5 Site and Plant Layout

A major property insurance broker cites 16 petrochemical and chemical losses of greater than $150,000,000 during the period of 1970 to 1999. Of these, 7 were VCE incidents, 6 were other types of explosions, 2 were hurricane related, and 1 was earthquake related. One of the lessons learned is to consider facility siting issues for both inside and outside the plant boundary. (Marsh, 2001)

The previous chapters have described what to consider and how to go about selecting a site for a new project or expanding an existing site. Now that the site is selected, the challenge is to make the best use of the site based on process needs, capital costs, life cycle costs, safety, health, security, and environmental considerations.

This chapter provides a method for site layout. This approach is equally applicable for new projects or modifications to existing facilities. The steps are shown below.

1. First, consider the site environment and its surroundings.
2. Next, arrange the major blocks of process, utilities, off-sites, and buildings. By laying out these blocks and providing spacing between them, an overall site layout will evolve.
3. Chapter 6 will cover the details of layout and spacing within the specific plants and units.

Typical separation distances between various elements are cited throughout this chapter and are provided in the tables in Appendix A. These distances are based on historical and current data from refining, petrochemical, chemical, and insurance sectors. The data were developed based on experience and engineering judgment (not always on calculations) and were updated based on incident learnings. Such numbers are frequently used in industry and are included in industry codes and practices. The separation distances cited are based on potential fire consequences for hydrocarbons and chemicals. Highly reactive and exotic chemicals, such as metal alkyls or hydrazine, may require greater spacing or protection. Explosions and toxic concerns will also require further analysis.

The separation distances in Appendix A and Chapters 5 and 6 are typical distances based on a review of the above data and were not arrived at by a statistical analysis of these data. Frequently the data offered a range of numbers from which a representative value was chosen.

These typical separation distances assume a minimal level of site fire protection such as fire hydrants, manual firefighting capabilities, and adequate drainage to prevent flooding during a major firefighting effort. Distances may be reduced or increased based on risk analysis of site-specific conditions or when additional fire protection, safety measures, or other layers of protection are implemented. Additional guidance may be found in the CCPS *Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities* (CCPS, 2003, no.29).

As stated in previous chapters, applicable codes, standards, and local regulations should be researched. If they contain more stringent spacing requirements than those quoted in these Guidelines, then they take precedence.

5.1. General

As F. P. Lees points out, the aim is to eliminate the hazard rather than devise measures to control it (Lees, 1996). Approaches to the design of inherently safer processes have been grouped into four major strategies by IChemE, IPSG, and Kletz (CCPS 1996, no. 23).

Minimize Use smaller quantities of hazardous substances

Substitute Replace a material with a less hazardous substance

Moderate Use less hazardous conditions, a less hazardous form of a material, or facilities that minimize the impact of a release of hazardous material or energy

Simplify Design facilities which eliminate unnecessary complexity and make operating errors less likely.

The safety, health, and environmental objectives of the layout are to minimize the potential for injuries, overall property and environmental damage, and related business interruption. Take measures during the site lay out to both minimize the incident size and impact. The magnitude of a potential incident may be reduced by:

- Minimizing the potential quantity of hazardous materials that can be released
  When laying out a plant, quantities can be reduced by siting more, smaller tanks, reducing and integrating storage and day tanks, or minimizing inventories in pipeways.
- Containing the release
  When laying out a plant, providing containment by using dikes, utilizing changes in elevation, and installing remote collection tanks and lined ponds.
- Minimizing inventory in piping and equipment
  When laying out a plant, locate units and equipment that interconnect to minimize running piping lengths and piping traversing through unrelated units.
- Appropriate drainage and grading
  When laying out a site, locate large inventories of hazardous liquids to drain away from process units and occupied structures. Design drainage to minimize water treatment needs and collection of liquids under vessels.

The impact of a potential incident may also be addressed by the following, among others:

- Providing adequate separation distances
- Segregating different risks
- Minimizing potential for and impact of explosion
- Minimizing potential for and exposure to toxic release
- Maintaining adequate spacing for potential firefighting
- Minimizing exposure to fire radiation
- Considering the prevailing wind direction in site layout
- Considering potential future expansions during site layout

Distance usually mitigates the consequences of loss of containment incidents; however, the importance of distance depends on the nature of the hazard.

For fires, the effect of distance is to reduce the intensity of radiation from the equipment on fire or the edge of the pool fire (CCPS 1993, no.14).

For explosions, especially vapor cloud explosions, the effect of distance is to reduce the intensity of blast waves. Because explosions are sudden and violent releases of energy, effects are immediate and allow no time for evacuation or shelter.

For toxic releases, distance reduces gas concentration in the atmosphere. Even though toxic clouds can travel greater distances than blast waves or thermal radiation, the time lag between release and potential public exposure may, in some cases, be utilized for warning people in the downwind direction to shelter-in-place or to evacuate.

5.2. The Site

Chapter 4 discussed the site selection and layout. Further details on the site are now required to lay out the site and plant. The objective of considering the site environment is to reduce the effects of controllable factors such as liquid spills as well as uncontrollable factors such as exposure to natural hazards (floods, winds, earthquake, snow load) and site slope. Site constraints may include topographical and geological features, natural hazards, limited exit routes, adjacent activities, existing facilities, and access to infrastructure.

5.2.1. Geotechnical Studies

Investigate the soil properties to identify the need for major structure and equipment foundation design. Local experience regarding soil load bearing, settlement, and need for piling may be helpful in anticipating any potential problems. If substantial variances in soil load bearing exist, locate large pieces of equipment and tanks where piling needs may be reduced or eliminated. This will reduce both cost of installation and risk of potential future problems.

Consider earthquakes in site layout. Utilize seismic data to determine the best site locations for equipment, piping, tankage, and structures.

5.2.2. Topography

Detailed topographical maps will be required for site layout. Try to utilize maps that depict streams, ponds, marshes, steep slopes, buildings, structures, terrain, vegetation, rock formations, elevation changes, current and planned right-of-ways. The maps should include any underground obstructions on the site such as underground pipelines, old foundations, burial sites, and archeological sites. When planning construction activities, identify locations for potential temporary storage of rock, sand, or gravel, and disposal areas for excavated earth, vegetation, and rock.

Relative elevation of site areas is an important consideration in site layout. Whenever practical, locate open flames (process units with heaters, direct fired utility equipment) at a higher elevation than bulk quantities of flammables (tanks and storage); this minimizes the potential for ignition of vapor releases or liquid spills as a spill migrates downhill. Where it is not feasible to locate storage tanks at elevations lower than process areas, increased protection measures may be required to offset the increased potential for ignition. These measures may include: diking, high-capacity drainage systems, vapor detection, increased fire protection, shutdown systems, and other safety systems. Similar precautions for spills and vapor releases are needed when siting units that will contain extensive quantities of toxic materials.

When siting potential release sources, consider topographical features such as hills or valleys that might affect dispersion of potential accidental releases or air pollutants. This can include items such as flammables, inert gases, toxics, and their release points such as stacks, elevated flares, or ground flares.

Example

A chemical plant was built on the side of a hill which rose 200 feet (61 m) from the main roadway on the north end of the plant to the south end of the property line. The initial layout of the plant located the flare west of the process areas at a slightly lower elevation. Flare plume modeling indicated that emergency releases from the flare can result in high H_2S and SO_2 levels in the process areas, surrounding roadways, and industrial neighbors. In addition, the heat intensity exposure to the area west of the property line in the event of a major power outage exceeds API RP 521 recommended maximum exposure levels.

It was decided to locate the flare at the highest elevation at the south end of the site. The cost was significant. However, flare releases no longer posed a safety or health concern. The new flare location did increase the possibility that embers from the flare could travel down hill toward the plant. However, when compared with the risk posed by H_2S and SO_2, it was judged that the higher elevation was appropriate. In addition, the elevation allowed liquids in the flare header to drain back to the process area minimizing the cost of liquid recovery and reducing the off-site concerns with flare radiant heat.

Lesson

Flares are unique pieces of equipment and require evaluation of thermal and vapor dispersion consequences to aid in their safe siting.

