LAYOUT AND FACILITY SITING GUIDELINE

EGPC-PSM-GL-004

PSM GUIDELINES

The Egyptian Process Safety Management Steering Committee (PSMSC Egypt)
PSM TECHNICAL SUBCOMMITTEE (PSMTC)

Acknowledgments

This publication has been produced as a result of the comprehensive efforts carried out by the PSM Technical Subcommittee on behalf of the Egypt PSM Steering Committee, formed per the Memorandum of Understanding signed between the Ministry of Petroleum and Mineral Resources and Methanex Egypt in February 2020 overseeing the design and implementation of a detailed PSM program to promote and enhance PSM culture for Ministry of Petroleum and Mineral Resources (MOP) and its affiliated COMPANIES following industry best practice, international codes and standards. The Egyptian Process Safety Management Steering Committee comprises MOP, EGPC, ECHEM, EGAS, GANOPE, and Methanex Egypt representatives.

PSM Technical Subcommittee team members during the project comprised:

Amr Moawad Hassan	**PSM Senior Consultant – Methanex Egypt**	**Team Leader**
Sayed Eid	HSE A. General Manager – Agiba Pet. Co.	Member
Ahmed Mostafa	Operations Section Head - ELAB	Member
Ahmed Roustom	Risk Management and Loss Prevention Studies Assistant General Manager – GASCO	Member
Hany Tawfik	OHS & PS General Manager – ETHYDCO	Member
Mohamed Ashraf Aboul-Dahb	Safety Section Head for Upstream – EGPC	Member
Mohamed Mesbah	Operations Department Head - KPC	Member
Mohamed Hamouda	HSE Department Head – Pharaonic Pet. Co.	Member
Mohammed Sabry	Risk Management and Loss Prevention Studies Executive General Manager – GASCO	Member
Tamer Abdel Fatah	QHSE Senior – UGDC	Member

All PSM technical subcommittee documents are subjected to a thorough technical peer-review process during development and prior approval. The PSM technical subcommittee gratefully appreciates the thoughtful comments and suggestions of the peer reviewers. Their contributions enhanced the accuracy and clarity of the documents. The PSM Technical Subcommittee acknowledges the following reviewers from major Process Safety consultants as well as major operators & EPC contractors who provided valuable comments during the technical peer reviews that resulted in an outstanding product structure and quality:

Process Safety Consultants (in alphabetical order):

- Baker Engineering and Risk Consultants, Inc. (BakerRisk).
- Bell Energy Services - By: Amey Kulkarni,Technical Director.
- Risktec Solutions - TÜV Rheinland.

Major IOCs & EPCs (in alphabetical order):

- ENPPI - By: Hossam Yehia, Process Technology | Safety and Loss Prevention Principal Engineer.

It should be noted that the above have not all been directly involved in developing this document, nor do they necessarily fully endorse its content.

Egypt PSM Steering Committee team members during the project comprised:

Gamal Fathy	EGPC CEO Consultant for HSE – EGPC	Member
Mohamed Mahmoud Zaki	Executive Vice President – ECHEM	Member
Salah El Din Riad	Q&HSE Chairman Assistance – ECHEM	Member
Dr. Ashraf Ramadan	Assistant Chairman for HSE – EGAS	Member
Emad Kilany	OHS & Fire Fighting Technical Studies GM - EGAS	Member
Mohamed Sayed Suliman	HSE General Manager – GANOPE	Member
Mohamed Mostafa	Inspection & External Audit GM – ECHEM	Member
Mohamed Shindy	Managing Director – Methanex Egypt	Member
Manal El Jesri	Public Affairs Manager – Methanex Egypt	Member
Mohamed Hanno	RC Manager – Methanex Egypt	Member
Amr Moawad Hassan	PSM Senior Consultant – Methanex Egypt	Member
Mourad Hassan	PSM Consultant – Methanex Egypt	Member

DOCUMENT NO.	TITLE	ISSUE DATE
EGPC-PSM-GL-004	LAYOUT AND FACILITY SITING GUIDELINE	Dec. 2022

Approval

NAME	TITLE	DATE	SIGNATURE
Amr Moawad Hassan	PSM Senior Consultant - Methanex Egypt PSM Technical Subcommittee TL	DEC. 2022	Amr Hassan Digitally signed by Amr Hassan Date: 2022.12.29 09:03:40 -06'00'
Gamal Fathy	EGPC CEO Consultant for HSE	DEC. 2022	Gamal Fathy

Endorsement

NAME	TITLE	DATE	SIGNATURE
Alaa El Batal	CEO - Egyptian General Petroleum Corporation (EGPC)	DEC. 2022	

Copyright

Disclaimer

No liability whatsoever in contract, tort, or otherwise is accepted by ENTITIES or its COMPANIES, their respective shareholders, directors, officers, and employees, whether or not involved in the preparation of the document for any consequences whatsoever resulting directly or indirectly from reliance on or from the use of the document or for any error or omission therein even if such error or omission is caused by a failure to exercise reasonable care.

Controlled Intranet Copy

The intranet copy of this document is the only controlled document. Copies or extracts of this document, downloaded from the intranet, are uncontrolled copies and cannot be guaranteed to be the latest version. All printed paper copies should be treated as uncontrolled copies of this document.

All administrative queries must be directed to the Egyptian Process Safety Technical Subcommittee.

