$$
 = TABULATED VALUES

2. IN CASE OF UNINSULATED D₁ LINE AND UNINSULATED D₂ FLANGE, BUT INSULATED D₃ LINE USE TABULATED VALUES:

$$C$$

3. FOR INSULATED LINES AND FLANGES ADD INSULATION THICKNESSES TO TABULATED VALUES:

$$D = C + x + y + \frac{D_1}{2} + \frac{D_2}{2} + 3" + x + y, \quad D_3 \geq D_4$$

FIGURE 4—Use this chart for determining line spacing in yard piping racks for bare lines with and without flanges and insulated lines.

4. USE TOP FIGURES IF a) FLANGES ARE IN LARGER DIAMETER LINE; USE BOTTOM FIGURES IF b) FLANGES ARE IN SMALLER DIAMETER LINE AND USE TOP FIGURES IF c) FLANGES ARE IN BOTH ADJACENT LINES. (FLANGES SHOULD BE STAGGERED).

5. FOR HEAVIER FLANGES (OVER 400 LBS), BRIDGE FLANGES, ANCHORS OR SPECIAL EQUIPMENT IN THE LINES SPACING SHOULD BE INDIVIDUALLY CALCULATED.

6. REMEMBER THE 3" GAP BETWEEN LINES OR FLANGES AND OUTSIDE PIPE WALL WHEN CHECKING LATERAL THERMAL MOVEMENTS OF ADJACENT PIPES. FOR EXCESSIVE LATERAL MOVEMENT INCREASE GAP ACCORDINGLY.

Typical cross-section of yard

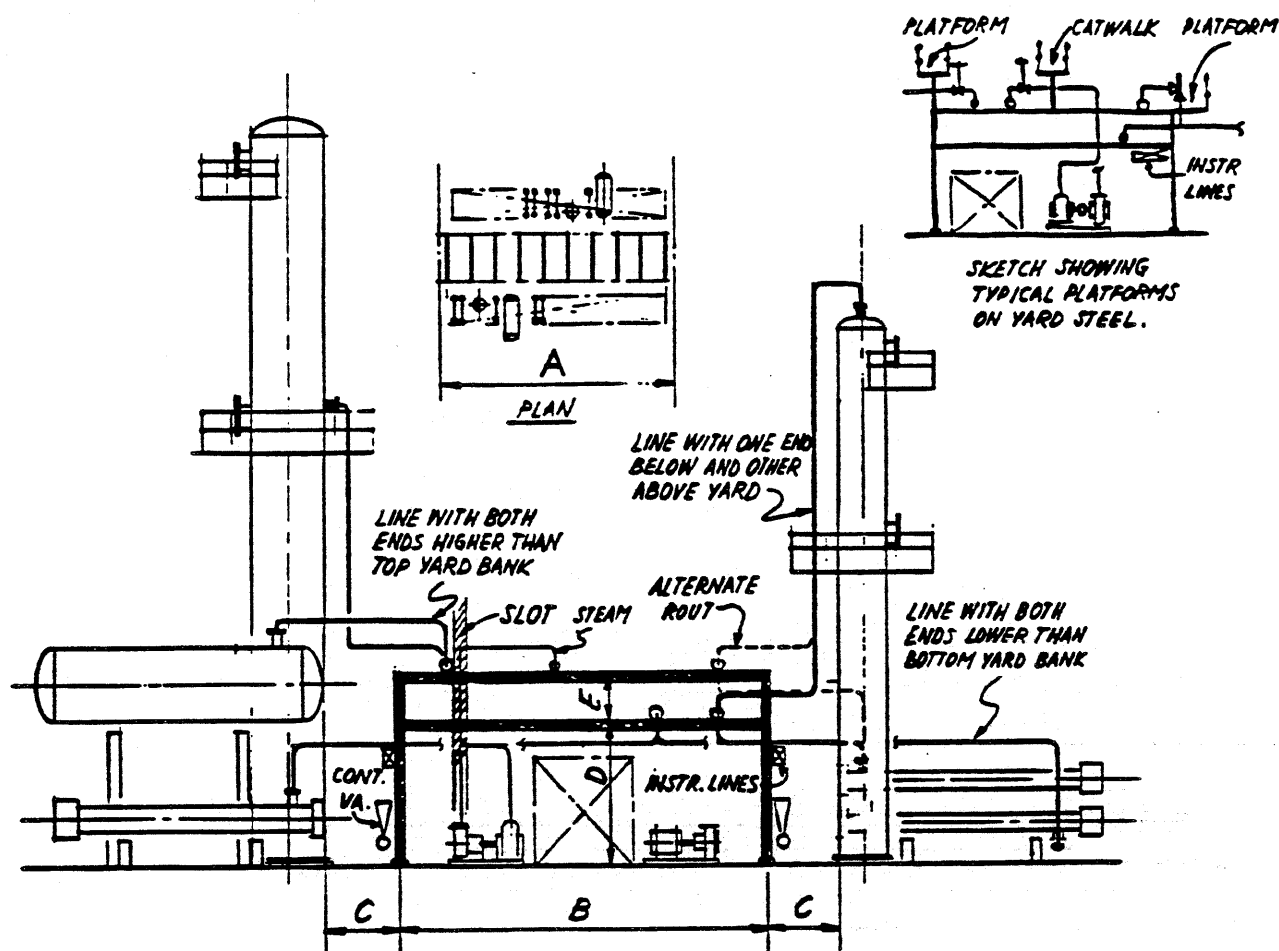


FIGURE 5—Typical cross-section of yard piping showing critical dimensions which affect piping cost. Notice the arrangement for platforms for access to valves in the upper right hand corner.

or to a point at the plant limit. A pocketed relief line system is more expensive, because usually an extra condensate pot is required with instruments, valves and pumps. To eliminate pockets some relief line headers must be placed at a higher elevation above the main yard usually on a tee support on the extended yard column. However, on some noncondensing gas systems self-drainage is not so essential. Relief lines can be in great numbers with some large diameters and occasionally high temperatures.

Utility lines in the yard can be put in two groups: (a) utility headers serving equipment in the whole plant. Such lines are: low and high pressure steam lines, steam condensate, plant air, and instrument air lines. If requested cooling water and hot return, service and fire water can also be arranged in the yard. (b) Utility lines serving individually one or two equipment items or a group of similar equipment (furnaces, compressors) in the plant. Such lines are: boiler feed water, fire steam, compressor starting air, various fuel oil lines, lubricating oil, cooling oil, fuel gas, inert gas, and chemical treating lines.

Steam headers should drain to the steam separator for more effective condensate collection. Branch connections to steam headers usually connect to the top to avoid excessive condensate drainage to equipment.

Instrument lines and electrical cables are often supported in the yard and extra space should be provided for them. The best instrument line arrangement eliminates almost all elevation changes between the plant and the control room. This can be easily achieved when instrument lines are supported outside the yard column on a suitable elevation.

All these lines have been listed in detail to emphasize the large number of process and utility lines which are usually located in the yard. Now, how to arrange these pipe lines in the yard?

Line Location. Figure 3 shows one level yard piping. Regardless of service, heavy lines (very large diameter lines, large lines full of liquid) are placed over or near the yard columns. (Centrally loaded column and re-

duced bending moment on the beam will result in a light structural design.) Next to these lines are placed all process lines and relief lines. Utility lines are in the center portion of the yard. A general sequence of utility lines is also shown on Figure 3.

Under position in the yard depends on the number and size of branch connections. If the majority of similar size branches connect to the header from the right, it is more economical to place it in the right half of the yard.

It is advantageous, from a support standpoint, to group hot lines requiring expansion loops as shown in Figure 3. Loops elevated horizontally over the yard is the most common adopted design, having the hottest and largest diameter line outside. Line guides, line stops, and anchor points are usually also required along a hot line somewhere in the yard. Pipe expansion forces, at some of these points, will affect yard support design.

Those process lines which interconnect equipment on the same side of the yard should be near the edges of the yard bank; lines which interconnect equipment located on both sides of the yard should be closer to the utility lines and can be placed either side of the yard. Position of product lines is influenced by their routing after leaving the plant limit. Right (left) turning lines should be on the right (left) hand side of the yard. Utility lines serving individually one or two equipment items should be on the same side of the yard as the equipment to which they connect.

If, because of the large number of lines, two yard bank elevations are required, generally all utility lines are placed in the top bank and all process lines in the bottom bank. Obviously, exceptions always can be made to the elevation of individual utility or process lines. Line sequence arrangement will be similar to the sequence already discussed for the one level yard. Line spacing in the yard is shown and explained on Figure 4.

Yard in Elevation. Figure 5 shows typical yard section with main elevations. Elevation of yard piping is determined by the highest requirement of the following: (a) headroom over a main road; (b) headroom for access to equipment under the yard, and; (c) headroom under lines interconnecting the yard and equipment outside the yard. The size of steel beam supporting yard piping should also be taken into account when considering headroom.

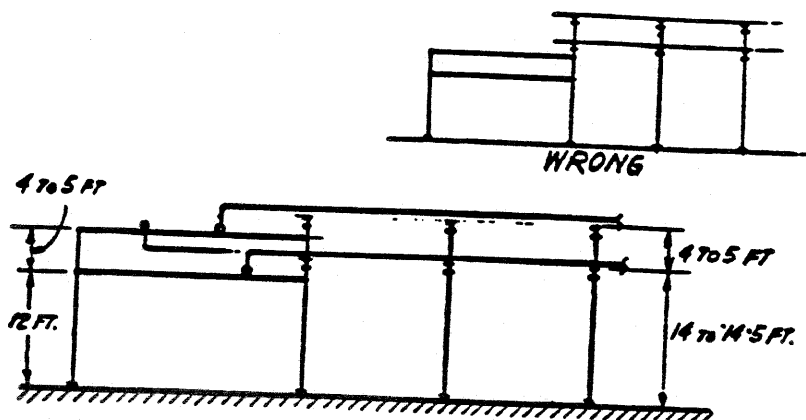


FIGURE 6—This is a typical elevation for yard piping intersection. Notice that the 14-foot elevation of the lateral rack permits turning up or down at the intersection.

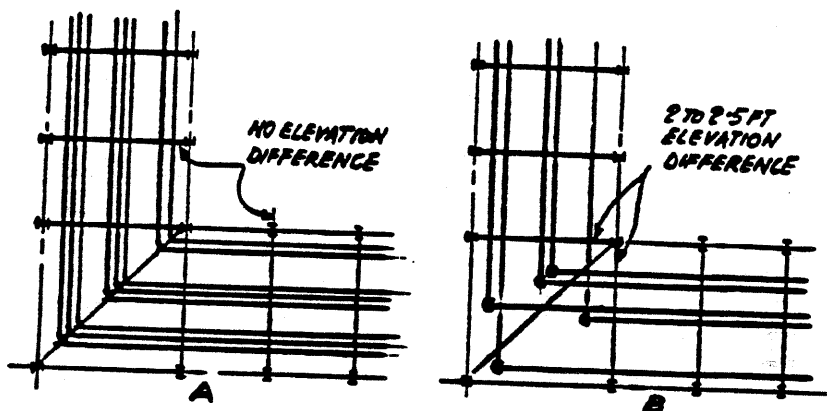


FIGURE 7—In sketch A, a flat turn is more economical if line sequence can be kept the same in both directions. Sketch B shows the need for an elevation change when line sequence changes after the turn.

Generally those process lines should be located in the top bank which interconnect two nozzles elevated higher than the top yard bank. Process lines with one end lower than the bottom yard elevation can run either in the top or the bottom bank. If both ends of a process line are lower than the bottom yard elevation the line should be located in the bottom bank.

The elevation of a line can also be influenced by valves and instruments in the line. Often a more convenient access platform can be provided for valves arranged in the top yard bank. The preferred location of lines with orifice runs is near the edge of the yard with orifice flanges near a yard column for more convenient portable ladder access.

The sketch on Figure 5, upper right corner, shows platform and walkway arrangements to valves, relief valves and instruments located in the yard.

When pumps are arranged under the yard often one or two slots are required along the yard usually over the pump discharge nozzle for process, steam and other

utility lines connecting from the yard to the pumps and drivers.

Economy of Yard Piping. Pipe economy depends primarily on the length of lines arranged in the yard. Fittings, valves and instruments are relatively few in the yard compared to pipe length.

Figure 5 also shows those critical dimensions which will influence piping cost from a yard piping layout standpoint. These dimensions depend on the over-all plant layout and should be carefully considered when the plot is arranged.

Dimension A is the total length of yard and is governed by the number and size of equipment, structures and buildings arranged along both sides of the yard. On an average, about 10 feet of yard length is required per process equipment (exchanger, drum, tower, unhusked compressors, etc.) A control house located along the yard, for example, will increase yard piping cost because all lines must pass by without really being associated with the relatively long control house.

If, with good layout practices, the same number and size of equipment can be arranged on a shorter yard length, yard piping cost can be considerably reduced. A 7- to 8-foot average length per process equipment is not unusual in a well arranged plant. Equipment in pairs, stacked exchangers, exchangers under elevated drums, drums or exchangers supported on towers, two vessels combined into one, closely located towers with common platforms, drums supported on exchangers, process equipment located under the yard are only a few examples which help shortening the yard. These arrangements, of course, shorten not only process lines interconnecting equipment directly or in the yard, but also shorten those lines which pass through this area and utility headers serving this area.

The careful selection of dimension B and C (Figure 5) can minimize pipe length between the yard and process equipment and pipe length interconnecting equipment on opposite sides of the yard. C is usually 6 to 7 feet. Not more than necessary yard height (Dimension D and E) will minimize vertical pipe lengths.

When changing direction change elevation—is an old rule in piping design. This happens with all lines connecting to yard piping. However, some large diameter lines can make a flat turn when entering the yard. Such

lines should be placed at the edge of the yard. Any other spot will block excessive space in the yard.

Figure 6 shows commonly used elevations for main yard heights at a yard piping intersection. Note that the 14-foot elevation of the lateral yard permits turning up or down at the intersection. It is important to elevate lateral pipe banks between the two elevations of main yard.

Elevation difference between main yard bank and laterally connecting pipe lines is about 2 to 2½ feet. This gives an elevation difference of 4 to 5 feet between two main yard banks.

If a building (control house, pump house) is located under the yard main piping elevations will be higher than without a building. Clearances in the building, pitching of the roof, steel structures and pipe line clearances will affect the height of the yard.

Elevation difference is not required if a flat turn can be made within the yard. Line sequence in this case must be identical before and after the turn as shown on Figure 7, sketch A. However, varying line sequence in the two directions introduces an elevation difference and an additional elbow in each line as shown on Figure 7, sketch B.

Yard Piping Supports. The width of yard is influenced by two conditions: (a) the number of lines, instrument, electrical lines and space for future lines in the yard, or (b) space requirement for equipment arranged under the yard.

The number of lines can be estimated by marking up the yard on a print of the plot plan, with the help of flow diagrams, showing all lines located in the yard. Adding the number of lines (n) up to 18 inches diameter in the densest section of the yard the total width (W, ft) will be as follows:

$$W_t = (f \times n \times S) + A \text{ (feet)}$$

Where f = safety factor—($f = 1.5$ if the lines have been laid out on the plot with the help of process flow diagrams. $f = 1.2$ if the lines have been laid out with the help of fully detailed mechanical flow diagrams).

S in feet is the estimated average spacing between lines, usually $S = 1$ foot. If lines in the yard are smaller than 10 inches the value of $S = 0.75$ foot.