5.2.3. Groundwater, Grading, and Drainage

Acquire groundwater levels and area flooding history to ascertain whether protective dikes or spillways are necessary. Do not site utilities or emergency response structures in areas prone to flooding. Collect a sample of groundwater at the site or from a nearby location if necessary, and test to determine the properties of the water. Properties such as high sulfates in groundwater can cause underground deterioration of foundations unless special concrete is used.

Drainage system requirements and water treating system designs will depend on rainwater, natural streams, site-generated releases, and firewater usage needs. Consider grading to minimize water volumes that require treatment and allowing plot space for containment and treatment facilities. Consider the transition of the grading from original to final design as it impacts the construction phase of the project. Install temporary drainage or delay the construction of valuable facilities until grading and drainage is in place to avoid flooding concerns. Additional real estate or containment equipment may be required for these temporary facilities.

Additionally, safety considerations such as preventing flammables and toxics from entering the surface water drainage may be built into the design. Provision of a containment basin for firewater runoff may be included. Keep in mind that surface drainage requirements might be altered as a result of the site preparation work.

5.2.4. Weather

In addition to rainfall, other weather considerations include the prevailing wind direction and speed. In many locations there is not a prevailing wind direction and other considerations will influence the site layout. The wind may blow in a number of directions such as onshore during the day and off-shore at night or from the west in the winter and from the south in the summer. The combination of all these wind directions, the speed that the wind blows, and the amount of time that each direction/speed combination occurs are combined into a wind rose. This wind rose can be used to locate process units such that the probability that potential releases will be carried toward ignition sources or a potential toxic release toward populated areas such as office buildings, shop areas, or existing neighboring community areas is reduced. Prevailing wind direction and speed data are particularly relevant to the siting of stacks, furnaces, flares, cooling towers, and toxic chemical storage and processing.

Severe weather conditions or natural phenomena that may warrant consideration during siting and layout include flooding and hurricanes or typhoon (wind-load and flooding concerns).

5.2.5. Neighbors

The surroundings may necessitate requirements restricting the levels of noise, light, and pollutants that may be emitted from the site. These requirements are often dictated at a local level. Providing separation distances from equipment of concern including flares and stacks will provide opportunity for dispersion and will aid in meeting these fence-line requirements.

Also, the areas that surround the potential site boundary are not within the control of the company preparing the site. An open field is likely to be used for housing once a company develops the plant site. Consider existing or potential future nearby population in site layout. As stated previously, one means to minimize the impact of a potential release is to provide separation distance between the release source and the population.

The areas surrounding the site may currently, or in the future, contain facilities that may pose a fire, explosion, or toxic risk on the site. In laying out the site, provide adequate distance between neighboring hazards and sensitive site equipment and structures.

The spacing to a property boundary that is adjacent to a populated area or an area that could become populated is of greater importance than the spacing to a property boundary adjacent to a minimally populated area. This spacing can serve to control the population level, and consequently the risk, adjacent to the site. Property boundaries are identified in three categories in Appendix A, Table B. These are:

- Property boundary or adjacent industry
- Public access ways
- Off-site populations

A “property boundary or adjacent industry” is the dividing line between the site property and the adjacent property where the use of that adjacent property may be industrial or may not be known. A “public access way” may border the site. It is not owned by the site and serves as a transportation or utility corridor for roads, parks, rivers, railroads, and telephone right-of-ways. “Off-site populations” are not on the site but immediately adjacent to it and have known populations. Examples of populated areas to consider include the following:

- Residential areas
- Offices
- Town centers, shopping areas
- Schools, hospitals, day care centers
- Nearby industrial sites and transportation centers
- Public recreational areas

5.2.6. *Emergency Response Support*

Mutual aid from neighboring industrial facilities and local fire fighting, ambulance, and rescue support may be available in the surrounding community. If their capabilities are judged to be acceptable, then consider this support in the site layout. This might include locating access gates convenient for their response, providing plot space for communication needs, mustering area for emergency vehicles, or locating a firewater tie-in point at a convenient location.

Ensure access for emergency response is available from at least two directions at all site locations. Provide at least two entrances to the site for emergency vehicles.

Provide space for on-site emergency response vehicles, supplies, medical facilities, and triage area(s) and locate this area apart from process units, accessible to outside emergency resources, and in a location that is not subject to damage by the initial emergency event.

Example

A plant being built within an existing industrial complex provided mutual aid for firefighting equipment and limited firefighting personnel. During the early construction stages of the new plant, an emergency response exercise was conducted by the new plant owner to test the response efficiency of the mutual aid system to an incident in the new plant. Because of the road system around the complex and the distance to the new plant from the mutual aid site, the response time exceeded 20 minutes. It quickly became obvious that the mutual aid facility would not always be available to meet the needs of the new plant. Fire trucks were purchased and firefighting training was conducted in the new plant prior to plant start-up.

Lesson

Research and test the availability and reliability of the mutual aid emergency response. If judged insufficient, provide on-site support facilities.

5.3. Block Layout Methodology

Now that the site, its surroundings, and the infrastructure needs are established, the process of laying out the plant or plants on the site may begin. One method of laying out the site uses a block layout methodology. This is done by first grouping large blocks of like characteristics. By laying out these blocks, the basic plot layout may be assembled. Typical blocks are process areas, tankage, utilities, offsites, office buildings, and administration buildings. An example of using this concept was cited in Section 3.3 when estimating plot space requirements. It is repeated below to illustrate this block concept.

Taking this approach allows segregation of different risk types into separate blocks. Blocks of similar risk types (such as high risk process units into a process block) may be located together and separated from other types of risks (such as buildings or tankage). This approach is also efficient because it focuses on the large areas first. Once the large blocks are defined, the details of the intra-unit spacing within each block may be addressed. This minimizes reworking detailed spacing with each revision of the overall plot layout.

In Figure 5-1, the offices were grouped into one block. The parking, maintenance, and warehouse were grouped into a second block. The process areas pose a greater risk and were grouped together into a third block.

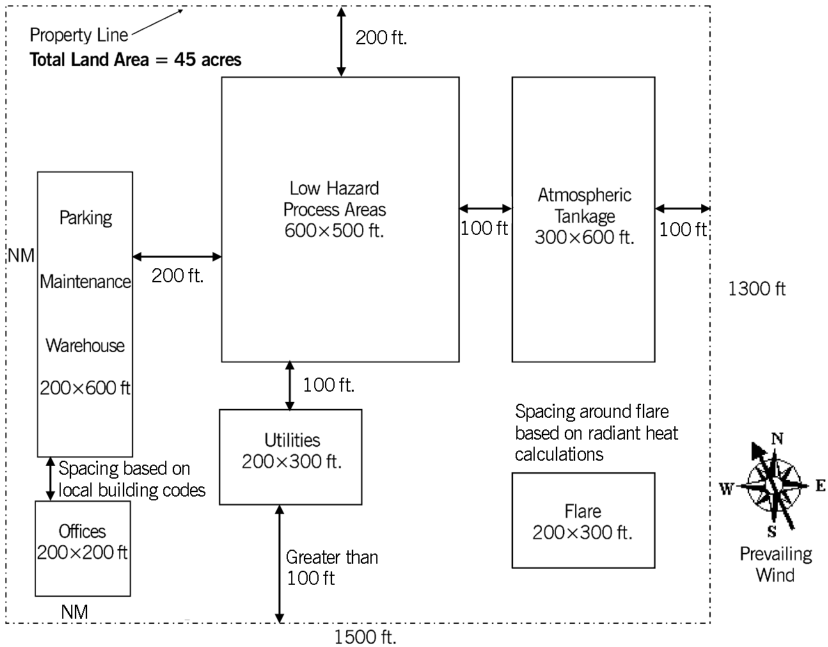

Figure 5-1. *Block Layout Concept (1 ft equals .305 m; 1 acre equals 4046.8 m^2)*

Tankage also poses a different level of risk than offices or process areas and was grouped into a fourth block. The utilities were grouped separately. And, lastly, the flare comprises its own group. The typical separation distances between these areas were taken from Appendix A as noted in Table 5-1. The initial site layout is presented in Figure 5-1.