Table of Contents

1. Introduction 5
2. Purpose 5
3. Scope 5
4. Definitions 6
5. Abbreviations 6
6. Facility Siting Study (FSS) and Facilities Life-Cycle Phases 7
7. Facility Siting Process 8
   7.1 Selection Stage 9
   7.2 Evaluation Stage 14
   7.3 Mitigation Planning and Implementation Stage 14
   7.4 Facility Siting Revalidation and Managing Changes 16
8. Documentation 17
9. Layout and Siting General Design Considerations 17
10. References 24

Annex A - CCPS Recommended Distance Tables for Siting and Layout of Facilities 26

1. Introduction

Layout and facility siting are complex and multidisciplinary tasks requiring inputs from different disciplines. The location of the facility and the arrangement of process units/equipment and buildings significantly influence material and construction costs, major accident risks, the safety of operation, and the cost of operation and maintenance. Applying inherent safer design principles during siting and layout design will have great potential for reducing complexity, risk, and cost. Siting and Layout study should be conducted to account for both off-site and onsite impacts from potential fire, explosion, and toxic release hazards. Although it is commonly known that facility siting study (FSS) is focused on occupied buildings, the current guideline is not focused only on the location of occupied buildings but also on siting and layout of the facility, process units, equipment, piping, people in outdoor areas and unoccupied buildings including those with critical equipment.

The words "siting" and "layout" are often used interchangeably, but they have different meanings as a structure speaking and throughout this guideline. Siting is concerned with the location of the facility concerning off-site surrounding facilities and activities. On the other hand, the layout concerns the location of the processing unit, equipment, piping, and buildings at the selected site.

This guideline describes the sequence for developing a facility siting study and different approaches that might be used during the development of this study. In addition, it emphasizes approaches and concepts for deciding the mitigation strategy and developing the mitigation plan. Moreover, it gives guidance for managing off-site and/or onsite changes that might affect the original facility siting study and the requirements for revalidation.

2. Purpose

The scope of this guideline includes siting and layout study for Greenfield, Brownfield, and Extensions/Modifications of an existing plant. This guideline covers facilities such as oil & gas plants, refineries, petrochemical, chemical plants, and fuel or chemical storage sites where hazardous materials are stored, handled, or processed.

3. Scope

The scope of this guideline applies to Egyptian General Petroleum Corporation (EGPC) and Oil & Gas Holding Companies, including the Egyptian Natural Gas Holding Company (EGAS), the Egyptian Petrochemicals Holding Company (ECHEM), and the South Valley Petroleum Holding Company (GANOPE) covering all their operational subsidiaries, state-owned companies, affiliates, and joint ventures.

4. Definitions

COMPANY: Refers to any operating company, subsidiary, affiliated, or Joint Venture companies belonging to an ENTITY.

ENTITIES: Refers to the Egyptian General Petroleum Corporation (EGPC) and Oil and Gas Holding Companies, including the Egyptian Natural Gas Holding Company (EGAS), the Egyptian Petrochemicals Holding Company (ECHEM), and the South Valley Petroleum Holding Company (GANOPE).

5. Abbreviations

FSS	Facility Siting Study
CCPS	Center of Chemical Process Safety
MCE	Maximum Credible Event
LSIR	Location-Specific Individual Risk
IRPA	Individual risk per annum
PLL	Potential Loss of Life
ALARP	As Low As Reasonably Practicable
MOC	Management of Change

For other definitions and abbreviations, refer to the PSM Glossary of Definitions and Abbreviations Guideline (EGPC-PSM-GL-011).

6. Facility Siting Study (FSS) and Facilities Life-Cycle Phases

We can distinguish eight main phases throughout the facility life-cycle, as shown in Figure 1. The most effective strategy to reduce the impacts/risks associated with the site and layout of any facility and reduce the life-cycle costs is to apply the siting and layout approaches and principles early in the project's development phase. A well-thought-out layout contributes to successfully planning the design and construction stages. Once the project moves away from the early stages (e.g., concept and basic engineering phases), the opportunity for applying the principles of siting and layout of the facility decreases. Consequently, costly changes may be required, which might have been avoided. Moreover, it is anticipated that more safeguards/controls will be required to meet consequence/risk acceptance criteria, resulting in increased operating and maintenance costs during the facility's life.

Preliminarily layout and siting study should be conducted in the early stage of the project (evaluation/ concept selection phase). Multiple locations and layouts are reviewed to minimize risks and costs to the project. At this stage, there is no sufficient project-related information exists. Accordingly, the preliminary layout and siting study is built considering typical spacing tables (Annex A), engineering practices, coarse risk or consequence study if available, and previous lessons learned regarding the layout and spacing of similar facilities. Moreover, environmental factors such as weather, sensitive areas, topography, access, and exposure to neighboring populations should be considered. The focus should be placed on inherently safer design (ISD) concerning layout and spacing where appropriate to minimize the impact/risk of exposures.

FSS should be performed in the early FEED phase for all new projects (Greenfield and Brownfield). Then, the FSS should be reviewed and updated in late FEED before moving to EPC, and all FSS recommendations should be closed before moving from FEED to EPC. The FSS shall be reviewed in EPC in case of significant changes to the facility design and/or layout.