A in feet is the additional width required: (a) for lines larger than 18 inches, (b) for future lines, (c) for instrument lines (about 2 to 3 feet) and sometimes, (d) for electrical cables (about 2 to 3 feet) if these are also supported on the yard steel, e for one or two slots for pump discharge and driver utility lines (about 18 inches or 3 feet).

The total width of yard W_t can be between 20 and 60 feet. If W is bigger than 30 feet usually 1½ or 2 yard banks will be required. The upper limit of yard steel span is 32 feet.

Space requirement for equipment plus access below the yard can also influence the width of yard. For a single row of pumps and 8 to 10 feet access to the pumps about 20 to 24 feet yard span is required depend-

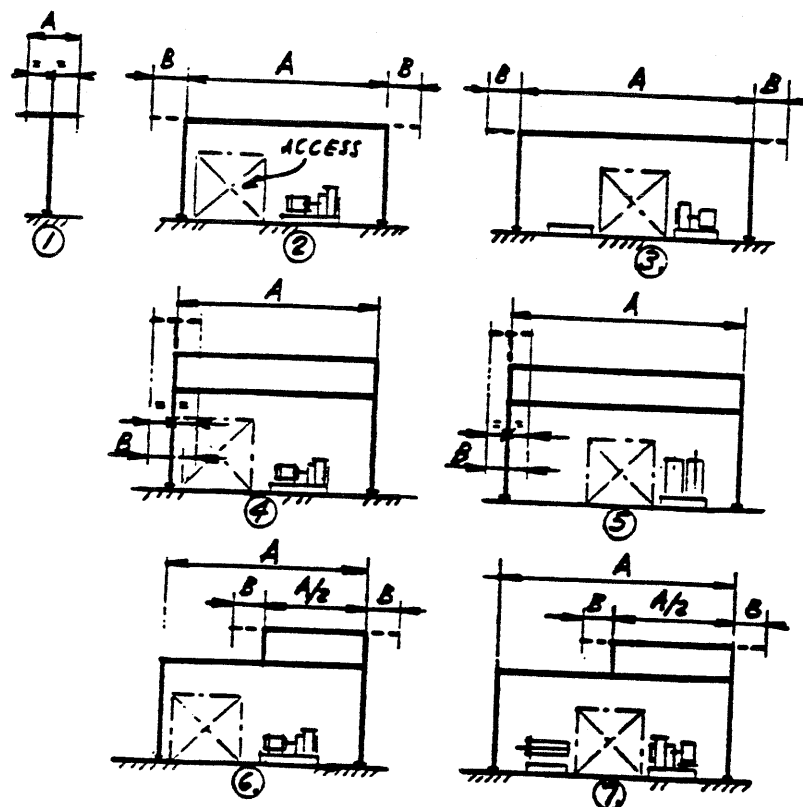
About the Author



Kern

Robert Kern studied mechanical engineering at the Royal Joseph Technical University, Budapest, Hungary, where he received his engineering degree in 1946. He left Hungary in 1948 and went to England where he joined an international engineering - construction firm to work in plant layout, piping design and design coordination. Kern has been in the United States since March 1958.

Typical yard piping supports with available total width and dimensions of span



TOTAL AVAILABLE WIDTH $W/2$ IN FEET		DIMENSIONS IN FEET		NUMBER OF ELEVATION	SKETCH No
WITHOUT CANTILEVER	WITH CANTILEVER	A	B		
10	-	10	-	1	1
20-24	30-34	20-24	5	1	2
28-32	38-42	28-32	5	1	3
28-34	36-42	20-24	4 (5)	1½	6
39-47	45-53	20-24	3 (4)	2	4
40-44	48-52	28-32	4 (5)	1½	7
55-63	61-69	28-32	3 (4)	2	5

FIGURE 8—From these data, total available width of these typical yard piping support bents can be determined.

ing on the length of the pumps. In case of a double row of pumps a 28- to 32-foot span will be required.

Type of Supports. Figure 8 shows typical yard steel bents with dimensions. Total available yard width to each type of support is included in the table of dimensions. This tabulation can be used for selecting a type of yard support after the total required width has been

estimated. The most commonly used yard piping supports are Types 2, 3, 4 and 5.

In almost all plants spacing between yard support bents is about 16 to 20 feet. Nevertheless consideration should be given to (a) line sizes: smaller lines have to be more frequently supported than large diameter lines; (b) liquid filled lines require a shorter span than gas

Yard piping junction with exchanger structure

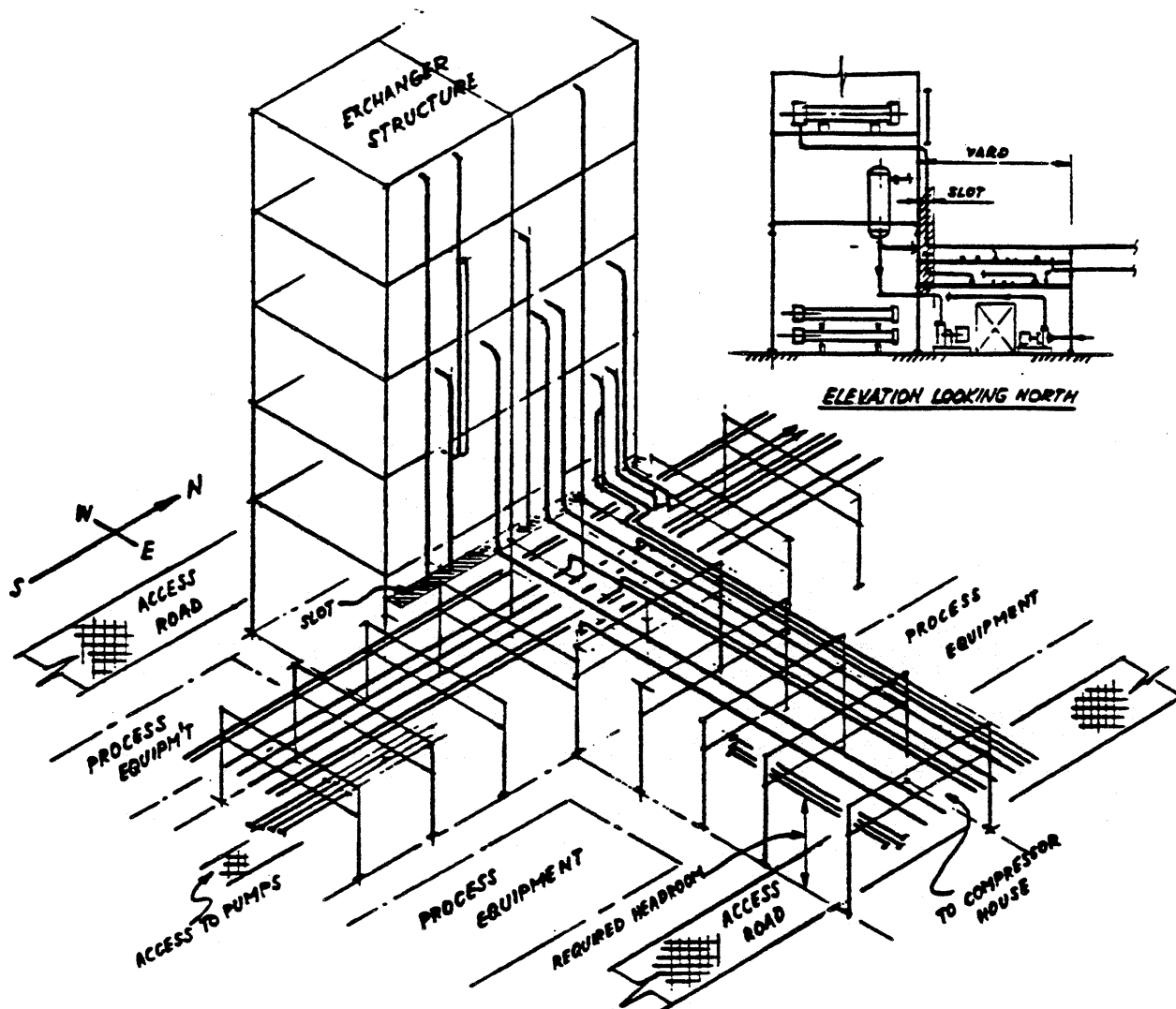


FIGURE 9—In this example of yard piping layout, notice how the elevations have been governed by headroom requirements over the North-South road. This elevation also sets the height of the first platform of the exchanger supporting structure.

lines; (c) line temperature: very hot lines span shorter distances than cold ones of same size and wall thickness; (d) insulation: heavily insulated small diameter lines with cold temperatures must be supported at relatively short intervals; (e) Space requirement for equipment at grade and under the yard can sometimes also influence the spacing between yard bents.

Example. Figure 9 shows a yard piping junction with an adjacent exchanger supporting structure. The yard elevations have been governed by headroom requirement over the north-south access road. The top of north-south yard set also the height of the first platform of the exchanger supporting structure because lines had to cross below the first platform to the top bank of the north-south yard.

All lines from the exchanger structure to the yard dropped along the east side of the structure. A slot has been left open in the yard adjacent to the exchanger structure for lines which connect to the lower north-south yard or to pumps below the yard. Process lines turning into the east-west yard from the exchanger structure have been arranged on the highest yard elevation.

A number of vertical reflux drums have been arranged on the first level of exchanger structure. All suction lines to pumps turn horizontally below the lower north-south yard bank.

This, of course, is an unusual example but it illustrates the necessity of choosing carefully yard elevations and an over-all system of design. ##

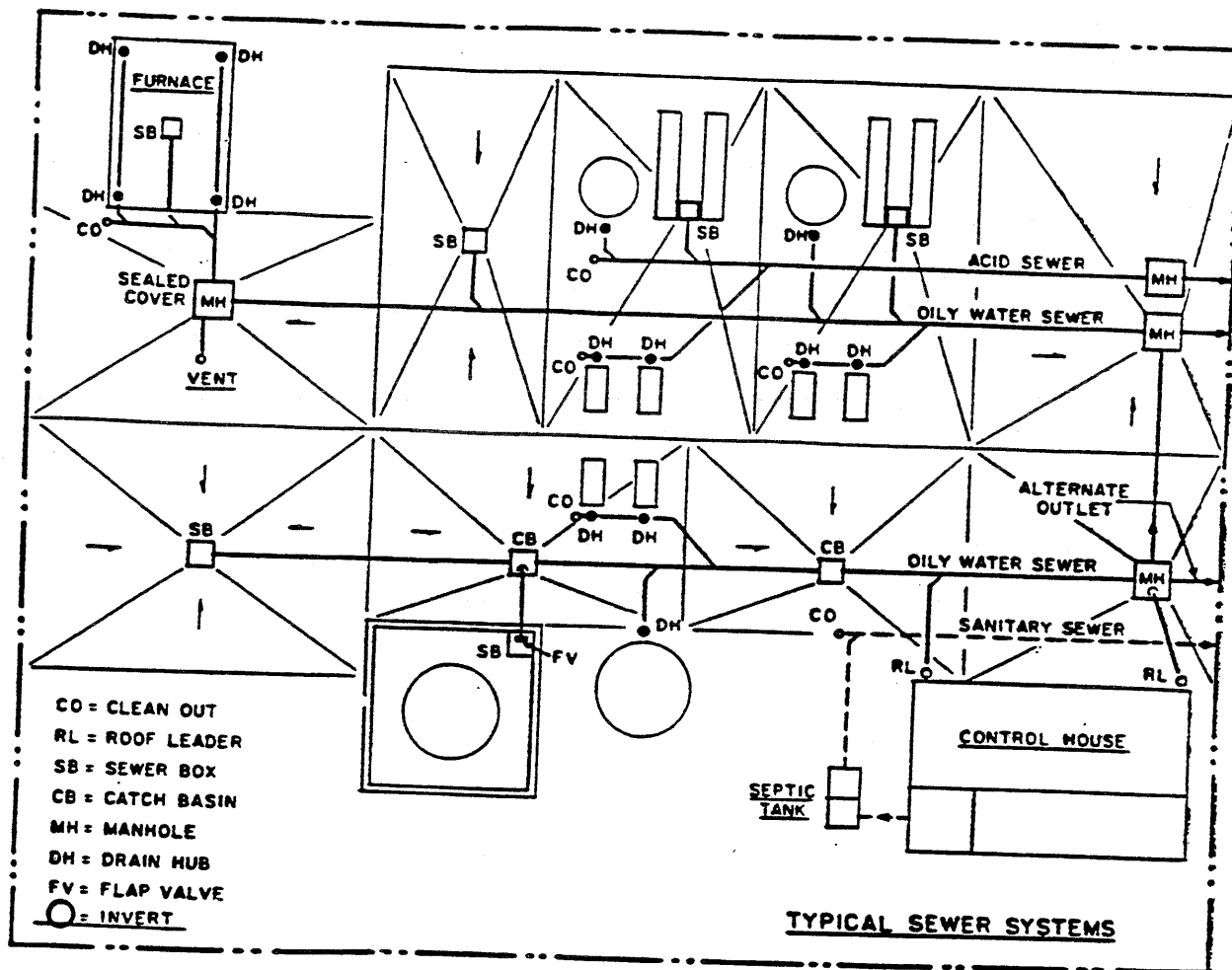


FIGURE 1—Typical process plant sewer system.

Fundamentals of Sewer Design

Four basic sewer systems are used in typical hydrocarbon processing plants. Descriptions and design procedures are given for these systems

William O. Seppa, New York City

THE WASTE STREAMS in most large plants can be classified under four basic sewer systems: (1) Oily water sewer, (2) acid (chemical) sewer, (3) storm water sewer and (4) sanitary sewer. Typical sewer systems are shown in Figure 1. The design and operation of each type will be described in detail.

The oily water sewer is designed to collect all the non-corrosive process wastes to be drained periodically

from tanks, towers, exchangers, pumps and other process equipment, using open end drain hubs located adjacent to the equipment served. During maintenance shutdowns and at turnarounds, these drain hubs are to be used for draining water from equipment that may be required for hydrostatic testing or washing out towers or tanks. Pumps and compressors should also be provided with open end drain hubs located at the ends of foundation blocks.

These open end drain hubs will collect drainage from pump bedplates, drainage from gland and seal piping at pump and compressor bearings.

Paved and unpaved surface drainage areas adjacent to tanks, towers, exchangers, pumps and compressors where process waste spillage is apt to be considerable, drainage should be diverted to the oily water sewer. This would be the case when wash water would be heavily contaminated during turnaround or maintenance operations. Rain water runoff may constitute the largest

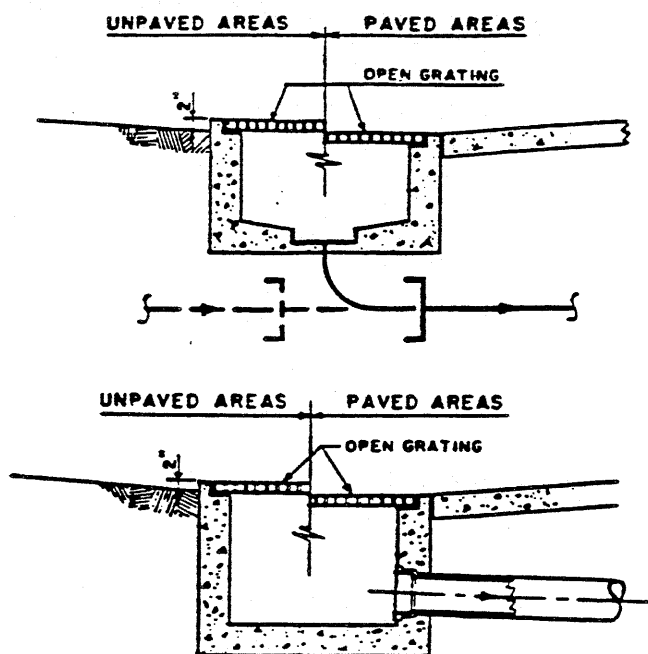


FIGURE 2—Sewer box outlet detail.

flow quantity collected in a drainage area and may be the governing factor in the sizing of the sewer pipes.