Consider future site modifications during the original layout. "Holding" the real estate for future use may provide cost-effective, inherently safer options when the future expansions do occur.

5.4. Spacing Tables

Separation distances are typically determined through one of two methods: either utilizing spacing tables or calculating distances required to prevent fire spread and laying out the site based on these distances (CCPS, 1993, no. 14). Spacing for explosions and toxics hazards must be based on calculations. Historically, company spacing tables were generally developed based on engineering judgment and were then modified based on learnings from

TABLE 5-1
References for Example Separation Distances

Block Spacing	Reference
Office to Parking/Maintenance/Warehouse	Section 5.10.3
Office to Process Areas	Appendix A, Table D
Office to Property Boundary	Appendix A, Table D
Parking/Maintenance/Warehouse to Property Boundary	Appendix A, Table D
Parking/Maintenance/Warehouse to Process Areas	Appendix A, Table D
Process Areas to Tankage	Appendix A, Table B
Process Areas to Utilities	Appendix A, Table A
Process Areas to Property Boundary	Appendix A, Table A
Tankage to Property Boundary	Appendix A, Table B
Utilities to Property Boundary	Appendix A, Table A

incidents, regulatory data, alternative approaches, and engineering experience. The tables included in Appendix A were developed based on a review of various major refining and petrochemical company spacing tables, insurance guidelines, historical spacing guidance, regulations, consensus standards, and engineering experience. Although spacing tables may not provide an exact, analytical answer, they are a means to quickly, and cost-effectively, lay out a site while taking advantage of significant experience contained in the spacing table.

A concern with the provision of spacing tables is the potential for their misuse. In the past, tables were developed based on fire scenarios but were often misapplied to a wider range of potential hazards. Spacing tables were also misapplied by considering the values to be absolute instead of as a first approximation that was to be followed up by specific consequence analysis. For the final layout, an appropriate approach would be to analyze the specific hazards and the layers of protection envisioned and then increase or decrease the value cited, as necessary.

When spacing tables are used, exercise care to assure that the spacing table is applicable for the process being used and the hazard of concern. If the spacing table is not applicable to the process being built, then utilize the alternative described in the following paragraph. For example, use this alternative if the spacing table is stated to address fires and the concern is an explosion or a toxic release.

The alternative methodology is to develop spacing distances for the site's specific layout and process parameters through fire, toxic, and explosion consequence modeling. Given the large numbers of equipment pieces involved in a site layout, this can be a time-consuming endeavor. Computer programs are available to facilitate these calculations. The basic steps when taking this approach are shown below.

- Identify the hazards inherent in the process unit
- Identify the consequences that could result from incidents involving the hazards
- Calculate the fire, explosion, and/or toxic impacts on exposed process or off-site equipment, populations, facilities and adjacent areas.
- Based on the calculations, estimate the spacing distance required to minimize the consequences of these impacts on the exposed equipment. This distance provides the minimum separation required.
- Identify opportunities to prevent the incidents
- Identify the opportunities to mitigate the consequences of incidents.
- Again, evaluate the spacing distances.

The best solution is likely a combination of the two approaches as shown in Figure 5-2. Use the spacing tables for the first layout. This will suffice for most equipment spacing. Follow with a more detailed layout for those distances of concern (i.e., because the real estate is not available or there is a specific high-risk operation). Toxic concerns and explosion concerns related to buildings will require consequence modeling to develop a site-specific spacing distance as described in API RP 752 or the CCPS *Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires*.

The spacing tables included in Appendix A are summarized in Table 5-2. They are all based on potential fire consequences in outside locations. Explosion and toxic concerns may require greater spacing.

5.5. Utilities

Typically water, steam, electrical power, and air utilities supply more than one process unit. Loss of that utility could cause a partial or total shutdown.

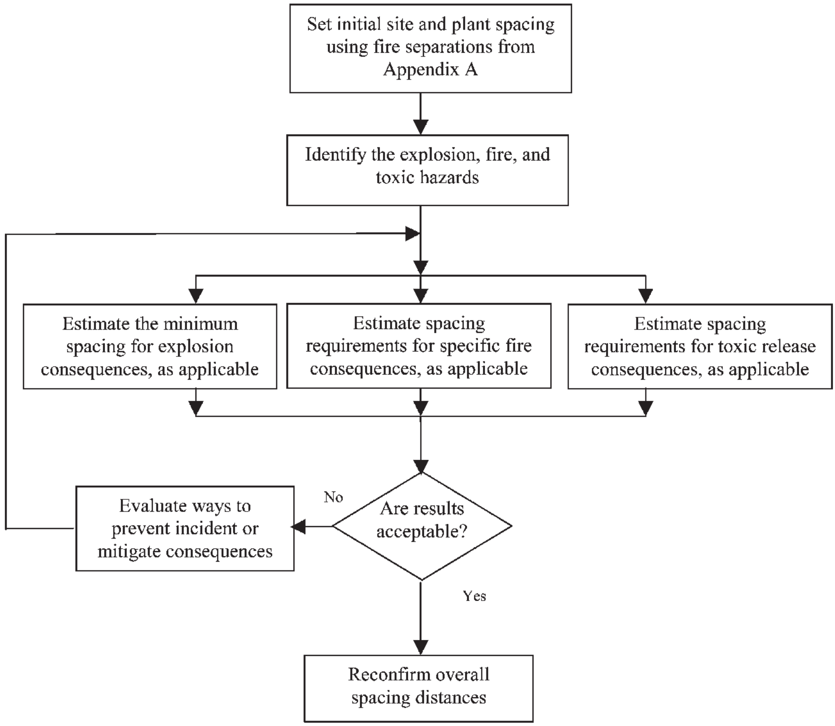

Figure 5-2. *Site Layout Flowchart*

TABLE 5-2
Typical Spacing Table Summary

Title	**Subject**
Table A— Typical Spacing for Plant Equipment for Fire Consequences	Primarily spacing between pieces of equipment in the same unit and spacing between that equipment and the edge of the unit.
Table B—Typical Flammable and Combustible Liquids and Liquefied Flammable Gases Tank Spacing to Other Areas and Equipment for Fire Consequences	Primarily separation distances between storage tanks and site/unit boundaries
Table C—Typical Tank-to-Tank Spacing for Fire Consequences	Separation distances between various types of storage tanks
Table D—Typical Spacing Requirements for On-site Buildings for Fire Consequences	Primarily distances between buildings and major site features such as process and property boundaries, tanks storage, loading racks, and utilities.
Table E—Miscellaneous Typical Spacing Distances for Fire Consequences	Miscellaneous values not included in Tables A through D.

Utilities may be critical to facility operations and a potential sabotage target. Loss of a utility is obviously undesirable from an economic point of view but also from a risk perspective since start-up and shutdown are higher risk operations than routine operations. Consequently utility units are typically located so that they are not vulnerable to process fires and explosions, to minimize the risk of a small incident escalating to a major loss incident.

Locate utilities away from:

- Flood hazards.
- Process areas, flammable and combustible tankage areas, loadings racks and other areas with higher risk.
- The site perimeter to minimize security risks and control access.

5.5.1. Wastewater Facilities

Optimizing grading may aid in minimizing the size of wastewater facilities. Natural drainage from adjacent areas may be diverted around the site to minimize the storm water treatment volume. Locate effluent outflow from wastewater facilities downstream of fishing, recreational, and utility intakes. Local restrictions may dictate the location of warm cooling water returns.

5.5.2. Water Supply

Determine possible sources of drinking water, boiler feed water, firewater, once-through cooling water systems, and service water. These sources might include a municipal water supply, river water, and well water. Locate intakes where they will not be susceptible to adverse impact due to accidental contamination or to fluctuations in level, salt content, pressure, or flow. Water intakes could be sabotage targets and should be protected to the extent possible. Local restrictions may dictate the location of water intake stations.

5.5.3. Steam Supply

Steam may be supplied from public utilities, municipal installations, or on-site facilities. If steam is produced on-site, locate the steam production and handling facilities such that the potential for damage from a process fire or explosion is minimal. Steam facilities may include boilers, boiler feed water storage and pumps, condensate handling equipment, boiler blowdown piping, waste heat recovery, control systems, and environmental protection systems.