The FSS should be completed for Greenfield Projects, and all FSS recommendations should be closed. For Brownfield Projects, the impact of the new facilities on the existing facilities shall be assessed in the FSS, and the existing FSS (if available) shall be updated to incorporate the new fire hazards and any effect on the firefighting capability of the existing facility (i.e., increased firewater demand).

Changes to layout during construction or after the project handover to operation is a very tough task considering the principle of facility siting. In such a case, a specific mitigation plan might be required, which might be very costly in both money and time to be implemented.

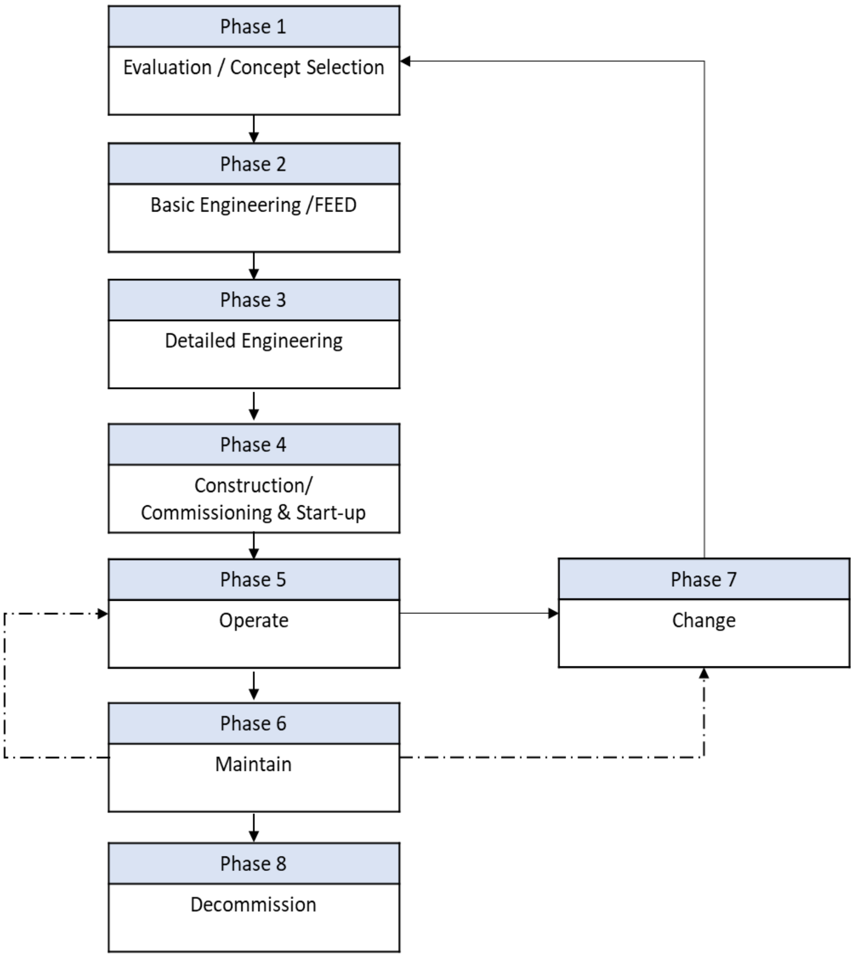

Figure 1. *Life-cycle phases for a facility, a processing unit, or the equipment.*

7. Facility Siting Process

There are several stages for completing a facility siting study, as indicated in Figure 2. These stages are selection, evaluation, mitigation planning & implementation, and revalidation & managing change. A full description of each step is provided in the following sub-sections.

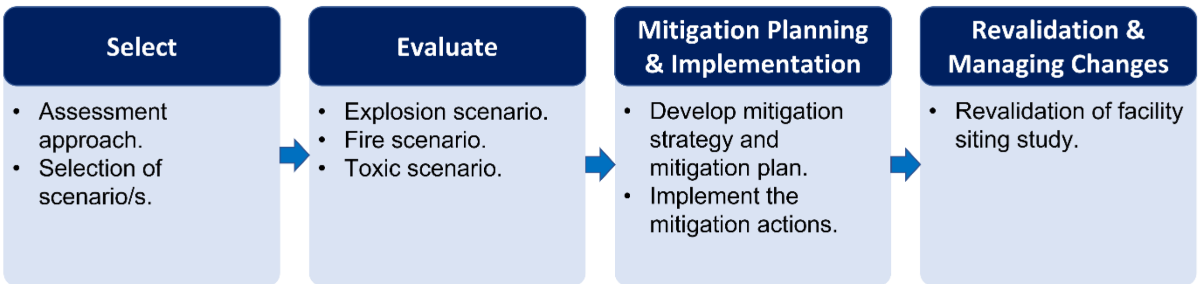

Figure 2. *Facility siting study stages.*

7.1 Selection Stage

This step or phase aims to select the assessment strategies or approaches, select the potential scenarios, and finally select and decide the evaluation criteria that will be used during the assessment.

7.1.1 Selection of Assessment Approach

Generally, three assessment approaches are well known for conducting a facility siting assessment. Those are the spacing tables, consequence, and risk-based approaches. The subsequent sections introduce a description of the three assessment approaches. Figure 3 shows the different assessment approaches and the conditions/circumstances for using each.

Typically, and in the early stage of any project, the facility siting assessment approach is the spacing tables approach. The outcomes of this assessment approach are normally subjected to further verification (using consequence-based approach outcomes) in the following cases:

- Potential for the presence of hazardous scenarios other than fire, e.g., explosion and/or toxic gas release, where spacing tables are applicable only to fire scenarios.
- The spacing distances required by spacing tables are difficult to be fulfilled.