Fire water from hoses should be added to the estimated maximum flow quantities within the unit areas which include hazardous hydrocarbon or chemical equipment. Where fire water is to be included, it will vary from 500 to 1,000 gallons per minute. The amount will be dependent upon the size and the number of pieces of equipment, as well as the number of sewer boxes or drains within the area under consideration.

The oily water sewer main should be run to the battery limit as a separate system and there connected to the oily water trunk sewer which runs to an oil-water separator.

The acid (chemical) sewer should be designed to collect heavily contaminated, corrosive process chemical wastes which occur as spillage, leakage and valved drains at process equipment and pumps.

Open end drain hubs should be located at all tanks, towers, exchangers and associated equipment to facilitate draining. Large drains at towers or tanks may be more conveniently handled by an acid proof concrete or acid brick lined sewer box rather than an open end drain hub.

Pump blocks should be provided with an open end drain hub to collect pump casing drains, drainage from gland and seal piping at pumps and drains in pump suction and discharge piping.

Acid areas which collect corrosive process wastes are usually provided with an acid resistant curbed paving to confine and collect any acid drainage or spillage within these curbed areas. Curbed and paved areas should be provided in locations where pump groups, storage and handling areas are subject to spillage and wash down water.

Wash water collected in these surface drainage areas should be collected in the acid sewer, however, where possible storm water surface drainage should not be run into the acid sewers, if avoidable.

The acid wastes should be run in a separate sewer from that of any alkaline waste. Acid and alkaline wastes should be run as two separate sewer systems to the battery limit and to an acid treating facility or a neutralizing sump.

The storm water sewer should be designed to collect the maximum surface drainage. This is to include the rainfall in one hour, wash water not of a contaminated nature and cooling water when not returned in return headers to the cooling water facilities.

Storm water runoff is calculated on the basis of 100 percent runoff for all paved areas and 50 percent runoff for unpaved areas. The remaining 50 percent in the unpaved areas is assumed to be absorbed into the ground.

Rainfall data for various geographic locations are readily available from government, state and city weather bureau records and from other published data. Storm water accumulation for each inch of rainfall per hour, per square foot, is equal to 0.0104 gallons per minute.

Fire water from hoses should be included in the storm water runoff, if flooding would cause damage to installations and present a hazard during fire fighting operations. The storm water main should be run to the battery limit and connected to the trunk sewer.

The sanitary sewer constitutes a separate sewer system, into which, wastes of other than sanitary facilities are not permitted. The sanitary sewer shall discharge into a septic tank. The effluent from the septic tank may be discharged into the oily water sewer, if there is no sanitary sewer main provided at the battery limit.

Waste Water Treatment. The oily-water sewer flows to an oil-water separator for oil removal and sediments are also removed in a sludge disposal chamber. Conventional chemical treatment will also be necessary.

The acid sewers will flow to some form of neutralizing sump or acid treating facility. These acid and alkaline sewer wastes are collected separately at sumps for the purpose of neutralization or treatment.

The storm water sewer should be provided with facilities for oil skimmers and a trash screen before final discharge to point of disposal.

Plot Plan-Layout Aid. The plot plan will be a major aid in the design and layout of the various sewer systems. The plot plan will indicate the locations of all the various pumps, exchangers, tanks and towers. It will also indicate the extent of paved areas, roadways, underground utilities (water and electric) and the locations and inverts of the various sewer tie-in to the sewer mains at the battery limits.

Layout Procedure. The layout of the various sewer systems can begin with a careful indication of all

the major equipment foundations, the locations of which are taken from the plot plan. Care should be exercised to indicate all pipe rack columns, lighting poles and all minor footings, which, if not shown, may result in interferences with the sewers. Underground cooling water systems should be integrated into the sewer system layout as an additional system as it would be impossible to avoid interferences. The same can be said of any underground electrical utilities, they must be also indicated on the sewer layout to avoid any interferences.

The problem now will be to design the sewer systems into an intricate and somewhat ingenious layout so as to have as many as four separate sewer systems underground. It will be necessary, to provide gravity flow in each of the systems, maintain the given inverts of the various sewer systems at the battery limits and, at the conclusion, be free of interferences at the cross-overs of sewer systems, underground water and underground electrical systems. To further complicate the sewer layout, there may be existing underground piping, electrical trenches and other encumbrances which will try the patience and ingenuity of the design engineer. The prosaic sense and feeling one has toward working on sewer problems, by this time, is hurriedly vanishing.

Classify Type Surface Drainage. The plot plan, having furnished the locations of all pumps, exchangers, compressors, tanks and towers, will also give the extent of the paved and curbed areas. The paved and curbed areas adjacent to process equipment should be segregated into proper sewer system classifications, namely, oily water sewer, acid (chemical) sewer system, storm water system, sanitary sewer and etc., depending on the type of process waste drainage or spillage therein contained. These areas must be divided into surface drainage areas which will collect and channel drainage to the proper sewer system classification.

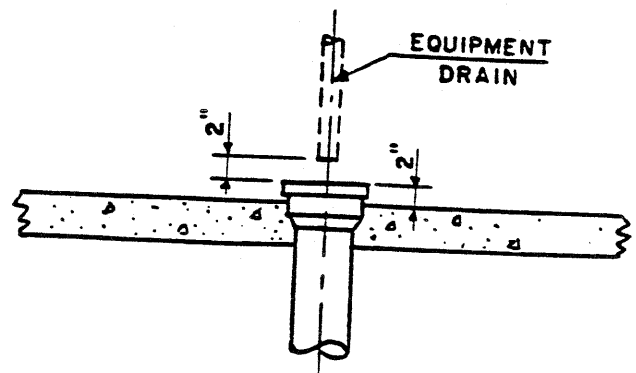
Paved or unpaved areas in outlying locations, not adjacent to process equipment or buildings, should be divided into surface drainage areas. These areas will most likely be free from contamination and may be channeled into the storm water sewer.

Diked or curbed areas at tank farm and storage locations will also require provisions for surface drainage and should be divided into suitable drainage areas. These drains should be run to the oily water sewer main.

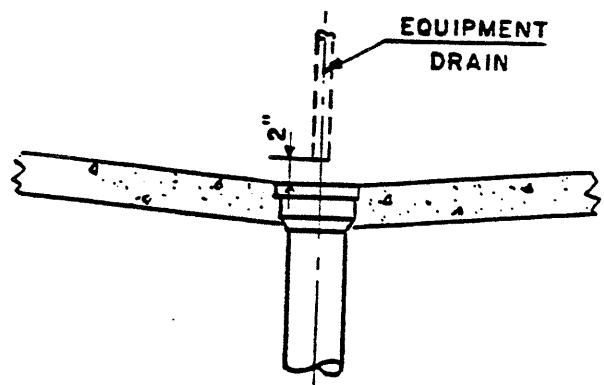
Establish and Check Slope. Surface drainage areas should be designed and sized, keeping mind, the limitations of the permissible slopes of paving or grade. The slopes of all drainage areas should be governed by the following limits so as not to present a hazardous or tripping condition.

The paving inside of buildings should have a minimum slope of one inch in ten feet and a maximum drop three inches in elevation, for each drainage area.

Paved areas and unpaved areas outside of buildings should have a sewer box or catch basin provided for each surface drainage area. The maximum difference in elevation between high point of grade and the



DRAIN HUB
NO SURFACE DRAINAGE



DRAIN HUB
SURFACE AND EQUIPMENT DRAINAGE

FIGURE 3—Drain hub details.

grade at the catch basin shall not be more than six inches, using a slope of one inch in ten feet.

It can now readily be seen that the total number of divided surface area divisions will depend upon the drop in elevation of surface drainage areas.

Sewer Design. The surface drainage area having been divided into areas, based on slope and drop in elevation, must now be segregated and run to proper classification of sewer.

The divided areas are to be provided with a sewer box or catch basin. The separate sewer systems are now to be connected to the proper classified sewer. The outlet connections at the sewer box or catch basin may be at the bottom or side depending upon the limits of sewer inverts (See Figure 2). The term "invert" refers to the elevation of bottom inside surface of the sewer pipe.

Flow diagrams. Drain hubs (See Figure 3) collecting drainage from equipment above grade or paving which were previously added to sewer layout should also be run to the proper classified sewer. Flow diagrams should be consulted to make sure that no drain connection has been omitted, especially those located at the upper levels. Drain hubs need not consist of an actual hub or bell attached integral with the pipe. A cut piece of pipe projecting two inches above grade

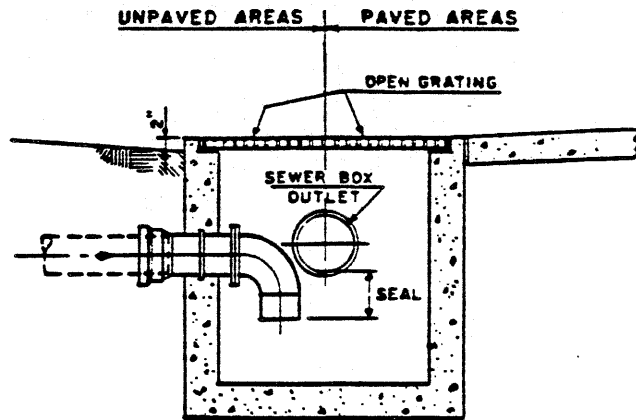


FIGURE 4—Catch basin detail.

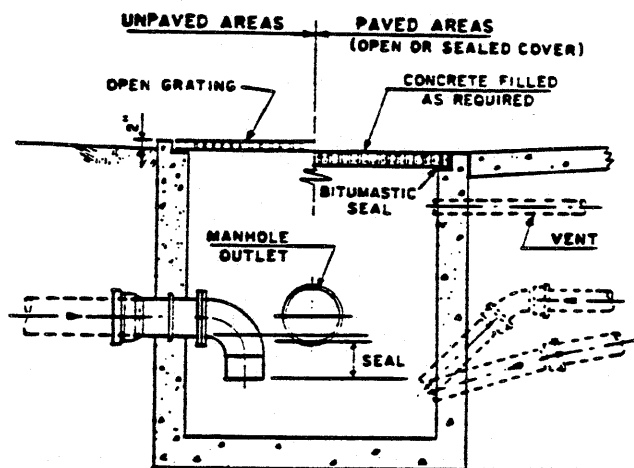


FIGURE 5—Manhole detail.

or paving will be sufficient. Drain hubs extending two inches above grade or paving will prevent the undesired surface drainage from entering the sewer systems.

Designers laying out piping above grade are urged to consult with the designer of the underground piping so as to aid in picking up all the tie-in connections. Coordination of this nature will result in a suitable location and a mutual agreement for the tie-in connections for both above ground and underground piping. Liaison work between designers will eliminate costly revisions and any omissions of tie-in connections.

The complete segregation of all sewer systems at this point will represent nothing more than a one line diagram layout for each system. Catch basins and manholes should now be added to the layouts.

Catch basins (See Figure 4) should be used as a junction for changes of direction of sewer branch lines. The location of junctions of sewer branches may so coincide, that a catch basin may be substituted for a sewer box, which would normally be provided for surface drainage. A catch basin is also to be used as a junction for a change in diameter (size) of all sewer mains.

Catch basins with open tops, covered with grating, should be used to collect surface drainage and process

wastes in unit areas where drainage may wash down appreciable amounts of debris or foreign matter. The bottom of catch basin is to be designed deep enough to provide a minimum of six inches for sediment settlement separation.

Catch basins in paved areas should be flush with the paving, in unpaved areas the top of catch basin is to be two inches above grade.

Catch basin having an open top, covered with a grating, may consist of standard stair treads of grating construction. The use of these standard stair treads will minimize the cost of these gratings. They can be used in groups of two, three or more and the catch basin designed to accommodate the number of gratings utilized.

Seals shall be provided on all inlets of sewer branches and sewer mains connecting to a catch basin or manhole (See Figures 4 and 5). Seals should consist of an elbow or a tee with outlet extending downward to provide for a minimum of a six inch seal. Some refineries use a special combination seal and cleanout fitting designed to be inserted into the wall of catch basin or manhole at the time of pouring the concrete. A simple method for providing a seal is obtained by running the inlet pipe into the catch basin or manhole at a sharp downward angle so as to have the upper edge of inlet pipe six inches below the liquid level in the catch basin or manhole. This method should only be used when the pipe line is reasonably short. Fittings should be removable from inside of catch basin or manhole to permit cleaning and rodding.

A catch basin and manhole may be constructed so as to have a weir type wall seal, where application warrants this type of seal.

Areas that are considered hazardous, from the standpoint of having accumulations of flammable gases in the sewer mains, shall have catch basin and manhole covers sealed or gasketed to prevent escaping or leakage of gases from sewer lines. Catch basins and manholes should be provided with a four inch minimum size vent. In areas having furnaces or other fired equipment or sources of possible ignition, vents shall be run underground at least 100 feet from the source of possible ignition and ten feet above grade, in a safe location.

Floor drains inside of buildings should be used in floors where they will only handle water. A sewer box or catch basin should be used where process waste spillage may occur inside of a building.

Floor drains should not be permitted in control rooms, switch room or lavatories. There is always the possibility of sewer gas accumulation backing up through floor drains of these installations causing explosions and flash fires. A source of water for seals in the running traps, normally provided in sewer branches running from buildings, will not be available, as there will be little, if any, water used for washing down floors or from any other source. The floors usually receive an occasional mopping, so the sewer line and trap seal if sewer pipe were installed, would have dried up, allowing sewer gases to enter the buildings.

Running "P" Trap. Sewer branch mains from a pump house, compressor house or any enclosed building

should have connections made to the sewer systems at manholes or catch basins with the inlet provided with a seal. Where this is not feasible, drains from buildings and separately defined areas should be provided with a running trap ("P" trap) of the clean-out type located outside the building wall, with clean-out plugs accessible without disturbing the paving.

A sewer branch or sub-branch should be run in one plane from a drain hub to a catch basin and from a catch basin to a manhole to prevent clogging of the sewer line and to facilitate rodding and cleaning. Whenever possible, all branch connections to sewer systems should preferably be made at a catch basin or manhole.

Flap Valve. Storage areas, which are curbed or diked, should be provided with sufficient catch basins to accommodate the surface drainage. Sewer pipe will run from the catch basin through the curb or dike wall to the nearest manhole. A flap valve (See Figure 6) should be used at the sewer outlet connection inside the catch basin.

The flap valve should be operable, by chain, at the curb or dike wall. The flap valve should be closed at all times except to drain surface water from the enclosure after rain storms. In lieu of the flap valve, a gate valve may be used for containing contents of the enclosure. The gate valve should be installed in the sewer line, outside of the enclosure and provided with an extension stem for operation at grade level.