Within the steam utility area:

- Separate fired equipment such as steam generators from non-related equipment handling flammables and combustibles.
- Separate equipment containing flammable or combustible liquids such as fuel-oil day tanks, pumps and heat exchangers from other utility equipment.
- Locate feedwater pumps, deaerators, and similar equipment to provide adequate spacing for operation and maintenance.

5.5.4. Fuel Gas and Liquids

Fuel gas storage and mix drums represent a potential flammability and explosion hazard. Locate them so as not to put other utility supply sources at risk.

5.5.5. Instrument Air Compressors

Locate instrument air compressors where they are not vulnerable to process fire or explosion damage or intake of contaminated air.

5.5.6. Cooling Towers

There are several types of cooling tower designs, including induced draft, forced draft, and natural draft (e.g., hyperbolic). The induced draft type is more common in manufacturing facilities while natural draft type are common in the power generation industry.

The location of cooling towers can present problems for the site as well as the neighboring areas. In locating cooling towers, the following concerns should be addressed:

- The water-laden air causes fog and clouds to form. This may reduce visibility and hamper traffic both inside and outside the site. It may also cause icing conditions in the colder climates, external corrosion to structures and equipment, and high humidity conditions and odors inside adjacent buildings. Locate cooling towers downwind from substations, pipeways, roadways, and process equipment.

- Where more than one cooling tower is located in an area, warm water-laden discharge from one cooling tower can be drafted into the adjacent cooling tower. This can have a detrimental effect on the cooling performance of adjacent towers. The best grouping of cooling towers is based on prevailing winds and good spacing and orientation to minimize the effects of one tower on adjacent towers.
- The location of equipment such as air compressors, fired heaters, or other air intake stacks that operate at a negative pressure should be located away from area where water-laden vapors from cooling towers may be discharged.
- The locations of forced draft cooling towers should be perpendicular to the prevailing wind to maximize the intake of fresh air in hotter weather. This will permit a high discharge of outlet vapors from the top of the cooling tower thus reducing the effects of water-laden vapors on the surrounding areas.
- Cooling towers entrain air in their cooling function and thus can entrain vapor releases. Cooling towers may be made of wood, concrete or combinations thereof. Although cooling towers are inherently wet, wooden towers can burn. They are also easily damaged in an explosion.
- Lastly, cooling towers can serve multiple process units or even an entire site. Loss of the cooling tower could result in high hazard consequences as well as significant downtime. Thus, typical separation distance between a cooling tower and process unit equipment is given in Table E. In cases where loss of the cooling tower is not a significant loss, then this distance may be reduced.

5.5.7. Flares

Spacing of elevated flares from process equipment depends on the flare height, load, and the radiant heat level permitted at the equipment. Separation between the flare and the property line may be dictated by local regulations. Typically there are maximum permissible thermal radiation, luminosity and noise levels mandated. Distances to these levels can be based on consequence modeling or on calculation methods such as that provided in API RP 521. Do not locate people and equipment in the sterile exclusion zone without conducting a risk analysis. It is advisable to lay out a bigger exclusion zone than the minimum required to allow for increased flare loads due to future process modifications, the addition of new equipment, or the requirement of an additional flare.

In addition to elevated flares there are also grade level flares and burn pits. Ground flares may be open or may be enclosed by walls. Careful consideration must be given to spacing to potential flammable release sources. Utilize calculation methods referred to in the paragraph above to determine the exclusion zone for unenclosed ground flares and burn pits.

- Locate flares upwind from process units to minimize the potential for ignition of a vapor release from the process units.
- For elevated flares, an exclusion zone of at least 500 ft (152 m) is typical to address concerns of flash fires from liquid spills at the base of the stack, burning rainout from droplets in flared gas, and explosions from flare flame-out and reignition.
- Exclusion zones may be greatly reduced for enclosed ground flares typically to a distance of 100 ft (30 m).
- Consider the risk of windblown embers from an elevated flare tip. The embers may ignite materials below the flare. Do not locate flares near flammable and combustible containing equipment (e.g., storage tanks, process units, and loading rack facilities).

Example

Typically the radiant heat levels from flares are controlled by standards or regulations. In some cases, the noise level and luminosity are also controlled. In one petrochemical plant located in a flat, arid location, both the radiant heat and luminosity were regulated. Given the expanses of open terrain around the complex, the radiant heat off-site was not a concern. However, given the constant elevation of the surrounding area, even a ground flare could be seen in the neighboring community some distance away. In order to meet the luminosity controls, a layout with the flare encircled by process units was considered to utilize the units to block the line-of-sight to the flare. This was considered to be neither safe nor practical. The final solution was to modify the design of the ground flare by raising the walls.

Lesson

It is important to consider noise level and luminosity to minimize impacts on neighboring communities.

5.5.8. Other Utility Systems

Other materials that may be considered utilities or raw material include oxygen, nitrogen, and inert gases. These materials may be distributed throughout the plant in a utility system which may be owned by the site or leased. When locating these facilities, consider the following:

- The access to perform maintenance and inspection activities required by the leasing company.
- The location of loading, regeneration or cleaning of these facilities with respect on-site facilities including process units, buildings, or roadways.
- The location of these facilities with regard to property line and adjacent neighboring sites.
- The location of air separation facilities which are sensitive to gases such as carbon dioxide and hydrocarbons.

5.6. Electrical and Control Facilities

As with other utilities, electrical and control facilities may be critical because loss of power and control capabilities may quickly shut down site operations. From a security viewpoint, electrical and control facilities are also targets for sabotage. Separate these facilities from the site perimeter to minimize this risk. Consider providing independent and redundant routing of electrical power and control facilities to minimize the risk of loss. Some companies provide this redundancy by running one supply above grade in piperacks and one below grade.

5.6.1. Electrical Substations

Separate substations that serve either the entire site or multiple process units from structures that also contain offices, shops, or laboratories. This minimizes the risk of an unrelated event causing loss of the substation and business interruption to a portion of or the entire site. Where separate locations cannot be achieved, separate the substation from the other portion of the structure by a minimum two-hour rated firewall with no penetrations (doors, utility chases) through the wall and with independent drainage and HVAC systems.

5.6.2. Main Substations

A main substation houses the electrical distribution systems for all incoming power sources to a site. This substation should be capable of providing power to support site emergency systems in the event of a fire, explosion, or other emergency.

Consider the following:

Separate a main substation for the entire site from equipment containing flammables with the potential to form a vapor cloud.

- Design main substation structures to be blast resistant if located in area subject to explosion overpressures.
- Separate main substations from potential fire damage including that from process unit pipeways.
- Elevate main substations in flood prone areas.

5.6.3. Unit Substations

Separate unit substations from process equipment handling flammables to reduce concerns of adjacent fires.

5.6.4. Outdoor Electrical Switch Racks

Separate electrical switch racks supporting shutdown or emergency functions by at least 20 ft (6 m) from equipment handling flammables and by at least 50 ft (15 m) from fired heaters or gas compressors. All other switch racks should meet electrical classification criteria distances.

5.6.5. Satellite Instrument Houses (SIH)

A Satellite Instrument House (SIH) is a structure containing instrument and process control equipment for one or more process units. Loss of an SIH will necessitate shutdown of the unit(s) it is serving. Thus, main and multi-unit SIHs should receive increased spacing and layout consideration as fire and explosion damage of the SIH may lead to extended shutdowns of multiple process units.

Additionally, minimize internal risks to the multi-unit SIHs by ensuring that the SIH contains only those facilities essential to its operation. This will minimize the probability that a kitchen fire, for example, will cause the shutdown of multiple units. Where facilities posing a fire risk are housed within the SIH, provide separation by a rated firewall.

Considering fire exposure, separate all SIHs by at least 50 ft (15 m) from equipment containing flammables. This separation is needed to protect the SIH from an adjacent fire that could impact the SIH and its capability to manage the safe shutdown of the unit.

Separation distances for explosion impacts and blast resistant construction requirements should be analyzed as described in Section 5.9.