Whenever the consequence-based approach outcomes indicate the presence of significant vulnerabilities or it is very hard to apply its requirements/mitigation actions, a risk-based approach should be used. A risk-based approach will provide more refinement/mitigation options and determine whether a mitigation measure is cost-effective.

For offshore facilities with limited available areas, it isn't easy to use spacing tables or a consequence-based approach; instead, the risk-based approach should be utilized.

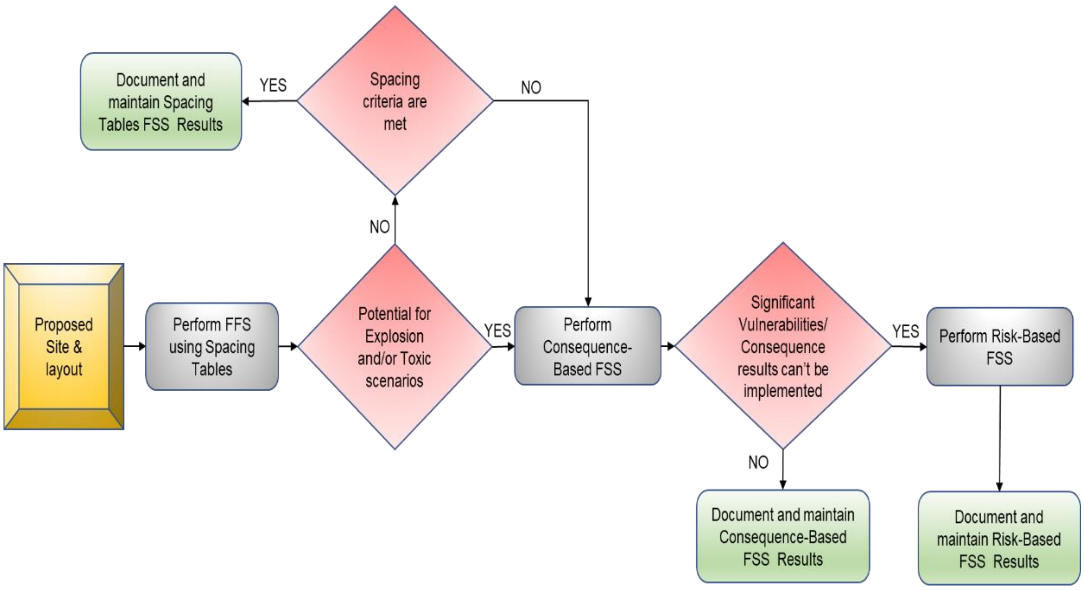

Figure 3. *Facility siting assessment approaches.*

7.1.1.1 Spacing Tables Approach

The spacing tables approach uses established tables that give the required minimum distance between different units, equipment, buildings, etc. Generally, this is a good tool to be used at the early stage of any project where there is very limited information to develop a detailed facility siting assessment. It is easy and quick and does not require plant details like other approaches, e.g., consequence-based or risk-based approaches. Moreover, its simplicity can be applied using the company's competent resources if available.

Spacing tables are applicable only to fire scenarios. Accordingly, if there is a potential for other scenarios, e.g., explosion or toxic release, the spacing tables will not be the proper approach. Therefore, it should be subject to further verification using detailed assessment approaches. Although the spacing tables focus only on fire scenarios, it does not consider the material on fire or the size of the fire. This makes it built conservatively and might make fulfilling its spacing requirements hard to achieve.

Several references/guidelines are commonly used, introducing spacing tables for inter and intra-spacing and off-site spacing. CCPS spacing tables (Annex A) are one of the main references, but PIP and GAP standards can also be used if the spacing requirements are not addressed in the CCPS.

7.1.1.2 Consequence-Based Approach

The consequence-based approach considers the impact of the explosion, fire, and toxic scenarios based on the Maximum Credible Events (MCEs), which is the hypothetical explosion, fire, or toxic material release event with the maximum potential consequence. The outcomes of the consequence-based assessment should include hazard contour maps illustrating toxic gas dispersion, explosion overpressure, and fire radiation levels overlaid onto the Facility Plot Plan(s).

Consequence-based approach outcomes are more site-specific than the spacing tables approach outcomes. The consequence-based approach requires more resources and uses more process-specific information. This kind of assessment might be done in-house, subject to the availability of the required tools and competent resources. Consequence analysis is relatively easy and fast compared to a risk-based approach. Moreover, the decision process is simple (either "safe" or "not safe"). On the other hand, the consequence-based approach is more conservative than the risk-based approach, making it difficult to prioritize mitigation measures. For more details about the principles of consequence analysis, it is helpful to refer to the Quantitative Risk Assessment (QRA) Guideline (EGPC-PSM-GL-008) and Fire and Explosion Risk Assessment (FREA) Guideline (EGPC-PSM-GL-009).

7.1.1.3 Risk-Based Approach

Whenever significant vulnerabilities are predicted using a consequence-based approach, it often becomes worthwhile to perform a risk-based approach. Transitioning from a consequence-based approach to a risk-based approach will help identify additional and more reasonable mitigation measures. Taking the opportunity of expressing the risk in financial terms (cost-benefit analysis) will help in the selection of the different mitigation alternatives.