In the event of a leak or break in any storage tank or piping, the flap valve will prevent the loss of valuable tank contents and allow for the recovery of the tank contents retained within the diked area. It will also prevent any large amounts of hazardous and flammable liquids from entering the sewer system, which would create the possibility of a hazardous fire condition should the tank contents be of a volatile nature.

Hot Waste. Drain lines which collect hot, noncorrosive waste drainage, above 210° F, such as boiler blow-off, steam trap discharges, hot waste drainage, etc., that do not receive any cooling quench from other streams, should be constructed of steel pipe and fittings. The steel sewer pipe should be run to the nearest catch basin or manhole. Hot acid waste drainage should be run in acid resistant alloy material sewer pipe and fittings.

Valve boxes for underground pipelines should have side walls only with drainage of boxes through a gravel bed at the open bottom of the valve box.

Pipe Sleeves. Sewer pipes running under roadways, trucking areas, etc., should be protected from damage. Heavy concrete slabs or protective pipe sleeves should be provided.

Sewer pipes that are to be embedded in concrete foundations should be constructed of steel pipe and fittings.

Sanitary Plumbing. Plumbing and piping for sanitary facilities, including the septic tank when required, should conform to recognized sanitary practices. All sani-

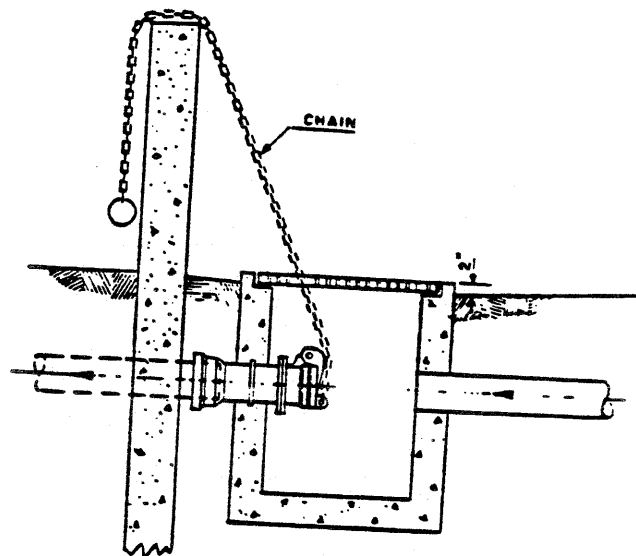


FIGURE 6—Flap valve detail.

tary plumbing and piping should be installed by a local contractor to avoid any conflict with any local codes, ordinances and regulations.

Manholes (See Figure 5) should be installed in the sewer mains at intervals of 300 feet maximum for sewer sizes up to 24 inches and at 500 feet maximum intervals for sizes above 24 inches. Manholes should be installed at dead ends of sewer mains to act as a junction to connect sewer branches. Manholes are also to be installed in sewer main runs as a junction where there is a change in diameter (size) of the sewer main. Manholes with open top covered with grating may be used to collect surface drainage as explained for catch basins. For sealed manholes requiring vent connections, grating cover should be filled with concrete and sealed or bolted down tight to prevent escape of sewer gases.

Sewer Pipe Sizing. The minimum size of underground sewer pipe, branch or drain hub should be 4 inches.

The minimum size of sewer main, (collecting two or more four inch sewer branches or drain hubs), should be six inches.

The minimum size of sewer pipe in any curbed or diked area should be eight inches.

Invert. The invert of sewer inlet and outlet at catch basins and manholes, should be at the same elevation when both inlet and outlet sewer main are the same size. Where the sewer increases in size at the outlet and the gradient permits, the tops of both inlet and outlet of the sewer mains should be at the same elevation. However, if this is not practical because of gradient limitations, the inverts of the inlet and outlet of sewer mains may be at the same elevation but preferably, the outlet should be slightly lower.

Straight runs of sewer mains should have a change in pipe diameter (size) only at a catch basin or manhole.

Sewer design should include provision for ample future expansion of the plant and unit areas. Sewer mains

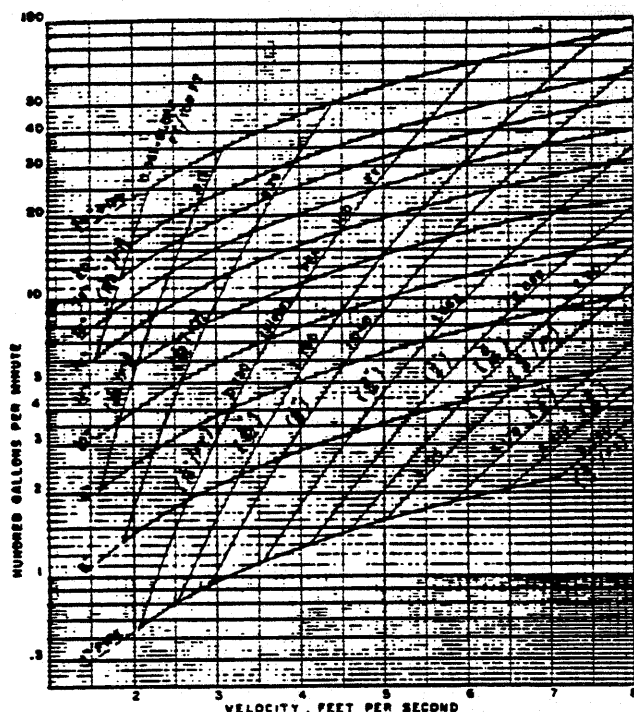


FIGURE 7—Capacity of sewer pipes running $\frac{3}{4}$ full. Sizes 4-inch to 24-inch inclusive. Turbulent flow $\epsilon = 0.00085$. Darcy formula: $Q = 19.65 d^{2.5} \sqrt{\frac{h_s D}{fL}}$

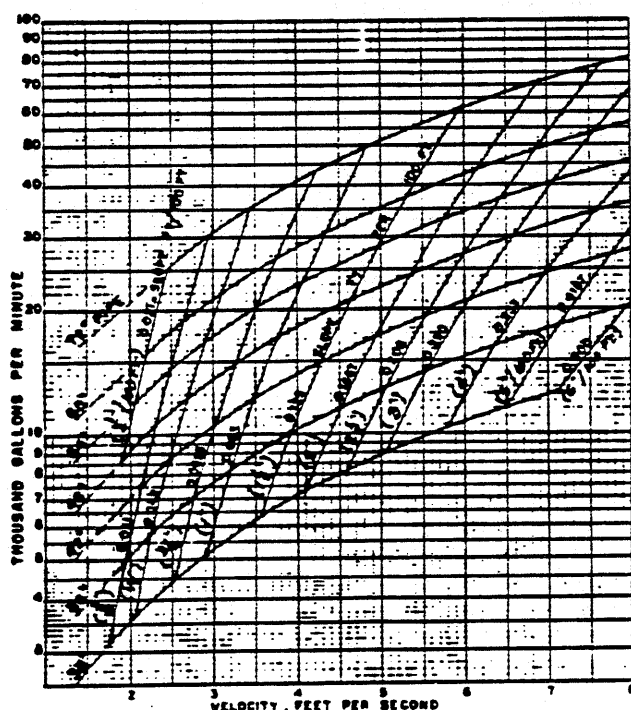


FIGURE 8—Capacity of sewer pipes running $\frac{3}{4}$ full. Sizes 30-inch to 72-inch inclusive. Turbulent flow $\epsilon = 0.00085$. Darcy formula: $Q = 19.65 d^{2.5} \sqrt{\frac{h_s D}{fL}}$

in particular, should be sized to include the estimated flow of any future expansion.

Fire water from hoses should be considered in the sizing of any sewer system, depending on the unit area location of any hazardous hydrocarbon and flammable chemical equipment. If fire water is to be included in the estimated maximum flow quantities, sizing should be based on: (1) fire water plus total process waste waters or (2) storm water plus total process waste waters, whichever is the greater.

Unit areas containing fire water from hoses that is to be collected by two catch basins should have a branch sewer assumed to receive 500 gpm. Unit areas containing fire water collected by as many as four catch basins should be assumed to receive 1000 gpm.

Hazardous areas subject to fire water from hoses should have sewer branches from each area sized accordingly, however, the amounts are not to be cumulative when estimating the size of sewer mains. One single 500 or 1000 gpm allowance for the fire water flow quantity should be added to the sewer main flows, regardless of the number of hazardous areas within the unit area under consideration within the plant site, starting at the upstream end of the sewer system under consideration.

Storm water accumulation runoff should be calculated in inches of rainfall, based on 100 percent runoff for all paved areas and 50 per cent runoff for the unpaved areas.

Storm water for each inch of rainfall per hour, per square foot equals 0.0104 gallons per minute.

Velocities used in the design of sewer systems should have a minimum of 3 feet per second and a maximum of 7 feet per second.

Flow capacities, velocities and slopes (for sewers running $\frac{3}{4}$ full) can so be coordinated that the curves shown on Figures 7 and 8 will give the size of sewer line required for the assumed slope and velocity for the desired flow capacity in gallons per minute.

Flow capacities, velocities and slopes of sewer lines should be contingent on the grades available at the plant site. The flat grades necessary at most plant sites will be a determining factor in the slope and velocity of the sewer lines. Where possible, and if gradients permit, the maximum velocity should be used.

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About the author



WILLIAM O. SEPPA is a project engineer with Scientific Design Company, Inc., New York City. He has had 25 years experience in oil refinery and chemical plant design. He has held positions as squad leader, drafting supervisor, and project engineer. Mr. Seppa was recently resident engineer in a Japanese petrochemical plant. He has also been resident engineer in the U.S. and Europe. His experience has been with Ebasco, Alco Products, Chemical Construction Company, Socony Vacuum Oil Co., M. W. Kellogg Co., Bechtel, and Scientific Design Co., Inc. He attended Columbia University and is a member of ASME.

Design Guide to Refinery Sewers

API survey reveals current practices in refinery sewer design, sealing and venting methods, and entrained vapor problems in pressurized sewers

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REFINERY SEWER SYSTEMS are often potential hazards. Unlike pressurized distribution systems, the refinery sewer flows by gravity and usually runs partially filled. The entrained hydrocarbons can vaporize and fill the vapor space with an explosive mixture. This condition is further aggravated because of the warm nature of the sewer effluent. Because sources of ignition are ever present to complete the fire triangle, there is always a possibility of sewer system explosions that can cause considerable damage. The recognition of this problem has led most refiners to adopt practices that help to minimize this hazard.

In 1961 the Subcommittee on Storage and Handling of the Operating Practices Committee, API Division of Refining, appointed a task force to investigate the requirements for safe operation of refinery sewers. The task force prepared a questionnaire on current design and operating practices for sewer systems and surveyed various refiners. The results of the questionnaire were summarized and presented as a report to the Subcommittee on Storage and Handling in May, 1962. This paper is a result of that survey and is intended as a guide to current practices used to minimize the hazards of refinery sewer systems.

Municipal Systems. Generally, refinery sewer systems do not tie into municipal systems. The reason is twofold. The type of waste products from refineries are not compatible with the type of treatment prevalent for sanitary sewage and, in general, the quantities of spent cooling water from a refinery may equal or exceed the flows expected in a municipal sewer system. To prevent waste products from entering rivers and lakes, almost all refiners have provided their own facilities to separate and

collect the waste products. Thus, the hazards discussed in this paper are not to be expected in municipal sewer systems.

In some instances refiners do discharge their sanitary sewage into municipal systems. In these cases, great care is taken to exclude oil-bearing streams. Pressurized sanitary sewers are frequently used to prevent oil infiltration. When oil can enter the refinery sanitary sewer, the effluent is treated to remove the oil before the effluent is sent to the municipal system.

The scope of this paper includes the layout and design of refinery sewers, the methods of sealing and venting, and the problems caused by entrained vapors in pressurized sewers.

Storm Sewers. Refinery sewers collect storm water, spent cooling water, condensate, varying amounts of spills and leaks, and under emergency conditions fire water and blow-down. Separate storm sewers sometimes are used and an effort is made to exclude oil-carrying streams. When this is done, the possibility of collecting hydrocarbons in the system cannot be completely ignored. Storm sewers should have some form of separating facilities prior to the final outfall. In addition it is recommended that precautions similar to those which will be suggested for process sewers be taken to protect the separate storm sewers. In one case cited, an explosion caused by an inflow of oily water resulted in considerable damage to a separate storm sewer. An oily water catch basin had been mistakenly connected to this sewer. The source of ignition, while unknown, was possibly caused by welding adjacent to a stormsewer catch basin.

Refinery Sewer Layout. The layout of most refinery sewer systems consists of a skeletal trunk sewer with branch lines connected to processing units, diked area drainage, and other processing or work areas. The main trunk sewer is generally isolated from branch sewers by some form of a gas-trap manhole. In this way vapors in the trunk sewer cannot back up into processing areas. The design capacity of the trunk sewer will, in general, depend upon the cumulative amount of spent cooling water and condensate from the units it is draining plus storm drainage from surface drains and catch basins up-

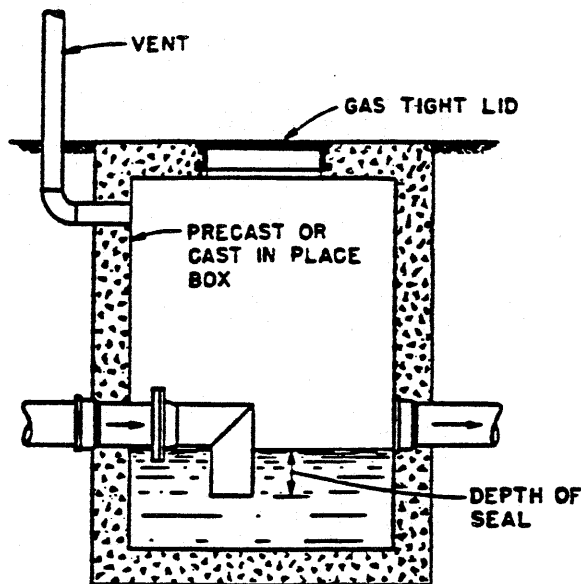


FIGURE 1—Typical junction box.

stream. Trunk sewers generally drain large watersheds; therefore fire-water flows probably will not be a governing factor. Branch sewers on the other hand may be more affected by fire-water flows. Under normal conditions branch sewers to refining units and the laterals from the branch sewer will handle varying amounts of spent cooling water and condensate. During storms or when fire water is needed, the branch sewer may reach capacity. To avoid flooding or backup, the sewer must be sized to handle these flows. Backup or flooding in a municipal sewer may inconvenience motorists and may cause some property damage. Around a refinery unit, backup can cause serious fires or spread fires that are confined to one area. Thus, in sizing a branch sewer or lateral, it is very important to consider the probable amount of fire water which may be used in the event of a fire. On crude oil units the problem may be aggravated if the blowdown from the unit discharges into the branch sewer. The quantity of fire water will depend on the number of hoses and turret nozzles that would be drained to a given area. For branch sewers from units, the flow specified by various refiners ranged from 1,000 gpm to 2,500 gpm plus normal process water flows. Storm flows will depend on the geographical area in which the refinery is located.

Diked areas around tanks are frequently provided with storm drains that discharge into the trunk sewer. An overflow as the result of an overfilled or ruptured tank could discharge large quantities of oil to the refinery sewer and would ultimately overload the separating facilities. To prevent this and to allow recovery of the oil within the diked area, it is common practice to provide some type of valve arrangement to isolate the storm drains in tank fields from the trunk sewer.