Locate SIHs to minimize the need for instrument cables to traverse the unit in accessing the SIH and minimize exposure from: fired equipment, vents or flares, and vessels containing large inventories of toxic or flammable liquids, or rotating equipment containing flammables operating at high temperatures or pressures.

SIHs provided with purge air intakes should have such intakes located appropriately to maintain electrical area classification. Additional information is provided in NFPA 496.

Separate SIHs from the property line to protect them from an off-site risk.

5.7. Process

Process units are usually grouped together and separated from low hazard areas in order to minimize fire and explosion exposure. Process equipment includes reactors, vessels, heat exchangers, and rotating equipment. Process units are groupings of equipment that transform raw chemical components through mixing, heat transfer, pressure, separation, and chemical reactions into a desired intermediate component or product. Typically each process unit is separate and is started up and shut down independently. In some cases, integrated process units act as one large unit and are started up and shut down together. The unit battery limits are the outer boundary limits of its plot space and encompasses all of its equipment.

Typically process units are located outside. In some cases due to climate, toxic release, odor control, or quality control concerns, a process unit may be enclosed within a building or structure. Analyze processes within enclosures using a hazard analysis. Through this analysis, spacing between equipment may be reduced by compensating with additional layers of protection as mentioned in Chapter 3. Consequence modeling may be used to define spacing needs both within the enclosure and between the enclosure and surrounding structures.

5.7.1. Emergency Access

Provide emergency access to all areas of the site from at least two directions without requiring the crossing of a process unit. Provide accessways at least every 200 ft (61 m) An accessway should be at least 20 ft (6 m) wide and should not pass under pipeways, equipment or other structures. These will serve as firebreaks and permit firefighting operations to safely approach a process fire from two directions with a standard 100 ft (30 m) fire hose.

5.7.2. Maintenance Access

Maintenance access around process units should allow the use of mobile equipment and power tools for equipment maintenance during operation and turnaround periods. Consider overhead clearance under pipeways and other structural supports as the block unit layout is being developed. Consider providing adequate crane access to limit the amount of lifts over the existing piping and equipment.

5.7.3. Process Unit Spacing

In cases where process units are very large or represent a very large capital investment, it may be appropriate to separate these units from other hazards to minimize the potential financial loss from a single incident. This type of segregation may be an insurance requirement.

Separate equipment in a process unit by at least 100 ft (30 m) from equipment handling flammables in adjacent units or off-site equipment. This spacing is required to minimize risks due to turnaround maintenance activities in a unit while the adjacent unit or off-site equipment remains in service. Where process units are integrated, and shut down at the same time, this separation distance can be reduced to 50 ft (15 m)

Separate a process-unit battery limit by at least 50 ft (15 m) from a roadway with unrestricted access. This provides separation from the process unit and uncontrolled ignition sources such as vehicular traffic.

Reduced separation may be permitted where vehicular access is controlled; however, this is not appropriate in high-risk units.

Consider the electrical classification of the equipment in the unit to control potential ignition sources in the surrounding area.

Controlling security risks associated with the sabotage of process units containing flammable or toxic chemicals must address saboteurs both inside and outside of the site property. Controlling access to such units may serve to minimize the risk from internal saboteurs. Minimizing the risk from external saboteurs may be accomplished by minimizing the units' visibility from the site perimeter, and minimizing the ease by which their contents may be identified.

Typical separation distances between individual pieces of equipment are addressed in Chapter 6.

5.7.4. On-site and Unit Shipping or Receiving Facilities

Loading, packaging, and shipping operations are usually more economical to build, more efficient to operate, and pose fewer safety and health risks when all shipping needs are concentrated in one or more central locations to serve the entire complex. However, it sometimes is necessary to provide loading or shipping facilities on-site or within the process unit. On-site and unit shipping facilities should be located so that packaging and loading functions can be carried out safely and efficiently with proper supervision. The following are considerations regarding the location of these facilities.

Locate the shipping or receiving facilities on the periphery of the process block.

- Provide access for trucks, forklifts, or railcars outside the process equipment area.
- Ensure trucks and railcars do not block access routes when loading, unloading, or standing-by.
- Provide adequate spacing for maneuvering of trucks and other vehicles for loading and unloading so they do not interfere with process or storage equipment on the process site.
- Ensure adequate spacing between rail shipping facilities and the on-site storage tankage and process equipment. Refer to Table 5-3 in Section 5.8.8 (page 89), which lists typical separation distances for railway lines.

5.8. Outside Battery Limits (OSBL)

5.8.1. Site Support Facilities

Site support facilities might include: laboratory, vehicle refueling, garages, mechanical shop, electrical shop, welding shop, sand blasting facilities, and warehouse for materials, supplies, and spare parts. Locate these facilities upwind of the process units when they include uncontrolled ignition sources (e.g., vehicle traffic, smoking, and non-intrinsically safe electrical fixtures) and locate them such that they are not impacted by on-site incidents.

5.8.2. Emergency Response Facilities

Locate structures housing personnel, equipment, or storage essential to an emergency response in an area not subject to damage. Thus, locate fire stations, medical offices, and emergency response equipment storage structures outside of the potential fire or vapor cloud explosion damage areas. Areas that include muster locations inside buildings, medical offices, and triage centers must protect occupants from toxic releases. This will assure their availability when needed.

5.8.3. Transportation

Transportation routes in and around the site are a concern because the vehicles contain potential ignition sources, and route arrangement can minimize or increase the probability of accidents. Transportation routes leading to and from the site may carry large volumes of flammable or toxic materials. Locate these routes to minimize exposure to the public and site personnel from a potential incident.

Transportation of materials to and from a site is a topic for security evaluation. Traffic into a site must be controlled such that the company, driver, and contents are known and expected. Manage the on-site transportation in terms of:

- Controlling points of access to the site
- Minimizing the speed within the plant
- Minimizing the extent of travel inside the site
- Controlling the travel routes away from highly populated or critical areas.

Within the site, consider the purpose and potential traffic volume on the site roads. Locate roads carrying large numbers of office personnel away from potential hazards. Roads carrying chemical supply and products should be located to maximize separation from office and administration buildings. Arrange roads carrying large tankers to scales, loading, and unloading facilities such that the need for sharp turns and backing up is minimized. Locate access from the main public transportation routes to the site gates such that traffic on small roads is kept at a minimum. While sharp turns will provide a potential risk for incidents with trucks and other vehicles, there is a trade off with regards to security. Secondary security stops and sharp turns prevent unauthorized vehicles from speeding into a site.

Port facilities must be located to facilitate the safe berthing of ships. Locate these facilities as far as practical from the main channel flow. Arrange port facilities such that there is sufficient under keel clearance for a fully loaded ship, channel width to accommodate the ship's turning radius, and protection from wind or tidal effects. As marine operations involve transfer and storage of large volumes of chemicals, provide separation from the remainder of the site based on hazard analysis.

Special transportation requirements may exist during the construction phase of the project (or during future expansions) such as transporting large heavy loads to the site. For sites where heavy or large loads will be brought in by water, access from the marine location through the site must be sufficient to accommodate the size of the equipment (road width and overhead clearance). Incoming heavy or large equipment will require consideration of height clearances (including bridges and tunnels) for both highway and railroad.

5.8.4. Pipeline Metering Stations

Pipeline metering and pigging stations are a potential release point. Locate pipeline metering and pigging stations containing hazardous materials to minimize exposure to populated areas, potential ignition sources, and environmentally sensitive areas. Orient the end cover of the pigging station away from other equipment.

5.8.5. Transfer Pumps

Transfer pumps handling flammable and combustible liquids, located outside of battery limits, should be located outside of tank dikes. Transfer pumps handling high hazard toxics should be located within the diked area or their own containment area to contain the material in case of a release. Separate transfer pumps from main and unit substations to minimize fire exposure to the substations.

5.8.6. Pipeways

Pipeways are structures that support pipes, power leads, and instrument cable trays. They are referred to as pipeways, piperacks, or pipebands. The piping may contain hazardous and non-hazardous materials. Consider segregating lines carrying incompatible materials from each other and from cableways. Main pipeways transfer material from the unit pipeway to storage or utility areas. These pipeways may be elevated or at grade. Main pipeways should be located outside of unit battery limits. Unit pipeways are located within the battery limits and transfer material between the unit process equipment.