On the other hand, this approach is less conservative and requires the most time and resources but does give a result most specific to the studied facility. The main challenges during the risk-based assessment are using various assumptions that could lead to uncertainties in the result.

Risk-based assessment requires more specific resources and a certain level of competency compared to the consequence-based approach, so it is commonly conducted separately with an external consultant. For more details about the principles of the risk-based approach, it is helpful to refer to the Quantitative Risk Assessment (QRA) Guideline (EGPC-PSM-GL-008) and Fire and Explosion Risk Assessment (FREA) Guideline (EGPC-PSM-GL-009).

7.1.2 Selection of Scenarios

A critical first step to performing FSS is thoroughly identifying potentially significant fire, explosion, and toxic hazards scenarios that could pose consequences/risks to onsite and off-site facilities and populations. Scenarios must be selected for consequence and risk-based approaches, not for the spacing table's approach. A typical approach to identify hazard scenarios is to review process-related information, e.g., process flow diagrams (PFDs) and/or piping and instrumentation diagrams (P&IDs). Additional significant hazards can be identified by interviewing knowledgeable facility personnel and reviewing results from a PHA to capture scenarios not easily identified by reviewing PFDs and P&IDs.

A secondary step to performing FSS is determining the Maximum Credible Events (MCE) and/or the range of release sizes from small leaks up to the maximum credible release size. The consequence-based approach considers the impact of the explosion, fire, and toxic scenarios based on MCEs, which is the hypothetical explosion, fire, or toxic material release event with the maximum potential consequence. In other words, the MCE can be considered the worst-case scenario and identified as the scenario corresponding to a full rupture. However, assessing larger releases on a consequence basis may provide results that would lead to impractical or extremely costly mitigation.

On the other hand, the risk-based approach allows the evaluation of small, medium, large and full rupture events together with the likelihood of occurrence. Accordingly, the risk-based approach effectively eliminates consideration of MCE release size since it incorporates likelihood into the full range of release scenarios. A typical hole or release sizes that are used during the modeling of different scenarios are:

- Small: 1 mm to 10 mm size hole.
- Medium: 10 mm to 50 mm size hole.
- Large: 50 mm to 150 mm size hole.
- Full rupture: > 150 mm.

The output from the Hazard Identification stage will be a discrete scenario listing for input to the consequence modeling stage. In addition to listing the credible fire, explosion, and toxic gas events for each scenario, the scenario listing should also include the following:

- Unique scenario reference.
- Description of the scenario.
- Equipment within the isolatable section.
- Location of the scenario.
- Representative process stream.
- The release phase (i.e., liquid, gas, or 2-phase).
- Process conditions (pressure and temperature).
- Hold-up inventory for liquid streams.

7.1.3 Evaluation Criteria

Generally, the evaluation criteria must be consistent with the selected assessment approach. Consequence tolerance criteria must be specified by hazard (explosion, fire, toxic). In contrast, risk tolerance criteria are generally specified as a total risk (including explosion, fire, and toxic hazards) when we study the risk to people. Still, the asset will be specified by hazard (explosion, fire, toxic).

For the spacing tables approach (a pre-determined consequence-based approach), and as mentioned before, the only scenario that can be considered in this approach is fire, the evaluation criteria are built-in, and the given separation distance in the spacing tables are the criteria that have to be met.

For the consequence-based approach, it is required to select certain criteria corresponding to specific scenarios to judge the potential impact on different targets (e.g., people, buildings, equipment, etc.) both onsite and off-site. The evaluation criteria are mainly focused on exposure consequences criteria as follows:

- Blast loads.
- Thermal flux and exposure time.
- Flammable gas concentration.
- Toxic concentration and exposure time.

A comprehensive description of the asset's EGPC consequence criteria (vulnerability) is fully described in the Fire and Explosion Risk Assessment (FREA) Guideline (EGPC-PSM-GL-009). Also, human vulnerability was fully identified in the Quantitative Risk Assessment (QRA) Guideline (EGPC-PSM-GL-008).

For the risk-based approach, the evaluation criteria will consider both the consequence and likelihood of a potential event. So, the event outcome frequency will be combined with its impacts to give the risk of the potential scenario. As mentioned before, the risk tolerance criteria are generally specified as a total risk (including explosion, fire, and toxic hazards) to study the risk to people. Still, for assets, it will be specified by hazard (explosion, fire, toxic). The risk evaluation criteria for people are mainly expressed in forms:

- Location-Specific Individual Risk (LSIR) is introduced as an ISO-Contours plot to represent the geographical variation of risk for a hypothetical individual positioned at a particular location for 24 hours per day, 365 days per year.
- Individual risk – the risk experienced by a person and commonly expressed in the form of Individual risk per Annum (IRPA).
- Societal (or Group) Risk – the risk experienced by the whole group of people exposed to the hazard. The Frequency-Number of fatalities curve (FN) and Potential Loss of Life (PLL) are commonly used to represent risk tolerability for societal risk.

A comprehensive description of EGPC risk criteria for people is described in the Quantitative Risk Assessment (QRA) Guideline (EGPC-PSM-GL-008).

For assets, the risk evaluation criteria are specified by hazard (explosion, fire, toxic). The general risk tolerability criteria are introduced in Table 1. A comprehensive description of EGPC risk criteria for an asset is described in Fire and Explosion Risk Assessment (FREA) Guideline (EGPC-PSM-GL-009).