Seals play a vital role in maintaining safe operation of a sewer system. Under normal flow conditions many sewers are only partially filled because design flow rates are based upon storm or fire-water quantities. The vapor

space will frequently contain an explosive mixture. Without intermediate seals, a flame front or explosion could run the full length of the sewer system. Seals in conjunction with venting serve to isolate or sectionalize portions of the sewer so that fires or explosions will be confined to limited areas.

The methods used by various refiners for sealing and trapping differ somewhat in the details, but all are aimed at accomplishing the same end. Open drains on units such as cup drains, floor drains, and sample drains are generally equipped with P-traps or running traps. Cast iron soil pipe P-traps provide a 2½-inch water seal in sizes 3 inch to 6 inch and a 3-inch water seal in sizes 8 inch to 12 inch. Laterals from the open drains and catch basin are in turn sealed at junction boxes. A common practice is to elbow incoming laterals below the water level in the junction box. The invert of the outfall line in these cases is generally 2 feet or so above the bottom of the box and on the average permits a 12-inch seal on incoming lines. A typical junction box of this type is illustrated in Figure 1.

Branch lines from refinery units and processing areas generally flow through a gas-trap manhole prior to entering the trunk-sewer system. On units, the gas-trap manhole frequently is located at the unit limits. A typical arrangement of a gas-trap manhole is shown in Figure 2. All laterals which leave the unit enter the upstream compartment, and the branch line to the trunk sewer flows from the downstream compartment. Incoming laterals are elbowed downward to below the water level, as in junction boxes. When gas-trap manholes are used to sectionalize trunk sewers, it is usually impractical to elbow the incoming line because of the larger size piping. Such is the case in Figure 2. The gas-trap manhole is an effective device to prevent vapors backing from the trunk sewer into branch systems.

It is of great importance to maintain seals when units are shut down permanently or for repairs. Most methods of sealing require a small amount of flow to offset evaporation losses. While the practice is generally considered undesirable, it is not uncommon to have floor drains in buildings and in pump houses. In most of these cases the sewer from the building discharges into the refinery sewer system. If one of these buildings is unused over a period of time, the water seals in the P-traps will evaporate and allow vapors from the refinery sewer to collect in the building. It is usually advisable to blind or block an unused branch or lateral where it enters into an active

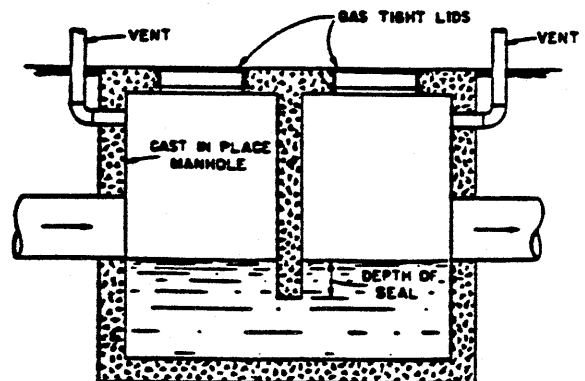


FIGURE 2—Gas-trap manhole.

sewer. When welding is in progress near open catch basins, the usual procedure is to seal the catch-basin lid with sandbags or place a tarpaulin with a cover of sand over the lid. Similar precautions should be taken near floor drains or other open drains that may be discharging flammable vapors.

Hot liquids and corrosive materials are frequently discharged into the refinery sewer. To protect the sewer system, care is needed in the proper selection of materials to be used in the methods for handling these flows. The drains from furnaces, particularly in crude oil units, should be able to resist thermal shock in the event of tube failure. In some cases the sewer must carry corrosive material until the material reaches a main which will dilute it. The material used in joints should have the same resistance to heat, corrosive materials, and solvents as the pipe. Proper materials, good workmanship, and timely inspection are required to insure having a sewer adequate for its designed purpose available in the event of an emergency.

Full Running Sewers. Some trunk sewer systems rely upon the sewer running full to maintain a seal between operating areas. This is particularly true in the older sections of many refineries. As the refinery is modernized, many of the older units become obsolete and are taken out of service. If the spent cooling water and process water to these trunk sewers is thereby reduced, the sewer may flow only partially full. Under these conditions a fire in one section could be spread to other areas through the sewer. A few accidents of this nature were reported in the survey. When there is a possibility that the sewer may flow only partially full, it is probably wise to provide some positive means of sealing the system. Gas-trap manholes can be installed in the existing system. Weirs installed in manholes to back up the flow and keep the sewer full provide another means of sealing the system.

Sewers, in general, are designed for gravity flow. In a tightly sealed system a rise in water level would reduce the vapor space and cause an increase in pressure. Such a tendency would in turn reduce the design capacity of the sewer. Under these circumstances vents are necessary to release vapors and to prevent vapor lock. Vents are functionally designed to maintain atmospheric pressure in the sewer and to release vapors to safe locations.

A wide range of hydrocarbons enter the sewer system. Many of the lighter fractions will vaporize immediately. In addition, the warm nature of the effluent will cause some heavier fractions to vaporize. Therefore, under normal conditions, there will always be some venting of hydrocarbon vapors.

Venting Rules. Rules and regulations on the location of vents vary considerably among the refiners who were questioned. There was agreement, however, that vents should:

- Discharge to areas that are apart from furnaces and other permanent sources of ignition.
- Not be placed near operating platforms or ventilating-fan intakes.
- Be high enough to insure that the emitting vapors will be dispersed rather than accumulate at grade.

The vapors which are released can be toxic and are frequently flammable, and it is further recommended

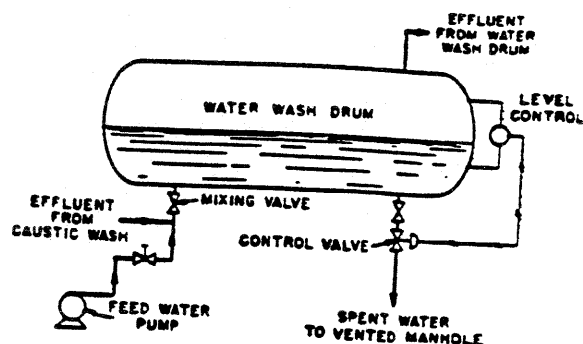


FIGURE 3—Water-wash drum.

that the vents be distinctively marked to warn personnel of the vapors being emitted.

Most refiners require that vents on manholes and junction boxes be of at least 4-inch pipe size. Smaller piping has a tendency to freeze during low temperatures or clog through gradual buildup of scale and sediment. The vent should drain to the manhole or box and be free of pockets, which might be subject to clogging, or other obstructions. On crude oil units the blowdown stacks will frequently drain to the gas-trap manhole at the battery limit. Under these conditions the blowdown stack is usually equipped with an internal spray nozzle to prevent condensibles from being emitted through the stack. The vent from the manhole is sized to handle the larger quantities of vapor and is connected to the blowdown stack.

Manhole Tops. Unexpected quantities of light hydrocarbons which enter the sewer and manholes may cause a sufficient rise in pressure within a box to crack or lift the concrete top. The concrete top on precast manholes usually fits into the hub of the concrete culvert pipe that form the side walls. A small rise in pressure in the box will lift the top and allow vapors to escape at grade. One accident cited illustrates this problem. Figure 3 shows the flow to a water-wash drum on a light-ends processing unit. In this case effluent from a caustic-wash drum mixes with water prior to entering the water-wash drum. The effluent in this instance contains butane. The water level in the drum is maintained by a level controller that controls the flow of water from the drum to a vented manhole. The accident occurred when the pump which supplied water to the drum lost suction and the control valve on the discharge line failed to close. The loss of water level allowed from 15 barrels to 20 barrels of butane material to reach the manhole. The vent was inadequate to handle the vapors and the resultant pressure lifted the concrete top and adjacent paving, allowing butane vapors to escape at grade. Fortunately, a fire did not occur. In this case an equipment failure permitted the accident to happen. The remedy was to provide a low-level alarm on the drum to alert the operator so that a butane spill to the sewer would not recur.

Flame Arrestors. The use of flame arrestors on vent piping is infrequent. A major criticism, cited by various refiners, is the tendency of flame arrestors to become blocked by corrosion or the formation of ice. If a vent is designed to handle relatively large quantities of flammable vapors, it may be desirable to provide some means of extinguishing a vent fire caused by a source of igni-

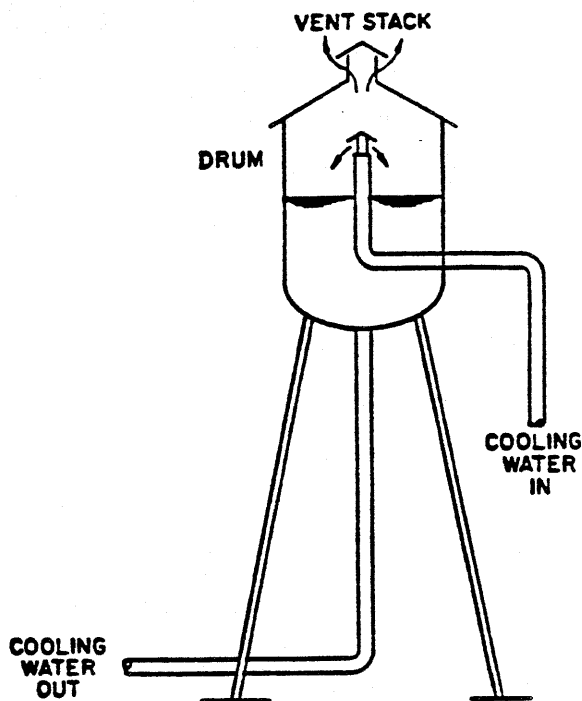


FIGURE 4—Atmospheric-vent drum.

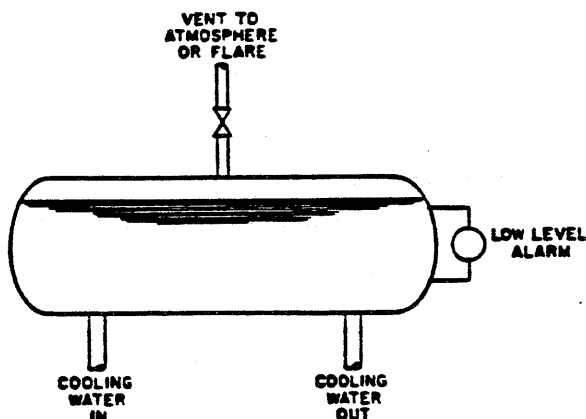


FIGURE 5—Pressure-vent drum.

tion such as lighting. A relatively inexpensive method is a hose connection for snuffing steam. A valve with a hose connection on the vent line at grade is all that would be needed.

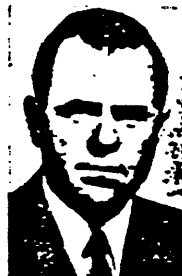
Entrained Volatiles. Pressure sewers and cooling water return lines often contain entrained volatiles. The origin of the volatiles is frequently leaky or ruptured tubes on water-cooled exchangers. When the return cooling water discharges into a cooling tower basin or an oil-water separator, the light hydrocarbons vaporize and escape into the atmosphere. At one refinery a fire in the cooling tower was attributed to a carryover of light-hydrocarbon vapors in the return water. Atmospheric or pressure-separating drums can be used to remove the entrained hydrocarbon vapors. In the atmospheric drum

shown in Figure 4 the cooling water discharges to an elevated drum that is vented to the atmosphere. The vent of the drum is high enough so that the discharging hydrocarbons cannot reach a source of ignition while still in a flammable state. Leaking exchangers are discovered by observing the vent for signs of hydrocarbon vapors. The pressure-separating drum shown in Figure 5 operates somewhat differently. Hydrocarbon gases in the cooling water stream accumulate in the top of the drum. As the volume of entrained vapors increase, the water level in the drum falls and actuates a low-level alarm. At this time the vapors are vented to the atmosphere or to the flare system. When a serious tube leak occurs, the operator is instantly alerted because of the falling water level. Some refiners rely on detection procedures such as mechanical or analytical gas alarms, sampling, or changes in residual chlorine levels to alert operators that an exchanger tube is leaking. **Design Points.** Some of the considerations that should be reviewed during the layout and design of refinery sewers are:

- Within the limits of a processing unit various processing areas should not have interconnecting laterals. As an example, laterals which drain furnace areas should not be tied into laterals which may contain light hydrocarbons. The sewer system on a unit should be capable of handling emergency flow which result from fire fighting and of minimizing backup that may impede fire fighting or spread contained fires to adjacent areas.
- Seals should be designed with sufficient depth to prevent the escape of hydrocarbon vapors into a processing area or areas where sources of ignition might exist. Seals should have sufficient depth to stop flame fronts that are moving through partially filled sewers. Vents should be adequately sized to handle the quantities of vapors that might be anticipated and should be located in such a manner as to release the vapors to the atmosphere well above possible sources of ignition.
- Careful control should be taken during the design and construction phases to insure that process piping and equipment cannot accidentally discharge large quantities of oil, particularly light hydrocarbons, to the sewer system without such a discharge sounding an alarm to warn the operators.

Originally Presented to the API Div. of Refining, Philadelphia, May 14, 1963. ##

About the Speaker

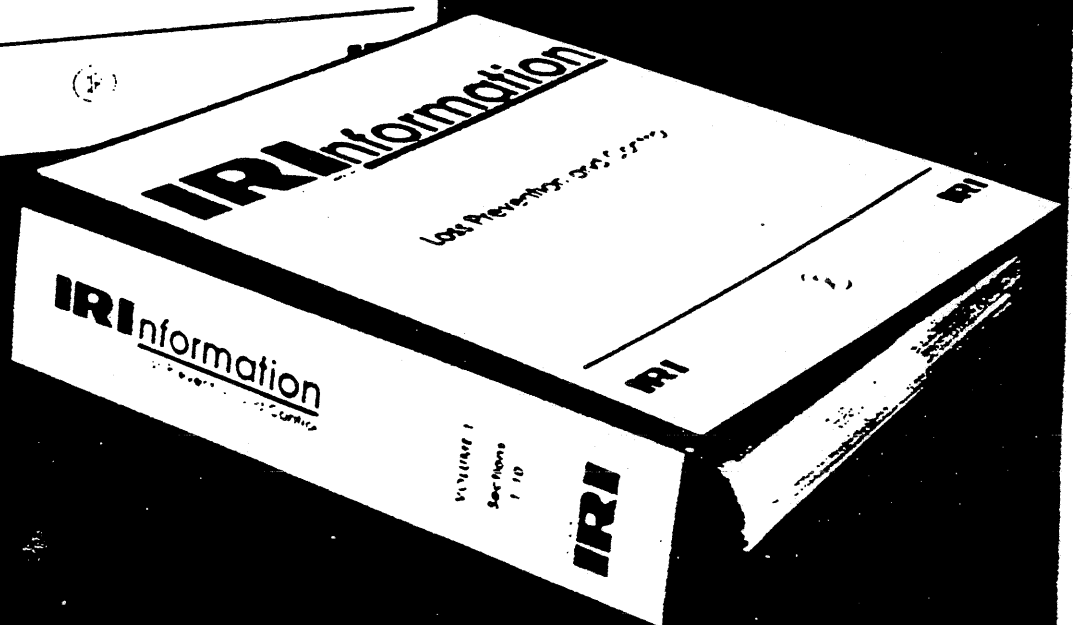
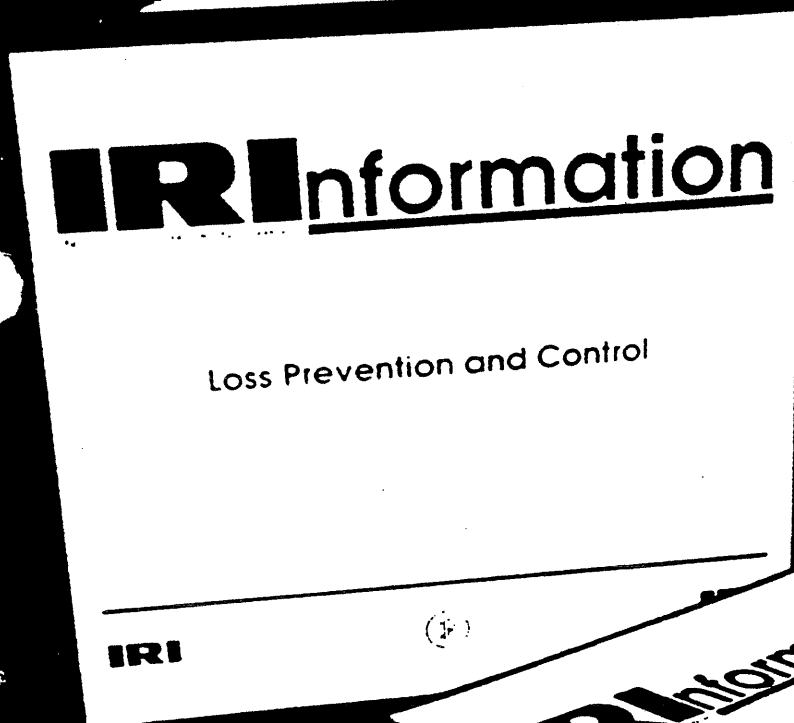


Shannon

G. T. Shannon supervises a project engineering section in the technical division at Humble Oil & Refining Company's Baytown refinery. He holds a B.S. degree in civil engineering from Oklahoma State University. Prior to joining Humble in 1946, Mr. Shannon worked for a consulting firm, the Oklahoma State Highway Dept., and the U.S. Corps of Engineers.