The density of piping in a pipeway may impact potential VCE overpressure levels as discussed in Chapter 6. Route pipeways to minimize the number of main road crossings and other situations where they are vulnerable to external impact. Additionally, segregating materials in separate piperacks may serve to minimize incident downtime or incident escalation; for example, segregate products from utilities, and segregate highly flammable, reactive, toxic materials, or incompatibles from each other.

5.8.7. Underground Piping

Once the block layout for the site is developed, the routing of underground piping and other utilities is generally considered. However, local conditions may require that underground installations be considered first and process units and other support facilities made to conform to this plan. Factors that effect the location and routing of underground installations include topography, groundwater, existing underground installations, soil conditions, and local construction regulations. This is particularly applicable when expanding an existing site or complex. Future expansions must also be considered when designing underground systems in new plants.

Consider the following in the design and layout of underground piping:

- Determine the shortest and most direct route to minimize the length of piping required. This will also minimize the length of pipe requiring inspection and maintenance.

- Do not locate piping under buildings or major equipment.
- Route underground installations where they will not interfere with future expansion areas.
- Design the underground systems that pass under roadways, railroads, and maintenance accessways for the maximum vehicle/equipment loads.
- Evaluate the location of open culverts or pipeline tunnels with regard to process units and occupied buildings. While these channels or tunnels may provide access for inspection and maintenance of subterranean pipelines and other installations, they also provide a below grade collection point for heavier than air vapors and consequently may generate high overpressures in the event of ignition.

5.8.8. Truck and Rail Loading and Unloading Racks

Truck and rail cars often contain flammable, reactive, or toxic materials. An analysis of the potential consequences of a release may be conducted to provide data for use in siting these facilities.

Locate LPG and LFG truck and rail loading and unloading racks and truck staging areas remotely from equipment containing flammables, from other truck racks, and from storage tanks. Refer to Appendix A, Tables A and B for typical separation distances from LPG/LFG loading racks and platforms. Due to the activities of making up and breaking connections, these racks have a greater probability of being a release source than the permanent piping within a unit. Spacing of rail and truck racks and truck staging areas should also consider VCE, BLEVE, toxic release, and polymerization consequences.

There may be four types of railway lines on or near a process complex. The off-property main railway line, whether public or private, is located outside of the property line and may be part of either intra- or interstate railway corridors. On-property main railways are used for transportation or storage of materials in rail cars. On-property railway spurs are the short take-offs from the on-property main railway to an end point such as a loading dock or loading rack. Lastly, on-property rail loading racks and platforms are located at the end of the spur, on-site, e.g., within the confines of the process unit area.

Separate on-property main railroad tracks from process equipment by 100 ft (30 m). Locate spur tracks outside of the process units and at least 25

TABLE 5.3
Typical Spacing for Railway Lines

	Distance in ft (m)		
	Process Equipment	Off-site Storage	On-site Storage
Off-property main railway (public or private)	200 (61)	200 (61)	200 (61)
On-property main railway	100 (30)	100 (30)	100 (30)
On-property railway spur	25 (7.6)	100 (30)	25 (7.6)
On-property rail loading rack or platform	100 (30)	100 (30)	100 (30)

Note: Refer to Appendix A, Tables A and B for separation distances to smaller storage tanks and central railway loading facilities.

ft (7.6 m) from any process equipment. Locate tank car loading racks so as to prevent potential blockage of emergency routes by rail cars. Also refer to Section 5.7.4 which addresses on-site and unit rail loading facilities.

Provide space for the safe storage of rail cars. Rail sidings may be used to store large numbers of cars, and thus large quantities of hazardous materials, in a single location. Additionally, the geometry of rail tank car storage may intensify a VCE due to the confinement and congestion. Provide appropriate fire protection for rail tanks storage yards. Rail sidings may be either on the site or adjacent to the site where they are controlled by others. Where others control rail tank storage, ensure that adequate security and fire protection measures are provided.

Loading racks and their pumps can be spaced closer than the 50 ft (15 m) listed in Appendix A where additional layers of protection are provided (such as automatic fire suppression, tandem seals, or automatic or remote pump shutdown).

5.8.9. Piers and Wharves

The risks associated with marine traffic movements should be considered in the siting of the marine facilities. A marine study should be carried out to select a pier or wharf location that addresses the following.

- Collisions between vessels visiting the facility and third party vessels
- Grounding on approach or departure
- Striking of the pier or wharf by third party vessels
- Striking of a berthed ship by third party vessels
- Striking of third party piers or wharves by ships visiting the facility
- Impact (heavy berthing) damaging the pier or wharf.
- Pollution, fires, or explosions at the pier or wharf in terms of their affect on the pier or wharf, onshore facilities, and neighboring locations.

Separate wharves handling flammable liquids by at least 200 ft (61 m) from equipment containing flammables, and at least 250 ft (76 m) from continuous sources of ignition. Separate wharves handling LPG and LFG by at least 250 ft (76 m) from all other facilities. Locate and arrange wharves handling toxic materials to allow natural air flow around and between ships when loading and unloading.

Piers, wharves, and the shoreline can be challenging locations to control site access due to the length of the site perimeter, minimal personnel attendance, separation from the site operations, changing river / tidal levels, and open travel on waterways. A good practice is to segregate different hazard levels on separate wharves. For example, locate the LPG and LFG loading and gasoline loading on separate wharfs.

Provide plot space for additional facilities associated with ship loading such as vapor recovery systems for flammables and toxics.

5.8.10. Wastewater Separators

Locate wastewater separators that handle flammable materials a minimum of 100 ft (30 m) from continuous sources of ignition. This separation protects against a minor wastewater separator fire escalating to include an adjacent process unit.

5.8.11. Toxics and Reactive Chemicals Storage

Evaluate the properties of toxic and reactive chemicals being considered in the site layout. There are many such chemicals and their properties vary widely, thus, it is not practical to develop spacing tables that address the range of highly toxic and reactive materials. Facilities should be designed to separate incompatible chemicals. Consequence modeling should be used to further define the potential impacts and determine the appropriate separation distances between these chemicals and occupied buildings, accessways, and the property line to minimize the impacts in the case of a spill or leak.

Toxic chemicals may include chlorine, hydrogen fluoride, organic lead compounds (e.g., tetramethyl and tetraethyl lead), ammonia gas, hydrogen sulfide, and methyl isocyanate. Highly reactive materials may include pyrophoric compounds (e.g., metal alkyls), shock-sensitive compounds (e.g., metal acetylides), decomposition-sensitive compounds (e.g., acetylene, organic peroxides), temperature sensitive materials (e.g., acrylic monomers), and water-reactive chemicals (e.g., sodium). The CCPS *Guidelines for Safe Storage and Handling of Reactive Materials* provides guidance in this area (CCPS 1995, no. 19).

5.8.12. Multi-unit Blowdown Drums

Multi-unit blowdown drums are sometimes used to manage liquids or toxic fluids in pressure-relieving and emergency systems. Separate blowdown drums from unit battery limits by at least 100 ft (30 m) and from all other facilities by at least 200 ft (61 m).

5.8.13. Fire Training Areas

Fire training areas are ignition sources and can create a nuisance due to smoke in the neighboring community. Fire training areas should be located to minimize this concern. Separate fire training areas from all site facilities and equipment by at least 200 ft (61 m).

5.8.14. Compressed and Liquefied Gas Storage in Portable Containers and Bulk Storage

Separate operations involving filling of portable gas cylinders by at least 25 ft (7.6 m) from equipment handling flammables. Separate storage of cylinders from units processing flammables. Refer to API RP 2510 and API RP 2510A and NFPA 58 for further information on siting and layout of gas filling and storage operations.

Locate and arrange bulk oxygen systems in accordance with NFPA 50 and bulk chlorine supplies in accordance with guidelines published by The

Chlorine Institute. Locate liquid nitrogen containers in areas relatively free of exposure to fire and mechanical damage. The manufacturer can provide guidance on spacing information for other compressed and liquefied gases such as ammonia, oxygen, and acetylene.