Table 1. *Risk tolerability criteria.*

Risk Category	Risk [occurance/y]
Unacceptable Risk (Exceeding the Upper Tolerability Limit)	$\geq 10^{-3}$
ALARP	$< 10^{-3}$ & $>10^{-5}$
Broadly Acceptable Risk (Under the Lower Tolerability Limit)	$\leq 10^{-5}$

7.2 Evaluation Stage

This step focuses on assessing the different identified scenarios (explosion, fire, or toxic release) and then evaluating the extent to which the calculated results align with tolerance criteria. For the spacing tables approach, the process is very simple. The separation distances for the proposed layout should be compared to the required separation distance in the spacing tables, then decide to what extent the proposed layout aligned with these requirements. On the other hand, consequence-based and risk-based assessment approaches are more difficult compared to the spacing table approach. The assessments are typically based on specific modeling using recognized software.

As mentioned before, the outcomes of the consequence-based assessment are introduced in the form of hazard contour maps illustrating toxic gas dispersion, explosion overpressure, and fire radiation levels overlaid onto the Facility Plot Plan(s). Accordingly, and using the resultant hazard contours, it is easy to evaluate each receptor, based on its location, whether it is subjected to acceptable/tolerable impact or not based on the consequence acceptance criteria.

For the risk-based approach, the assessment outcomes are in a form depending on the kind of receptor (i.e., people or assets). For people receptors, the resultant risk is generally specified as a total risk (including explosion, fire, and toxic hazards). On the other hand, for asset receptors, the resultant risk is specified by hazard (explosion, fire, or toxic).

Similar to consequence assessment results, the risk-based assessment results for the asset are introduced in the form of hazard contour maps illustrating toxic gas dispersion, explosion overpressure, and fire radiation risk levels [occurrence/year] overlaid onto the Facility Plot Plan(s). On the other hand, risk-based assessment results are introduced in LSIR ISO-Contours plot, IRPA, FN curve, and PLL for people receptors. Accordingly, and using the resultant risk profiles for the different receptors, it is easy to evaluate each receptor based on its location, whether it is subjected to acceptable/tolerable risk or not based on the risk acceptance criteria.

7.3 Mitigation Planning and Implementation Stage

Once the impact or risk from different potential hazardous scenarios on various receptors is evaluated and understood, developing a mitigation plan for those not meeting defined threshold criteria or evaluation criteria is required. A mitigation plan is a structured framework that is developed to account for the facility's siting hazards by applying mitigation measures that might be active, passive, procedural, or a blend of them. The mitigation plan shall consider all applicable options to help decision-making.

Mitigation decisions should be made logically and justifiably. The core importance of a mitigation plan is its ability to help in the following:

- Develop a mitigation strategy.
- Organizing information presented in facility siting studies.
- Providing a basis to evaluate different alternatives.
- Prioritizing remediation activities.
- Identifying immediate high-impact/risk issues.
- Planning engineering and capital costs required to mitigate hazards.
- Develop a mitigation plan schedule.

Mitigation strategy may differ according to the selected assessment approach, i.e., consequence-based or risk-based. In the consequence-based approach, the mitigation strategy is built to determine whether the hazardous consequences are becoming acceptable or not. On the other hand, the risk-based approach introduces more mitigation options, and the mitigation strategy is built considering the risk ALARP demonstration concept.

The mitigation strategies development shall be based on the complete understanding of the results of the facility siting study, which are presented by hazards (explosion, fire, toxic release). A good understanding of the facility siting hazards will help define the main contributors in specific hazardous scenarios and locations subject to the highest impact/risk in the plant. This is an important precursor for the proper development of a mitigation strategy. In this respect, one mitigation strategy cannot serve all sources or locations; instead, it shall be assessed for each source or location.

Developing or identifying effective mitigation strategies can be achieved through a dedicated workshop in which the contribution of knowledgeable site personnel and external subject matter experts has done brainstorming for different options. A mitigation strategy may be developed considering one of the following mitigation options or a blend of them:

- Inherent safer design.
- Separation of Source and target (receptor).
- Protection of the target.
- Containment of the hazardous source.

During the development of the mitigation plan, other considerations like operation and maintenance requirements should be considered. Finally, the mitigation strategies or a combination of strategies shall be justified or balanced concerning the economic considerations. Developing a mitigation strategy that considers both safety and cost assessment is not a trivial task because of the two contradictory objectives' trade-offs.

Once the mitigation strategy has been decided, a simplified process for developing the mitigation plan shall be started. In this respect, quick wins or interim actions might be considered till they reach long-term fixation. Finally, whenever the decision has been made for a certain option, the plan shall document and report all the required mitigation measures along with their corresponding cost and schedule for implementation.

7.4 Facility Siting Revalidation and Managing Changes

The initial facility siting study is not the end of the goal to address the hazards associated with siting and layout of the facility throughout its lifetime. Sites are always changed both onsite and off-site. Off-site changes include urban community sprawl and industrial expansions. On the other hand, onsite changes include expansions of the existing facility, relocation of facility units or buildings, demolishing some units, changes in occupancy loads, changes in process conditions, and developed scenario types, e.g., explosion, fire, or toxic release, etc.