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National Fire Codes

A Compilation of NFPA Codes, Standards,
Recommended Practices, and Manuals

Volume 3



This is one of 16 volumes of the National Fire Codes published annually by the National Fire Protection Association. The complete set contains the codes, standards, recommended practices, and manuals developed by the technical committees of the Association and processed in accordance with the NFPA Regulations Governing Technical Committees. See inside front and rear covers for listings of the contents of each volume.

National Fire Protection Association
470 Atlantic Avenue, Boston, MA 02210

Volume 2

Section	Section Numbers	Section Description	Section	Section Numbers	Section Description
IM 10	--	STORAGE AND WAREHOUSING	IM 14	--	WATER SUPPLIES
IM 10.0.1		Commodity Classification Guide	IM 14.0.1		Fire Protection Water Supply Systems
IM 10.0.2.1		Polystyrene-Foam Packaging Materials	IM 14.0.1.1		Municipal Water Supplies
IM 10.1.1		General Storage - NFPA 231-1987	IM 14.1.1.0		Estimating Fire Protection Water Demands
IM 10.1.2		Rack Storage of Materials NFPA 231C-1986	IM 14.1.2.0		Analyzing Water Supplies
IM 10.1.2.1		Maximum Reliability for High Racked Storage Protection	IM 14.1.2.1		Conducting Water Supply Tests
IM 10.1.2.2		Preplanning for Fire Emergencies Involving Storage in Racks at Heights of 25 FT (7.6 M) or Greater	IM 14.1.2.2		Water Measurement Using Two-Inch (50mm) Drain Tests
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IM 10.2.3		Foamed Latex and Flexible, Open-Cell Foamed Polyurethane Storage	IM 14.2.1		Centrifugal Fire Pumps - NFPA 20-1987
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IM 10.2.5		Hanging Garments	IM 14.2.1.2		Annual Fire Pump Tests
IM 10.2.6		Plastics Stored in Wire Baskets	IM 14.2.1.3		Testing of Fire Pump Controller Features
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IM 10.2.8		Rubber Tire Storage - NFPA 231D-1989	IM 14.2.2.2		Ventilation of Fire Pump Rooms
IM 10.2.10		Sugar Storage Facilities	IM 14.2.2.4		Balanced-Clapper and Butterfly Check Valves
IM 11	--	DETECTION AND ALARMS	IM 14.2.3.1		Cummins Engine Company, Inc., Diesel Drivers for Fire Pumps
IM 11.0.1		Fire Protection and Security Surveillance	IM 14.2.4.2		Firetrol, Inc. Controller Model FTA 1100/FTA 1100-EX Safe Operation
IM 11.0.2		Signaling Systems Wiring - NEC Article 760, NFPA 70-1990	IM 14.5.0.1		Private Fire Service Mains - NFPA 24-1987
IM 11.1.1.0		Central Station Signaling Systems NFPA 71-1989	IM 14.5.2.1		Supervision of Sprinkler or Water Supply Control Valves
IM 11.1.1.1		UL Certification of Protective Signaling Systems	IM 14.5.2.2		Instructions for Use of Plastic Fasteners for Sealing Valves
IM 11.1.3.1		Testing of Auxiliary Protective Signaling Systems			
IM 11.3.1.1.1		Use of Heat-Type Automatic Fire Detectors in High Temperature Environments	IM 15	--	NATURAL HAZARDS
IM 11.3.1.2.1		Automatic Fire Detectors - NFPA 72E-1987	IM 15.1		Arctic Freeze
IM 11.3.2.2		Drop-in-Pressure Waterflow Alarms	IM 15.1.2		Tornadoes
IM 11.3.4.1		Plug-Type Valve Supervisory Devices	IM 16	--	SPECIAL PERILS
IM 12	--	WATER-BASED EXTINGUISHING SYSTEMS			There is no material for this section as of this date.
IM 12.1.0.1.1		Hydraulically-Designed Sprinkler Systems Responsibilities	IM 17	--	SPECIFIC OCCUPANCY GUIDELINES
IM 12.1.1.0		Sprinkler Systems - NFPA 13-1989	IM 17.2.1		Guiding Principles for Protection of High-Hazard Chemical and Petrochemical Plants
IM 12.1.1.3		Use of Shields over Heat-Actuated Devices (Sprinklers or Thermostats)	IM 17.3.1		Guiding Principles for Loss Prevention and Protection of Refineries and Large Gasoline Plants
IM 12.1.1.4		Conversion from Wet-Pipe to Dry-Pipe Systems for Energy Conservation	IM 17.3.2		Guiding Principles for Loss Prevention and Protection of Gas Compressor Stations
IM 12.1.2.0		Inspection, Testing, and Maintenance of Sprinkler Systems - NFPA 13A-1987	IM 17.3.3		Guiding Principles for Loss Prevention and Protection of Crude Oil and Petroleum Products Pumping Stations
IM 12.1.2.1		Testing Field Samples of Automatic Sprinklers	IM 17.3.4		Guiding Principles for Loss Prevention and Protection of Crude Petroleum Products Storage Terminals
IM 12.1.2.3		Drain Tests	IM 17.4.1		Basic Oxygen Furnaces
IM 12.2.3.1		"On-Off" (Self Restoring) Sprinklers	IM 17.5.1		Black Liquor Recovery Boilers - Recovery Processes
IM 12.2.3.2		"Automatic" Sprinkler Corporation of America Mercury Check	IM 17.5.1.1		IRI Recommendations for Black Liquor Recovery Boilers
IM 12.2.3.3		"Automatic" Sprinkler Corporation of America Model C & D Deluge Valves	IM 17.5.1.2		Black Liquor Recovery Boiler Status of Protection Guidelines
IM 12.3.1.2		Closed-Head Foam-Water - NFPA 16A-1988	IM 17.5.1.3		Black Liquor Recovery Boilers - Emergency Shutdown Procedure
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IM 13.0.5		Extinguishing System - Acceptance Tests	IM 17.10		Electronic Data Processing Facilities
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IM 13.1.3		Dry Chemical Extinguishing Agents - Corrosive and Contaminating Effects	IM 17.11		Cleanrooms
IM 13.3.1		Carbon Dioxide Systems - NFPA 12-1989	IM 17.12		Electric Power Generation Abstract
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			IM 18.3		Definitions of "Listed," "Classified," "Recognized," "Approved," "Acceptable"

PLEASE NOTE: The practice of loss prevention and control is a dynamic discipline — growing, expanding, adding and revising information on a continuing basis. Therefore, the data presented here is current as of December 3, 1990. Quarterly additions and updates are planned.

Other loss prevention information or programs, such as OVERVIEW, IRI's Total Management Program for Loss Prevention and Control, or RSVP, IRI's Impairment Handling Program, are referenced in the IRI Index. The IRI Index is a complimentary booklet which lists all of IRI's publications, sound-slide presentations, films, and videotapes. Contact the IRI Library for your free copy: Industrial Risk Insurers, 85 Woodland Street, Hartford, CT 06105-1226 or telephone 203-520-7412.

New Technical Manual Available

How do you estimate the potential damage from a vapor cloud explosion? How do you set up a transformer maintenance program? How can you set up a maximum reliability sprinkler system for your high-rack storage warehouse? IRI's recommendations to key loss prevention questions like these are in *IRInformation*.

IRInformation includes interpretive guides to National Fire Protection Association standards, as well as information about IRI's own guidelines. A few of the many issues addressed include:

- emergency shutdown of Black Liquor Recovery Boilers.
- fixed fire protection for transformers.
- estimating water demands for fire protection.
- protecting high-rise buildings.
- addressing impairments to fire protection systems.
- establishing a safety-relief valve testing program.

The manual is a consolidation of IRI's technical guidelines and includes updated information that IRI had published in the past. It includes material formerly covered in *Recommended Good Practices* and a variety of other publications.

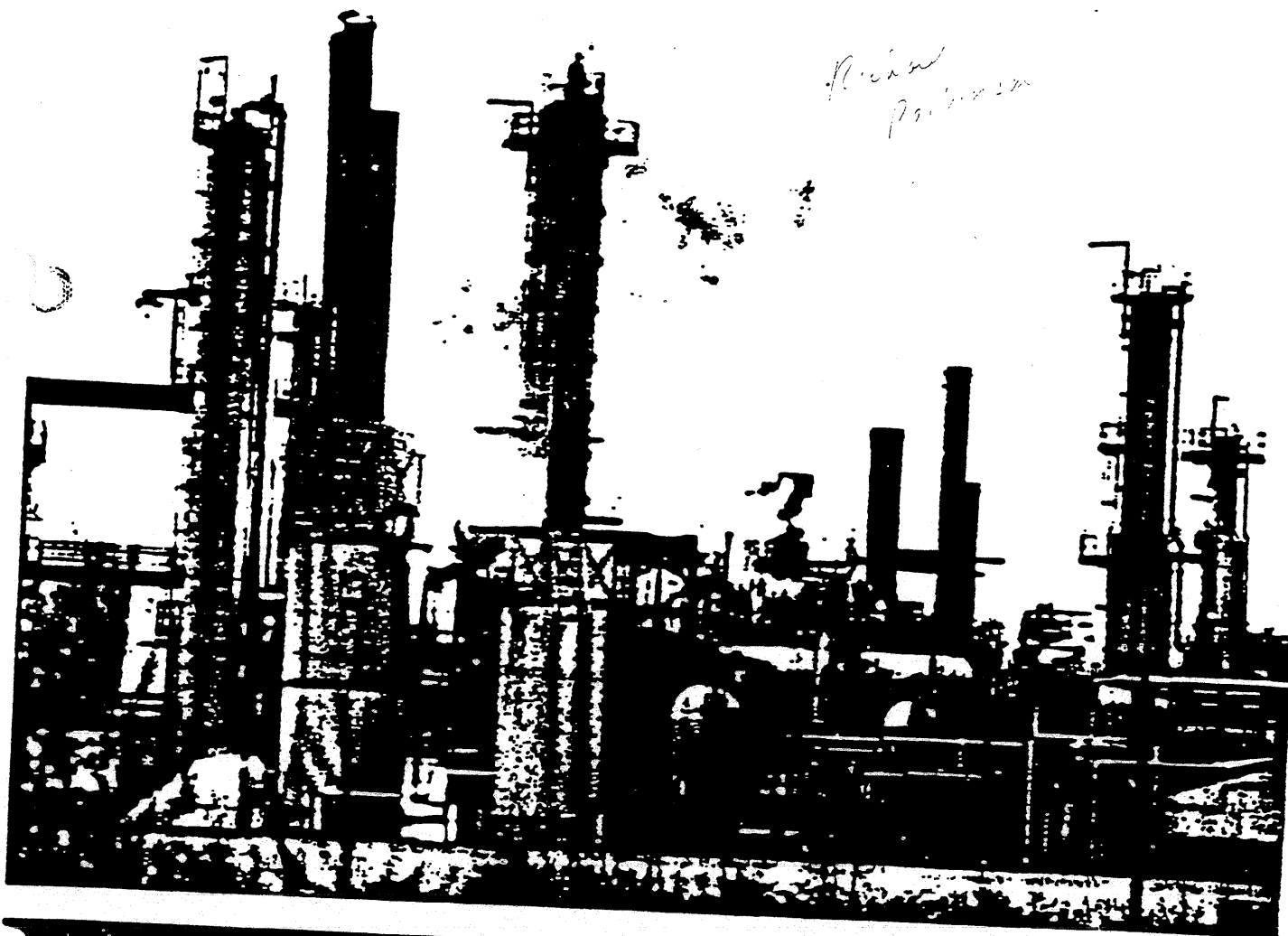
IRInformation is available on a subscription basis. For an initial \$250 plus shipping and handling charges, subscribers will receive the two-volume, loose-leaf technical manual and free quarterly updates for a year. Those updates will be in loose-leaf form, so they can be inserted in the manual. The quarterly update service can be renewed for \$50 per year. To order *IRInformation*, fill out the enclosed order form and return it, along with a check for the appropriate amount in U.S. dollars.

A summary of the 18 sections found in *IRInformation* is presented here.