5.8.15. Miscellaneous

There may be other facilities that are located on a site such as coal piles, landfills, surplus equipment yards, firewater ponds, equipment laydown yards, and temporary trailers. Buildings and trailers should be sited using API RP 752 and the CCPS *Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires* (CCPS 1996, no. 22) Where spacing criteria is not available for other facilities, electrical area classification distances may provide a basis for separation or a hazard analysis may be used to determine appropriate location.

5.9. Tank Storage

Tank storage is typically arranged in groups of tanks containing materials with similar flammability characteristics. This provides segregation and separation of risks, and allows for optimization of firefighting equipment and systems. Locate tanks downwind of potential ignition sources to minimize the risk of ignition during a release. Separate process units from atmospheric storage tanks and LPG and LFG storage tanks. This will minimize the risk of release, ignition, and the potential for tank damage during a unit fire or explosion.

Consider the effect of thermal radiation from a tank fire when laying out tank storage areas. This radiation may impact adjacent units or adjacent tanks. Separation distances between tanks will depend on the tank size, type, insulation, diking, and contents. Additional separation is appropriate for pressurized and refrigerated hydrocarbon storage tanks. Intratank spacing is discussed in Chapter 6.

Dikes are provided to contain tank spills and minimize the potential for fire escalation to adjacent tanks or areas. The number of tanks per dike and the dike size will impact the spacing and layout of tank farms. An alternative is to provide a smaller dike to contain small spills and direct larger spills toward a drainage path to an appropriately sized remote impounding area.

Guidance on dikes and remote impounding requirements are provided in NFPA 30.

From a security perspective, storage tanks pose a large visual potential target. As with process units, controlling access to storage tank areas may minimize risks from internal saboteurs. Given the size of storage tanks, it may be difficult to minimize risks from off-site saboteurs other than by separating tanks that pose higher potential consequences (such as LPG, LFG, or toxics) from the site perimeter.

The tables in Appendix A address separation distances from and between storage tanks. Table 5.4 describes the information provided in the Appendix spacing tables. Spacing to the property boundary is referred to in terms of the current or potential use for the adjacent property as described in Section 5.2.5. Tank spacing identified in the appendix and in this chapter refer to distances measured from the closed tank edge.

Separate process unit equipment from OSBL storage tanks. Consider the potential consequences of exposing substations, satellite instrument houses and control houses to tank fires. Consider the need to pump products during a fire, the potential loss of emergency shutdown, and potential business interruption. Separate substations, satellite instrument houses and control houses from OSBL storage.

For tanks storing crude oil or other products with boilover characteristics, provide the greatest spacing distance practical and at least 500 ft (152

TABLE 5.4
Appendix A Typical Spacing Tables Relevant to Tank Spacing

Title	Relevance to Tank Spacing
Table A— Typical Spacing for Plant Equipment for Fire Consequences	None
Table B— Typical Flammable and Combustible Liquids and Liquefied Flammable Gases Tank Spacing to Other Areas and Equipment for Fire Consequences	Primarily separation distances between storage tanks and site/unit boundaries
Table C— Typical Tank-to-Tank Spacing for Fire Consequences	Separation distances between various types of storage tanks
Table D— Typical Spacing Requirements for On-site Buildings for Fire Consequences	Contains separation distances between storage tanks and various types of buildings.
Table E—Miscellaneous Typical Spacing Distances for Fire Consequences	Contains miscellaneous values related to spacing from tanks

m) from on-site and off-site population centers. A boilover is a violent expulsion of contents caused by a heat wave from the surface burning at the top of the tank reaching the water layer at the bottom of the tank. Boilovers are rare but typically catastrophic due to the energy with which the large volume of oil is expelled from the tank.

Space and arrange low-pressure storage tanks operating at pressures of 0.5 psig (3.45 kpag), but not exceeding 15 psig (103 kpag), in accordance with provisions of NFPA 30.

Separate spheres, cylindrical pressurized storage tanks, refrigerated tanks, and cryogenic storage tanks containing flammable materials from process-unit equipment and continuous ignition sources, such as fired heaters. Locate these tanks down hill and downwind from ignition sources.

Determine spacing distances for refrigerated tanks through process hazard analysis and consequence analysis. Vapors evaporating from refrigerated liquids may travel long distances in a cloud with a concentration above the LFL. A separation of at least 200 ft (61 m) from all other equipment is typical for fire considerations.

Mounding (covering with earth, sand, or vermiculite) is sometimes used on cylindrical pressurized storage tanks to reduce the risk of BLEVE and also to reduce separation distances and minimizes security concerns.

Do not orient horizontal cylindrical vessels so that their longitudinal axis is pointed toward offices, shops, process units, emergency response equipment, or populated areas. This is advisable considering that when these vessels fail they tend to launch the shell ends along the direction they are oriented. Vessel fragments can be thrown great distances as depicted in Figure 5-3. Historical data indicate that a 20-ton (18,144-kg) vessel fragment can travel up to 3937 ft (1200 m) due to a BLEVE (Skandia, 1985). Provide vessels that may BLEVE with multiple layers of protection and address in emergency response planning.

5.10. Occupied and Critical Structures

Analyze the location of potentially occupied buildings and buildings housing safety- or business-critical functions to determine the risk to building occupants from process hazards including fire, explosion and toxic release. Facility siting analysis is described in API RP 752 and CCPS *Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires*. Inher-

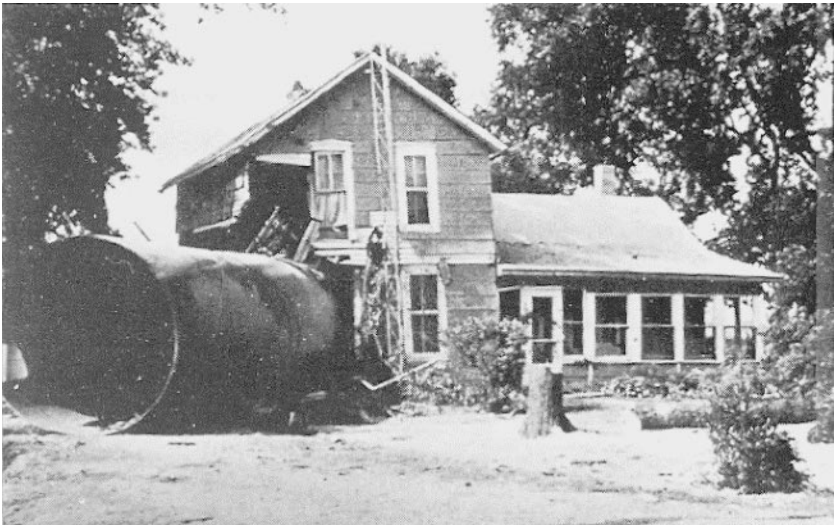

Figure 5-3. *Rail car fragment from Crescent City BLEVE (Baker, 1983)*

ently safer designs suggest that this risk can be minimized by providing adequate separation between the building and the process areas. Additional methods of protection may include fire protection, blast resistant design, and toxic gas detection.

Occupied buildings and those housing critical operations may be at risk from security threats. These risks may be minimized by controlling access to the buildings, protecting the buildings from vehicular assault, and, if warranted, hardening the structure. Security risks should be balanced with other risks including safety. For example, controlling access to a structure may increase security but could decrease safety if that structure is used as a safe haven. The CCPS *Guidelines for Analyzing and Managing Security Vulnerabilities of Fixed Chemical Sites* provides direction in this area.

5.10.1. Process Control Buildings

A process control building should contain the facilities and offices essential to process control. It should not be located in a structure with unrelated functions such as administration, accounting, engineering, and research laboratories. Where central control buildings include analytical laboratories or kitchens, consider the provision of a firewall to separate these areas from the process control areas. It is advisable to construct a control building with no equipment located above or below the control room (e.g., HVAC supported on the roof or switchgear room below). Where central control buildings house the emergency control center, consider the building location and the location of the personnel expected to staff the emergency control center. Will these people travel through a safe area or pass through process and storage areas that may be the origin of the flammable, explosive, or toxic incident to which they are responding?