Volume 1

Section	Section Numbers	Section Description	Section	Section Numbers	Section Description
IM.1	--	MANAGEMENT PROGRAMS (OVERVIEW)	IM.5.4.5		Transformer and Capacitor Dielectric Fluids
	IM.1.1.1	Impairments to Fire Protection Systems	IM.5.4.5.1		Dielectric Fluids Containing PCB's
	IM.1.3.0	Maintenance Program Evaluation	IM.5.5.4		Rigid Nonmetallic Conduit and Electrical Nonmetallic Tubing
	IM.1.3.1	Infrared Thermometers	IM.5.6.1		Control Power for Electrical Switchgear
IM.2	--	BUILDINGS AND STRUCTURES	IM.5.7.1.1		Guide to Off-Premises Power Analysis
	IM.2.0.1	Windstorms	IM.5.7.1.2		Utility System Problems - Capacity and Distribution
	IM.2.0.1.1	Design and Protection of Buildings and Structures from Windstorms	IM.5.9.0.1		Evaluating the Importance of a Transformer
	IM.2.0.2	Foamed Plastics in Building Construction	IM.5.9.0.2		Oil Insulated Transformers - Failures
	IM.2.0.3	Snow Loading of Buildings and Structures	IM.5.9.1		Transformers - Maintenance
	IM.2.0.5	Protection of Buildings from Exterior Fire Exposures	IM.5.9.2		Transformers - Arrangement and Fixed Fire Protection
	IM.2.1.1	NFPA 80A-1987	IM.5.9.3		Transformers - Electrical Devices, Instrumentation and Controls
	IM.2.1.1.1	Single Ply Membrane Roof System	IM.5.9.4		Transformers - Supplemental Precautions
	IM.2.1.2	Perimeter-Fastening of Insulation on Metal Decks	IM.6	--	MACHINERY
	IM.2.1.3	Protected Metal for Building Construction (A.P.M., A.A.P.M., R.P.M.)			There is no material for this section as of this date
	IM.2.1.4	Heat and Smoke Venting	IM.7	--	BOILERS, PRESSURE VESSELS AND PIPING
	IM.2.2.1	Firewalls	IM.7.0.5.0		Overpressure Protection
	IM.2.3.2	Plastic Ducts	IM.7.0.5.1		Pressure Relief Device Selection
	IM.2.3.3	Cellular Plastic Insulation for Mechanical Piping Systems	IM.7.0.5.2		Pressure Relief Device - Inspection, Test and Maintenance
	IM.2.4.1	Insulation of Heated Tanks	IM.7.1.0.1		Boiler and Fired Pressure Vessel Loss Prevention Management
	IM.2.5.1	Fireproofing for Oil and Chemical Properties	IM.7.1.0.2		Boiler and Fired Pressure Vessel Loss Prevention Inspection
	IM.2.9.1	Dams and Other Hydraulic Structures	IM.7.1.0.3		Boiler Fundamentals
IM.3	--	MISCELLANEOUS UTILITIES	IM.7.1.0.4		Boiler Construction, Repair and Alteration
	IM.3.1.1	Prevention of Explosions and Fire in Compressed Air Vessels and Systems	IM.7.1.0.5		Boiler Maintenance and Operation
IM.4	--	FIRED EQUIPMENT COMBUSTION SAFEGUARDS	IM.7.1.0.6		Low Water Protection for Boilers
	IM.4.0.1	Programmable Controllers for Use with Burner Management Systems	IM.7.1.1.0		Water Tube Boiler Characteristics and Terminology
	IM.4.0.1.1	Glossary of Burner Management Terms	IM.7.2.0.5		Sight Glasses and Gage Glasses
	IM.4.0.2	Non-Site Review Program for Ovens, Boilers, Furnaces, and Related Equipment	IM.8	--	MATERIALS HAZARDS
	IM.4.0.3	Procedures for Leak Testing Safety Shut-Off Valves	IM.8.0.1.1		Oil and Chemical Properties - Loss Potential Estimation Guide
	IM.4.1.0	Introduction to Boiler Codes and Standards	IM.8.2.0.1		Outdoor Storage of Liquefied Petroleum Gases
	IM.4.1.1	Single Burner Boiler-Furnaces NFPA 85A-1987	IM.9	--	HAZARDOUS OPERATIONS
	IM.4.1.2	Multiple Burner Boilers-Furnaces NFPA 85B and NFPA 85D	IM.9.2.3.2		Traveling Spray Booth Protection
	IM.4.1.3	Controls and Safety Devices for Automatically Fired Boilers ANSI/ASME CSD-1	IM.9.2.4		Fire Hazards of Hydraulic Systems
	IM.4.2.1	Heat Treat Furnaces with Internal Quench Tanks	IM.9.2.5.1		Solvent Vapor Degreasing
	IM.4.2.2	Heat Treat Furnaces - Synthetic Atmospheres	IM.9.2.7		Hazards of Industrial and Commercial Cooking Appliances
	IM.4.3.1	Space Heaters	IM.9.3.1		Belt Conveyors
	IM.4.3.3	Thermal De-Burring Machines	IM.9.3.2.1		Electrostatic Precipitators
IM.5	--	ELECTRICAL	IM.9.5.1		Heating in Plastic and Plastic Lined Tanks
	IM.5.0.1	Explanation of Electrical Terms	IM.9.6.1.1		Direct Chlorination Hazards
	IM.5.2	Lightning and Surge Protection	IM.9.6.2.1		Distillation of Flammable or Combustible Liquids
			IM.9.6.2.2		Solvent Recovery with Activated Carbon

HYDROREFINING PROCESS UNITS



Loss causes and guidelines
for loss prevention

Graphs Speed Spread Footing Design

When designing square or octagonal footings, these graphs will cut the calculation time to a minimum. No trial and error sizing is required

F. B. van Hamme, Chief Structural Engineer,
Fluor-Schuytlot N. V., Haarlem, Holland*

TRIAL-AND-ERROR SIZING of spread footings can be supplanted by a better method. A graph can be used to size footings with a minimum of calculations. Use Figure 1. to determine the size of square footings, Figure 2 for octagonal footings.

Stability and soil bearing are the main considerations in designing spread footings. Equipment must be supported by the foundation so it will not be overturned by maximum forces acting upon it. The load on the soil

below the foundation must not exceed the maximum allowable soil pressure. The most severe stability conditions are realized when the vertical load is minimum and the lateral loads (winds or earthquake) are maximum. Severest soil bearing conditions are realized when the vertical and lateral loads are maximum.

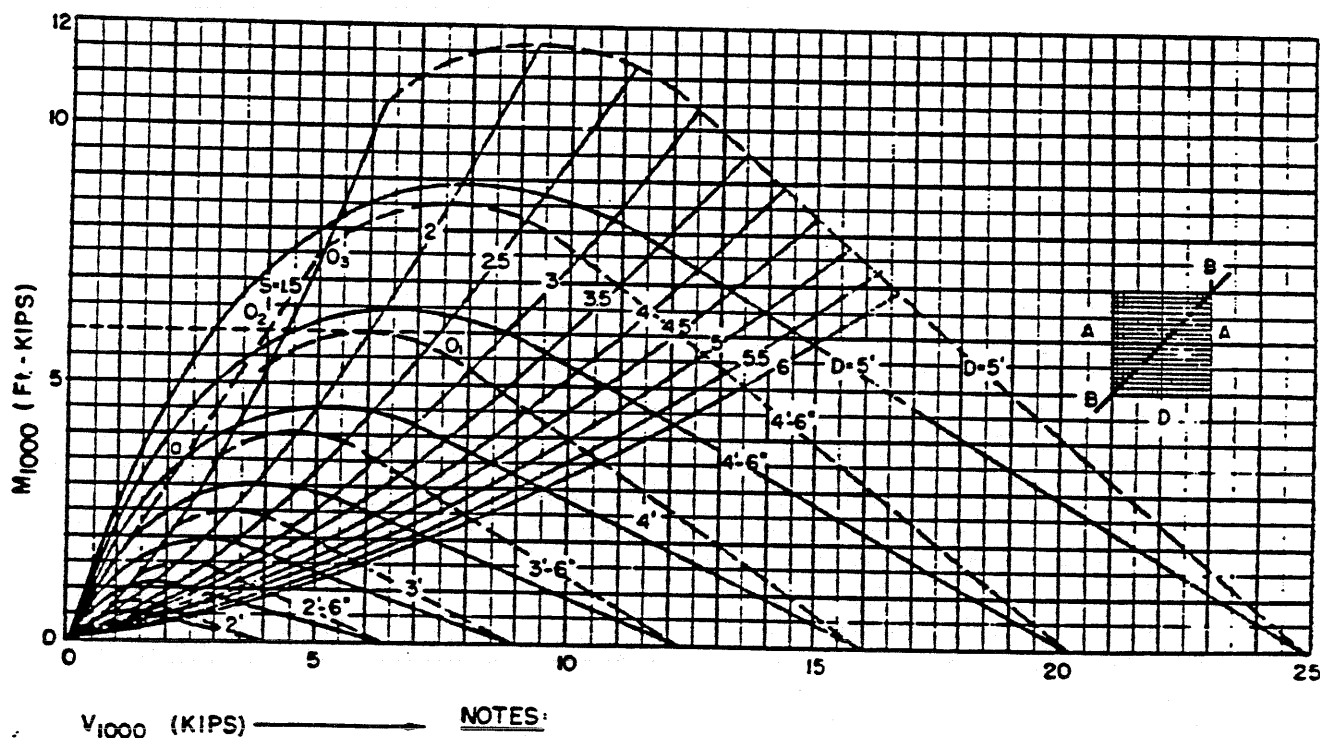
Both graphs were scheduled for an allowable soil pressure of 1000 lbs. per sq. ft. However, these graphs can be used for any allowable soil pressure if the vertical load (including the weight of the footing and backfill) and the overturning moment about the base of the footing are divided by the soil pressure coefficient N .

$$N = \frac{\text{allowable soil pressure in lbs. per sq. ft.}}{1000 \text{ lbs. per sq. ft.}}$$

$$V_{1000} = \frac{\text{total vertical load in kips}}{N}$$

$$M_{1000} = \frac{\text{overturning moment in ft.-kips}}{N}$$

Square Footings. When the footing can turn on the A-A-axis only (Figure 1) (pipe-rack footings, for ex-



NOTES:

1. Dotted D-lines are to be used for stability conditions and the solid D-lines for soil bearing conditions when footing can turn as well on A-A-axis as B-B
2. When footing can turn on A-A-axis only the dotted D-lines are to be used for stability as well as soil bearing conditions.

FIGURE 1—Use this graph to design square footings.

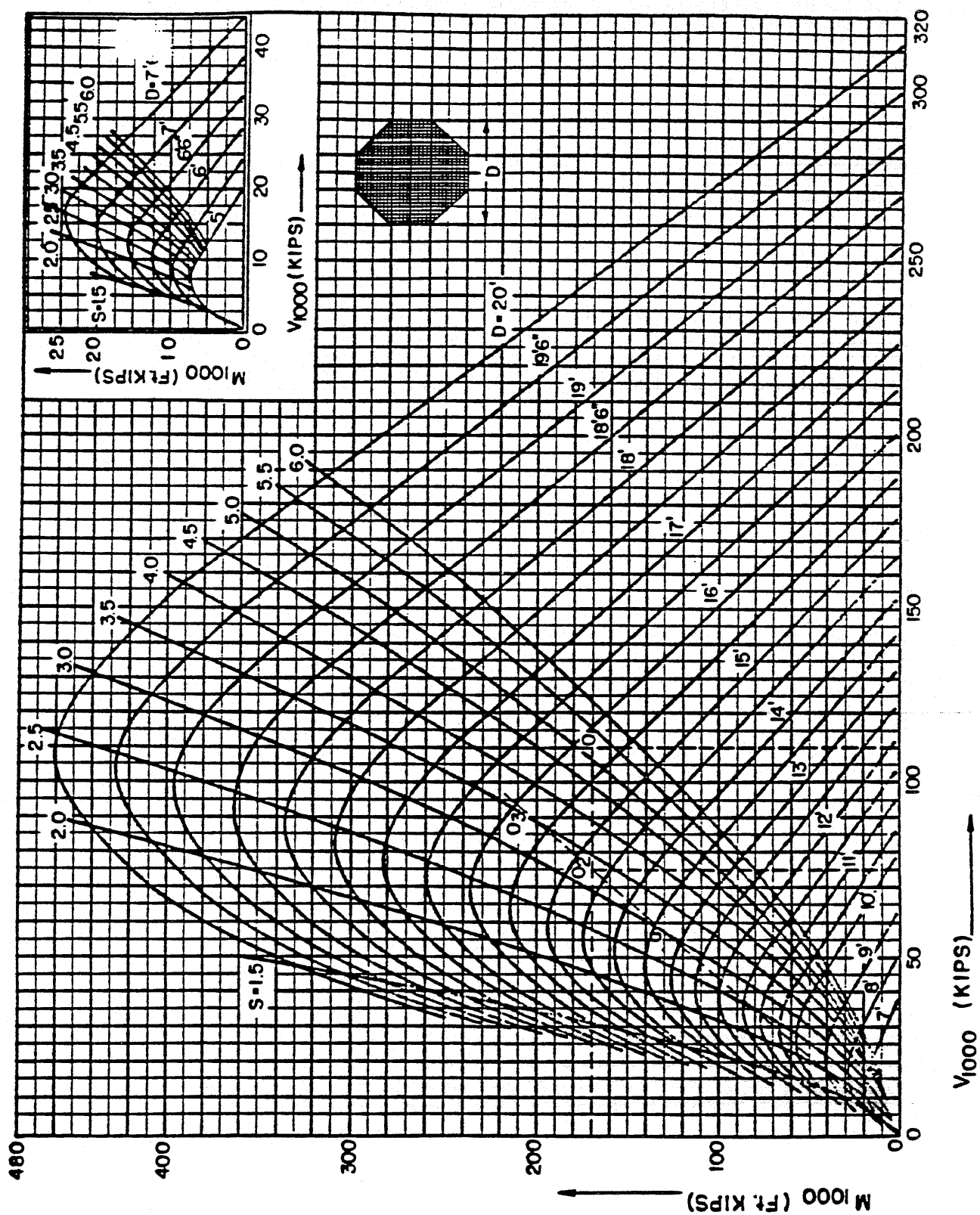


FIGURE 2—Use this graph to design octagonal footings.

ample), the dotted D-lines are to be used for determining the size of the footing. When the footing can turn on the B-B-axis as well as on the A-A-axis, the dotted D-lines are to be used when stability governs. But when soil pressure governs, the solid D-lines are to be used. The stability is smaller when the footing turns on the A-A-axis than when it turns on the B-B-axis. On the other hand, the soil pressure is greater when the footing turns on the B-B-axis.

Octagonal Footings. In Figure 2, the octagon was replaced by the inscribed circle of the octagon. The difference in soil pressure between an octagonal footing and a circular footing under the same loading conditions is not important.

When $\nabla 1000$ and $\nabla 1000$ are calculated, the point corresponding with these values can be found in either Figure 1 or 2.

If this point is at the right of the S-line (which gives the chosen value of the stability ratio), the soil pressure governs. The next greater footing given by the D-line (in Figure 1, the dotted D-line for square footings turning on A-A-axis only, and the solid D-line for square footings turning on A-A-axis as well as on B-B-axis) just above the point will take the loads without exceeding the allowable soil pressure.

If the point is at the left side of the S-line, the size of the footing can be determined as follows:

Square footing turning on the A-A-axis only. The footing given by the dotted D-line just above the point will be correct for soil bearing conditions, but this footing will not fulfill the stability conditions. Draw a straight line through the origin and through the point (mentioned above) to the intersection with the S-line which gives the chosen stability ratio. The next greater footing given by the dotted D-line just above the intersection will fulfill stability as well as soil bearing conditions.

Square footing turning on the A-A-axis or on the B-B-axis. The footing given by the solid D-line just above the point is correct for soil bearing conditions. To find the footing which fulfills stability conditions, draw a straight line through the origin and through the point to the intersection with the S-line which gives the chosen value of the stability ratio. The footing given by the dotted D-line just above the intersection is correct for stability conditions. The greater footing found from both cases will be correct for stability as well as for soil bearing conditions.

Octagonal footing. This problem can be handled in the same manner as a square footing turning on an A-A-axis only (see above) using Figure 2.

Footing Weight. Before starting calculations, the weight of the footing must be estimated. (To simplify this estimate, the weights per inch depth of square—and octagonal-shaped pedestals or pads are given in Table 1). The weight of reinforced concrete is taken as 150 lbs. per cu. ft. The size of spread footing can now be found by the following procedure:

1. Fix the size of the pedestal in ft. and choose the shape.
2. Fix the depth of the foundation below grade and the level above grade. This gives the total height of the foundation.
3. Estimate pad thickness in inches.

TABLE 1—Weights of Pedestals and Pads

SQUARE SHAPED		OCTAGONAL SHAPED	
Width (ft.)	Weight (kips per 1" of Height)	Width (ft.)	Weight (kips per 1" of Height)
2.0	0.050	6.0	0.371
2.5	0.078	7.0	0.508
3.0	0.112	8.0	0.661
3.5	0.153	9.0	0.839
4.0	0.200	10.0	1.036
4.5	0.254	11.0	1.250
5.0	0.313	12.0	1.490
		13.0	1.750
		14.0	2.020
		15.0	2.300
		16.0	2.650
		17.0	2.940
		18.0	3.330
		19.0	3.740
		20.0	4.140

(Intermediate values are obtained by straight interpolation).

4. Estimate pedestal height in inches (which is the total height of foundation minus the estimated thickness of pad).
5. Using Table 1, calculate the weight of the pedestal in kips.
6. Estimate the shape and size of the pad in ft.
7. Using Table 1, calculate the weight of the pad in kips.
8. Estimate backfill weight in kips.
9. Add 5, 7 and 8 for an estimated total weight of the foundation.
10. Determine the size of pad with Figure 1 or with Figure 2, taking into account the weight of equipment and the overturning moment about the base of the footing. Divide the vertical load and the overturning moment by the soil pressure coefficient N.

Example 1. Size a spread footing for a tower, 54 ft. high, skirt 5 ft. in diameter, empty weight 37 kips, operating weight 107 kips, test weight 187 kips. The lateral load due to wind is 10.5 kips. The frost line is 3 ft. below grade. The allowable soil pressure at 4 ft. below grade is 2000 lbs. per sq. ft. The weight of soil is 100 lbs. per cu. ft. The minimum stability ratio is 3.5 For tower under test condition, the wind load is not to be taken into account. The solution:

- The pedestal will be 6 ft. wide, since allowance must be made for anchor bolts, etc. The shape will be octagonal.
- The base of the foundation will be 4 ft. below grade (1 ft. below frost line). The level above grade is 1 ft. so that the total height of the foundation is 5 ft.
- The pad thickness will be assumed to be 2 ft. = 24 inches.
- The height of the pedestal is $5 - 2 = 3$ ft. = 36 inches.
- The weight of the pedestal is $36 \times 0.371 = 13$ kips (see table).
- The shape of the pad will be octagonal with an assumed size of 16 ft.
- The weight of the pad is $24 \times 2.65 = 63.6$ kips (see table).
- The weight of backfill is $0.8284 \times (16^2 - 6^2) \times 2 \times 0.1 = 36.4$ kips.

GRAPHS SPEED SPREAD FOOTING DESIGN . . .

- Total weight of the foundation is $13 + 63.6 + 36.4 = 113$ kips.
- The overturning moment about base of footing is $10.5 \times ((54 \div 2) + 5) = 340$ ft.-kips.

Empty weight of tower plus foundation is $37 + 113 = 150$ kips. Operating weight of tower plus foundation is $107 + 113 = 300$ kips. Test weight of tower plus foundation is $187 + 113 = 250$ kips. The soil pressure coefficient is $2000 \div 1000 = 2$.

$$\begin{aligned} \text{M}_{1000} &= 340 \div 2 = 170 \text{ ft.-kips;} \\ \text{V}_{1000} &= 150 \div 2 = 75 \text{ kips (empty).} \end{aligned}$$

$$\begin{aligned} \text{M}_{1000} &= 170 \text{ ft.-kips;} \\ \text{V}_{1000} &= 220 \div 2 = 110 \text{ kips (operating).} \end{aligned}$$

$$\begin{aligned} \text{M}_{1000} &= 0 ; \\ \text{V}_{1000} &= 150 \text{ kips (test).} \end{aligned}$$

Draw a line in Figure 2 through $\text{M}_{1000} = 170$ ft.-kips and a line through $\text{V}_{1000} = 110$ kips and find point O_1 . This point is at the right side of the $S = 3.5$ line, so the stability is all right. Point O_1 is between $D = 15' - 6''$ line and the $D = 16$ ft. line. The pad should be 16 ft. for operating conditions. Draw a line through $\text{V}_{1000} = 75$ kips and find point O_2 . This point is at the left side of the $S = 3.5$ line, so when the tower is empty, the stability condition governs. Draw the straight line "a" through the origin and point O_2 and find point O_3 , which is the intersection of line "a" and the $S = 3.5$ line. Choose the next greater pad size $D = 16'$. For test conditions, the pad should be 14 ft. wide. A 16 ft. wide octagon will be correct for soil bearing as well as for stability conditions.

Example 2. Size the footing for a pipe rack. The minimum vertical load is 8 kips; the maximum vertical load is 24 kips; the overturning moment at the top of the foundation is 9 ft.-kips; the lateral load at the top of the foundation is 3 kips. The anchor bolts are 5 inches, center to center. Top of the foundation is 1 ft. above grade. The frost line is 3 ft. below grade. The allowable soil pressure at 4 ft. below grade is 4000 lbs. per sq. ft. The

weight of soil is 100 lbs. per cu. ft. The minimum stability ratio is 1.5. The footing can turn on an A-A-axis only.

The solution:

- The pier will be 1 ft. wide and square shaped.
- The base of the foundation will be 4 ft. below grade (1 ft. below the frost line).
- The total height of the foundation will be 5 ft.
- The pad thickness is assumed to be 8 inches.
- The height of the pier is 5 ft. minus 8 inches = 52 inches.
- Weight of the pier is $52 \times 0.050 \div 4 = 0.65$ kips.
- The pad will be square shaped, and is assumed to be 4.5 ft. wide.
- Weight of the pad is $8 \times 0.254 = 2.032$ kips.
- Weight of backfill is $(4.5^2 - 1^2) \times (4 \text{ ft.} - 8'') \times 0.1 = 5.075$ kips.
- Total weight of the foundation is $0.65 + 2.032 + 5.075 = 8$ kips.
- The overturning moment about the base of the footing is $9.0 + 3 \times 5 = 24$ ft.-kips.
- Minimum vertical load + foundation is $8 + 8 = 16$ kips. Maximum load + foundation is $24 + 8 = 32$ kips. $N = 4000 \div 1000 = 4$.
- $\text{M}_{1000} = 24 \div 4 = 6$ ft.-kips.
- $\text{V}_{1000} = 16 \div 4 = 4$ kips (minimum).
- $\text{V}_{1000} = 32 \div 4 = 8$ kips (maximum).

As in example 1, point O_1 in Figure 1 can be found for 6 ft.-kips and 8 kips. This point is at the right side of the $S = 1.5$ line. The pad size should be $4' - 6''$ (use dotted D-lines). For 6 ft.-kips and 4 kips, point O_2 can be found. This point is at the left side of the $S = 1.5$ line and between the dotted D-lines, $D = 4'$ and $D = 4' - 6''$. Draw a straight line "a" to the intersection with the $S = 1.5$ line (point O_3). For stability, the pad should be 4.5 ft. wide. A 4.5 ft. wide pad will be correct.

Example 3. The footing for a pipe support is square shaped and 5 ft. wide. The total load + foundation is 16 kips minimum and 32 kips maximum. The overturning moment about the base of the footing is 24 ft.-kips. The soil pressure coefficient $N = 4$. $\text{M}_{1000} = 6$ ft.-kips; $\text{V}_{1000} = 4$ kips (minimum); $\text{V}_{1000} = 8$ kips (maximum). This footing can turn on an A-A-axis, as well as on a B-B-axis. Minimum stability ratio is 1.5. Check this footing. The solution:

Find point O_2 in Figure 1 for 6 ft.-kips and 4 kips. This point is between the solid D-lines $D = 4' - 6''$ and $D = 5$ ft., so, for soil bearing conditions, the footing must be 5 ft. wide. Point O_2 is at the left side of the $S = 1.5$ line. Draw line "a" and find point O_3 . For stability, the footing can be $4' - 6''$ wide (use dotted D-lines). Find O_1 for 6 ft.-kips and 8 kips. For soil bearing and stability conditions, the footing can be $4' - 6''$ wide in this case (use solid D-line). Conclusion: the designed 5 ft. wide square footing is correct. ##

About the Author

F. B. van Hamme is chief structural engineer for Fluor-Schuytvlot N.V., Haarlem, Holland (a subsidiary of the Fluor Corporation, Ltd.). He holds a civil engineer's degree from the Technical University at Delft, Holland. Following graduation, he enlisted in the Dutch army for two years. At the end of the tour of duty in 1957, he left the army as a lieutenant of the Royal Engineers. In 1958, he joined Schuytvlot as a technical assistant, and was later promoted to principal design engineer and then to his present position.



van Hamme

How to Design Yard Piping

Use this method to quickly and systematically design yard piping and save piping costs

Robert Kern
New York City

MINIMUM COST YARD PIPING is a direct result of precise engineering design. This method shows how to save piping dollars and gives a step-by-step evaluation procedure. Important sections are:

- How to evaluate flow diagrams and other data
- How to analyze yard piping design
- How to economize yard piping.

Examples of yard piping design highlight all these factors and show details of the best yard piping at minimum cost.

The main arterial system of a plant is in the yard piping. It is here where long process lines are located interconnecting distant equipment, and lines entering and leaving the unit. Also, utility headers are located in the yard supplying steam, air, gas and water to process equipment. Here are located all relief and blow down headers. Often instrument lines and electrical supply conduit are also supported on the yard steel.

Information Required. Data essential for yard piping design are:

Specifications. Usually, only a few items included in the job specifications affect yard piping design. Such items are: minimum headroom over roads, under overhead pipe lines, or steel beams; access, headroom and handling requirements to equipment arranged under the yard; ladder, catwalk and platform requirements to valves, relief valves, orifice flanges and instruments located in the yard; details affecting piping and structures, operating and safety requirements.

Project design data and site maps give required or existing conditions inside and outside the unit limits. These are: required location of cooling water mains, below or above grade; required location of furnaces,

control and switch house; location of utility and process lines entering and leaving unit limits; main pipe runs outside the unit; location of storage tanks relative to process units; also blending, loading, filling station, and cooling tower location; and site grade level variations.

Plot Plan. The relationship between plant units, equipment, buildings and yard piping is shown on the plot plan. Position of incoming and outgoing lines can be seen. Major structures, location of buildings and all equipment is shown. Roads crossing the yard or located under the yard steel are indicated.

Flow Diagrams. Process flow diagrams show essential process lines interconnecting process equipment. Mechanical flow diagrams (developed from process flow diagrams) indicate the complete flow systems necessary for plant operation; also, pipe sizes, valving, manifolds, all piping details and instrumentation. Utility flow diagrams show the number and size of water, steam, condensate, gas, air, etc. headers, also all equipment supplied by these headers with necessary valving and piping details.

Figure 1 shows a plot plan and process flow diagram. With this two drawings an assessment can be made regarding which portions of process lines will be located in the yard and which lines will interconnect directly nozzles on adjacent or nearby process equipment. Heavy lines on the flow diagram indicate piping assumed to be located in the yard. These lines are also shown on the plot plan to give a visual idea of yard space requirement.

A mechanical flow diagram is similarly evaluated. Greater number of lines can be drawn on the plot which gives a more accurate estimate of required yard width.

In addition to process lines, utility flow diagrams will show individual service lines and utility headers. Utility mains generally run the whole length of the yard. These

Flow diagram and plot plan showing process lines in the yard

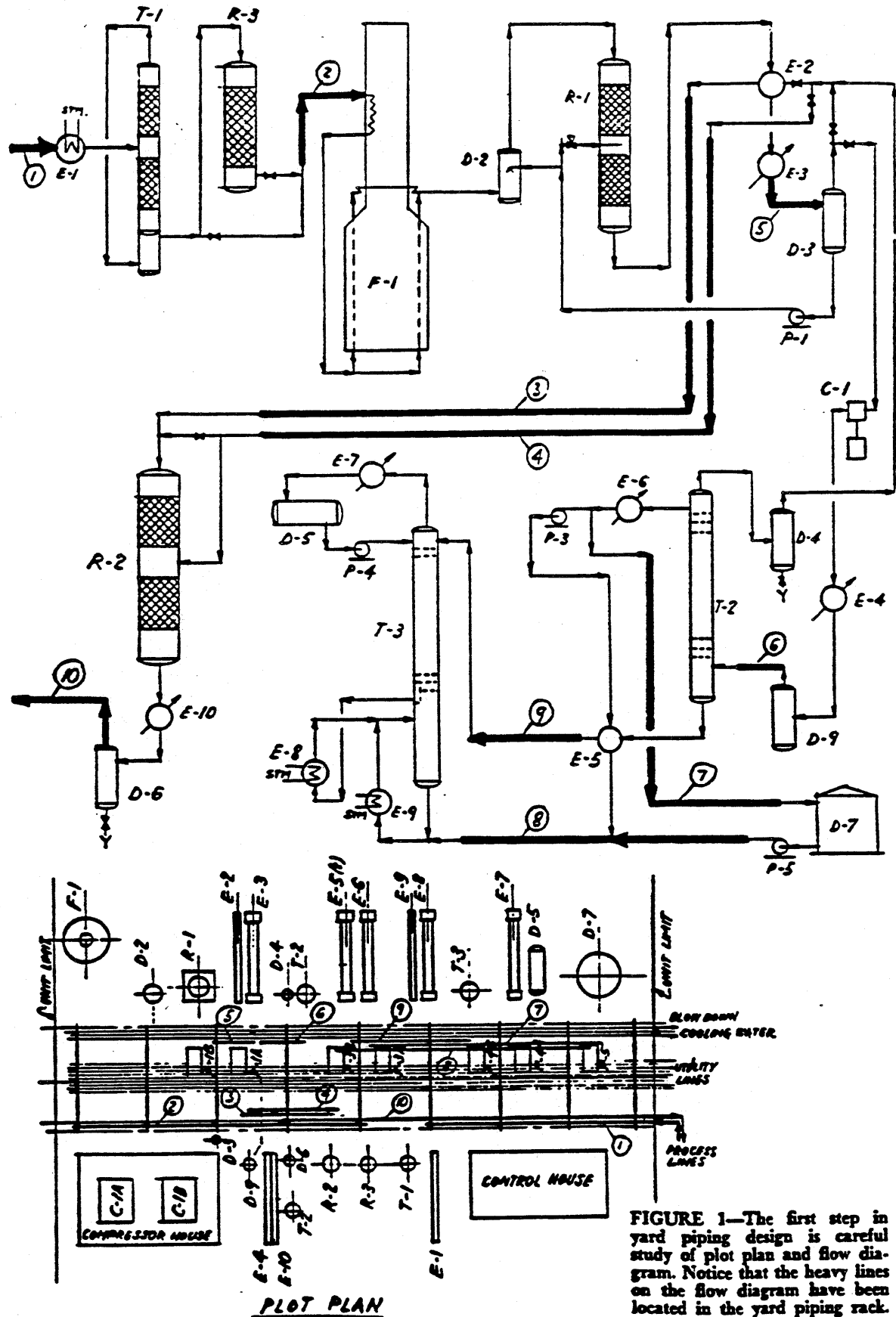


FIGURE 1—The first step in yard piping design is careful study of plot plan and flow diagram. Notice that the heavy lines on the flow diagram have been located in the yard piping rack.