The following three types of control rooms are considered.

1. A central control building is one that serves a significant portion of a site. Its loss would result in a major shutdown or adversely affect the safe shutdown of the site during an emergency.

2. A multi-unit control building serves several process units. Its loss would reduce plant throughput by removing several units from service but would not result in a total site shutdown.

3. A unit control building serves a single unit.

For a smaller plant, the main control building could be serving only a single unit. In this case, treat the control room as a single unit control room and consider business interruption risks in the siting of this structure.

Separate control buildings from equipment and storage containing flammable materials to reduce the consequences of fire exposure. Central and multi-unit control buildings should receive increased spacing and layout consideration as fire and explosion damage of the control building may lead to extended shutdowns of multiple process units or loss of unit control.

Evaluate control buildings for blast-resistant construction or locate conventional construction control buildings in an area where blast resistant construction will not be needed. Explosion analysis reference is provided in Section 5.9.

Consider control building location with respect to potential toxic release sources. Conduct consequence analysis per API RP 752 to address potential toxic impacts. If the control building is impacted, mitigation measures (e.g., supplied air, HVAC pressurization or shutdown) should be provided and emergency response plans should address the hazard.

Locate all types of control buildings adjacent to site roadways to ensure emergency access.

For security considerations, separate control buildings from the property line. Additional security measures to control access may be warranted for control buildings located close to property boundaries.

5.10.2. Normally Unoccupied Shelters

A shelter is a small structure used for breaks and weather protection. Exercise care to address these buildings in facility siting analysis as mentioned in section 5.9. Separate shelters from equipment containing flammables by at least 50 ft (15 m) (excluding weather shelters that provide no services except weather protection).

5.10.3. OSBL Buildings

Following inherently safer principles, locate occupied buildings that are not immediately essential to the operating units (for example, central laboratory, offices, warehouse, administration, or engineering) outside of vapor cloud explosion damage areas. Include these buildings in the facility siting analysis as mentioned in Section 5.9. Occupied buildings subject to blast damage may warrant upgrade to blast-resistant construction based on this analysis.

Establish toxic safe havens within or near the buildings to safely house all the occupants during a potential toxic release.

Determine spacing between buildings located outside of units based on local building codes and NFPA Codes and Standards. Provide two emergency egress paths from the building on opposite sides with one located away from the hazard.

5.11. Multi-Chapter Example

Continuing with the example started in Chapter 4, the topic of laying out major blocks of similar risks on the site is addressed.

Example

Management has endorsed the site selection team recommendation to proceed with Location 3. This site is located within an industrial complex. Consequently, there are industrial neighbors but no sensitive populations nearby. The marine facilities exist. The site has a significant slope and has a dry creek bed that turns into a torrent when heavy rains run off the hillside.

The site must be designed to include the following blocks:

- Process Units
  - —Ethylene
  - —Low Pressure Polyethylene
  - —Ethylene Glycol
- Palletizing and packaging facilities
- Offsites
  - —Ethylene Feed Pipeline
  - —Flare
  - —Tankage
  - —Warehouses
  - —Control room
  - —Cooling tower
  - —Port facilities for transport of finished products

It was decided to address the site slope first since that will impact all layout issues. The main concerns with the site are the time and cost associated with the site preparation and the rainwater runoff. Civil engineering conducted a study to determine the impact on drainage and water treatment facilities. The study made the following recommendations.

- All the planned units should be located toward the bottom of the site elevation near the existing road. This allows the higher elevations, which would be more expensive to work, to be left untouched.
- Diversion diking should be installed between the untouched higher elevations and the facilities below to divert rainwater runoff to perimeter canals thereby minimizing water runoff through the site that would require treatment.
- The site should be divided into tiers thereby allowing multiple level plots for the site with elevation changes between the tiers.

Once these site topographical issues were accepted, the layout of the major plants and units on the tiers was addressed. The main features of the layout are described below and shown in Figure 5-4.

- It was decided to locate the flare on the top tier. This locates the flare ignition source uphill and crosswind from potential release sources.

- It was decided to locate the tankage on the lowest tier such that in the case of a spill, the product would not cascade down the tiers toward the remainder of the site.
- Process plants and units were identified as high risk. Thus, it was desirable to separate them from both the tankage and the flare. They were sited on the middle tier.
- Utilities were identified as medium risk. However, due to the critical nature of the utility area, it was separated from the high-risk areas such as process and tankage areas. The location for the main substation (part of the utility area) was somewhat dictated by the location for the main power lines along the lower tier south property line. This provided a starting point for laying out the lower tier.
- Pelletizing and packaging was identified as low risk and were located on the top tier with the flare. Calculations were performed to determine the flare radiation impact to assure the packaging area was adequately separated from the flare.
- The cooling tower was designed to serve all the new units. Preliminary hazard analyses identified that loss of the cooling tower could result in releases and significant downtime. The Project Engineering Team identified the need for the cooling tower to be adjacent to the process units to minimize cost associated with long lengths of large diameter pipe. A compromise was reached locating the cooling tower on the tier with the process units but as far as possible from them.
- Offices, administration building, and warehousing were located on the lower tier. The warehousing was separated from but located adjacent to the tank farm. The offices and Administration Building were on the opposite side of the warehousing from the tank farm.
- The central control building was centrally located between the offices and the process units. API RP 752 analysis showed that it was not subject to structural damage or toxic impacts at this distance from the process units.
- Access to the site was located at the lowest tier adjacent to the main road. However, a single site access was identified as a concern both for emergency response and personnel egress in an emergency. Consequently, two accesses were located on the main road at opposite corners of the site.

Lesson

Each site presents its own challenges. First address the site environment and topography. Then employ the block concept to segregate the major blocks of like risk (process, utilities, OSBL, buildings). Consider issues such as wind direction and drainage in arranging these blocks. The spacing tables may then be used to identify typical separation distances between the blocks. Through this process, a first draft site layout is developed.

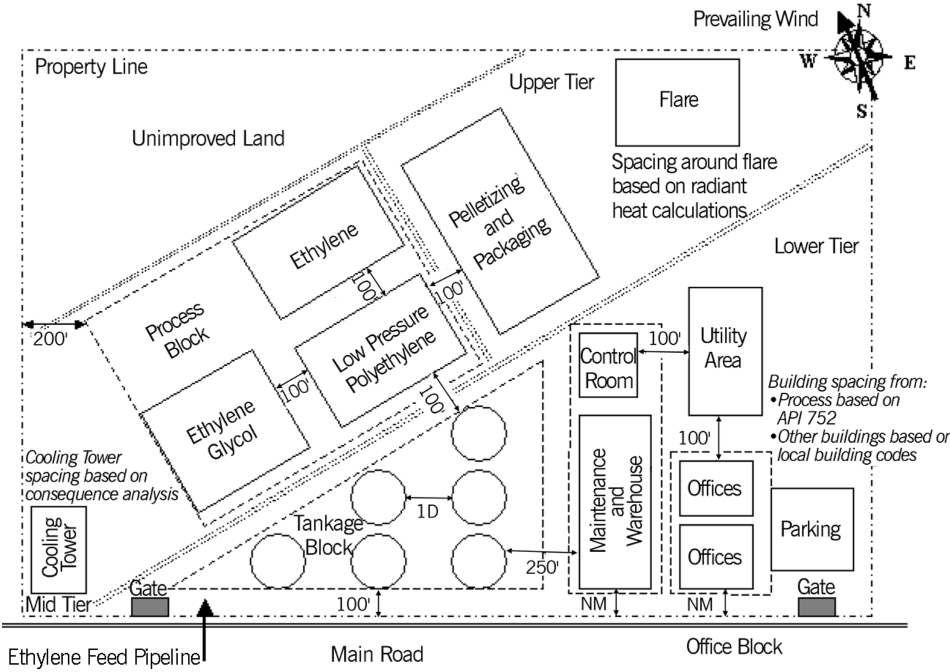

Figure 5-4. *Layout of Major Site Features (1 ft equals 0.3 m)*