As a response to these changes and considering the concept of management of changes (MOC), the facility siting should be revalidated to be in line with these changes. Also, revalidation may come as a response to changing the facility owner. At the same time, the new one might have different policies and standards regarding the approaches used for conducting the facility siting study or even criteria used during the evaluation phase. Moreover, revalidation might be required to respond to the lesson learned from incidents and any subsequently developed standards or regulations that might impact the facility's siting. Generally, and since facility siting is considered part of process hazard analysis PHA, it must be revalidated at least every five years.

Revalidation of the facility siting study does not mean redoing the whole study. The primary objective is to review the results of the previously conducted study and identify, evaluate and control any new hazards that have been introduced to the previously conducted study. Like any PHA revalidation steps, the facility siting revalidation process includes gathering the information, then defining the scope, i.e., redo, partial redo, or revise and update for the initial study, and finally conducting the revalidation based on the defined scope. Generally, the hard part of any revalidation study is to set the scope of revalidation. Determining the scope was found to rely on different aspects, e.g., the number of changes, the scale of changes, deficiencies, etc.

Although the revalidation studies are initially seen as an opportunity to address large site changes both onsite and off-site, other benefits can be addressed, such as:

- Inclusion of various preliminary or detailed studies into a single revised facility siting study.
- Considering any risk or hazard mitigation implementations since the previous study was issued.

- Benchmarking the progress of the facility siting remediation plan.
- Evaluate and revise existing hazard criteria.
- Take advantage of modeling, software, and methodology improvements.
- Assessing the effectiveness of the Management of Change (MOC) system to identify changes to the site that influence facility siting.

The revalidation process will start by reviewing and reassessing the owner's policies and procedures, then consider incident outcomes and MOC events. This is followed by verifying any studies based on preliminary or final designs to match the current situation and condition. Finally, the outcomes of the revalidation study will guide us to continue with the existing remediation plan or make adjustments to account for new hazards.

8. Documentation

FSS report should include assessment approaches, scenario selection basis, analysis methodologies, the applicability of analysis methodologies, data sources used in the analysis, applicability of data sources, evaluation criteria, results of analysis, mitigation plans, recommendations, and tracking to assure that the required recommendations are get done but also report what was done and whether implement the recommendations exactly as were stated or implement alternative protective measures which might provide more risk reduction. This FSS report should be updated throughout the process's lifetime as changes are made.

9. Layout and Siting General Design Considerations

In general, the plant site shall be selected to be inherently safe (in terms of distance) concerning the adjacent receptors. Moreover, the selected site shall account for uncontrolled factors, e.g., tidal waves, floods, earthquakes, subsidence, adjacent oil and chemical plants, etc. Once the site has been selected, the initial plant arrangement is usually based on subdividing the overall site into general areas dedicated to processing units, utilities, services, and offices. Since each area or unit block generally has a rectangular shape, it is required to keep the maximum unit size to 300 ft × 600 ft (92 m × 183 m) for firefighting purposes and provide access roadways between blocks to allow each section of the plant to be accessible from at least two directions.

Generally, the plant vessels and equipment are separated by sufficient distances to permit safe operation and maintenance without wasting space. The plant arrangement and spacing should be done to reduce the effect of any factor that contributes to losses:

- Uncontrollable factors include site slope, climate, exposure to natural hazards, wind direction, and force. However, locating ignition sources upwind of potential vapor leaks or locating the tank farm downhill of essential units may reduce the loss potential from an explosion or fire. Figure 4 illustrates a good layout based on the prevailing wind.

- Controllable factors include process design parameters, process equipment design, unloading facilities, maintenance, spare parts supply, control logic and automation, ignition sources, fire protection design, spare production capacity, flammable liquid holdups, spill control, and the type of process.

Also, one of the important factors (controllable factors) that is required to address its effect while spacing and layout of any plant is the hazardous classification of each unit:

- Moderate hazard: This category includes processes, operations, or materials with limited explosion and moderate fire hazards. This class generally involves endothermic reactions and nonreactive operations, such as distillation, absorption, mixing, and blending flammable liquids. Exothermic reactions with no flammable liquids or gases also fit in this hazard group.
- Intermediate hazard: This category includes processes, operations, or materials with an appreciable explosion and moderate fire hazard. This class generally involves mildly exothermic reactions.
- High hazard: This category includes processes, operations, or materials with high explosion and moderates to heavy fire hazards. This class involves highly exothermic or potential runaway reactions and high-hazard product handling.

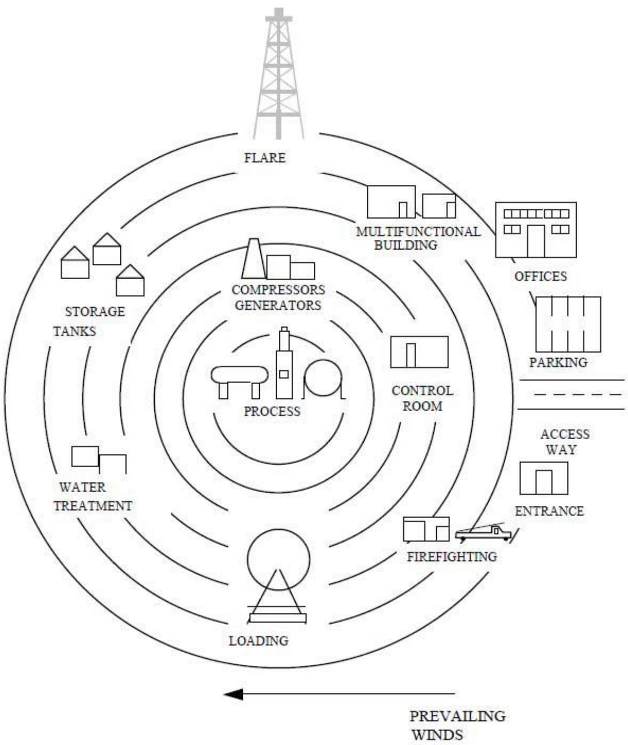

Figure 4. *Plant layout arrangement.*

During the initial plant arrangement, the following general design consideration should be considered:

- Operability—valves and instruments should be easily accessible to the operator, and operators should be able to move efficiently between plant areas.
- Control requirements—the selected means of control will impact the layout, e.g., whether centralized or distributed control is preferred.
- Ease of maintenance—a processing unit should be capable of being dismantled and, if necessary, removed for repair and/or routine calibration.
- Ease of construction—the locations of any items of process equipment likely to be delivered late in the construction program should be accessible without having to remove equipment already erected.
- Ease of commissioning—any extra facilities especially installed for commissioning should be accessible.
- Ease of future expansion and extension—foreseeable expansion should be possible with minimum interruption of production.
- Ease of escape and firefighting—in an emergency, operators must be able to leave quickly, and fire tenders must be able to approach close to the plant by more than one route.
- Operator safety—the operator must be protected from injury by (for example) protrusions, moving machinery, hot/cold surfaces, or escaping chemicals.
- Hazard containment—an explosion, fire, or toxic release occurring in one plant should be prevented (where reasonably practicable) from spreading to other equipment or plants, offices or accommodation, or off-site.
- Environmental impact—special consideration must be given to sites adjacent to residential areas. Obtrusive or nuisance-generating equipment should not be placed near such areas. Plants should be screened, if possible, by pleasant buildings in a landscaped setting.
- Insurance requirements—the business's insurers may have requirements that must be satisfied.
- Observation requirements—some industries will need to incorporate partitioned viewing and observation facilities into the layout.
- Wind direction—areas with a lower risk of release of hazardous materials and/or greater capacity for sustaining losses, such as offices, should be upwind of the prevailing wind direction, while areas with greater risk of release and/or lower

capacity for sustaining losses should be downwind of the prevailing wind direction. The wind rose diagrams can be useful in this context.

- Equipment stacking—some equipment may be necessary to utilize plot space effectively, but extensive stacking of equipment containing flammable materials increases the risk of serious fires. Generally, equipment with flammable contents should be stacked only at an equipment layout level (i.e., column overhead condensers and accumulators).
- Location of any off-site utilities—the existing locations of electricity, gas, and water supplies will have to be considered by the layout designer.

In addition to the general design consideration listed above, some unit-specific considerations need to be considered:

- **Process Units:**
  - Separate hazardous units from other hazardous units to avoid fire spread. "Separate" or "buffer" high-hazard units by using moderate or even lower-hazard units to reduce such exposure.
  - Locate equipment or structures common to multiple process units, such as large compressors and turbines, central control rooms, and fired heaters, to prevent a single event from impairing the overall operation and causing the extensive business interruption.
  - Wherever it does not conflict with loss control, consider accessibility for maintenance and operations in determining spacing and layout. Locate equipment needing frequent overhaul, maintenance, or cleaning at unit boundaries. Locate large vessels or equipment close to unit boundaries to allow easy crane access.
- **Intra-Unit Spacing:**
  - Do not group pumps and compressors handling flammable products in one single area. Do not locate them under pipe racks, air-cooled heat exchangers, and vessels. Orient pump and driver axes perpendicular to pipe racks or other equipment to minimize fire exposure in case of a pump seal failure. Separate high-pressure charge pumps from major process equipment and other pumps by at least 25 ft (7.5 m).
  - Locate compressors at least 100 ft (30 m) downwind from fired heaters and at least 30 ft (7.5 m) from any other exposed equipment. Do not locate lube oil tanks and pumps directly under any compressor to avoid unnecessary exposure.
  - Detach heaters and furnaces from the unit or locate them at one corner of the unit. Locate continuous ignition sources upwind of the process units.

- If increased spacing for very high-hazard equipment susceptible to explosions, such as reactors, is not possible, separate them from other areas by blast-resistant walls.
- Keep flammable product storage to a minimum within the process unit boundaries. Install tanks, accumulators, or similar vessels with flammable liquid holdups at grade, if possible.
- The preferred layout of a processing unit is a pipe rack located in the center of the unit, with large vessels and reactors located outwards of the central pipe rack. Place pumps at the outer limits of the process area. Limit equipment stacking in process structures to equipment with no fire potential. Slope the ground surface, so liquids drain away from the unit's center. Do not put drainage trenches under pipe racks. Put cable trays in the top tier of the pipe racks.

- **Utilities:**
  - Locate central services, such as cooling towers, boilers, power stations, and electrical substations, away from hazardous areas so they will not be affected by a fire or explosion within the plant nor be a source of ignition for any potential flammable liquid or gas release. Maintain adequate separation between different utility services because utility losses could lead to unsafe conditions in other plant units, possibly creating fires or explosions. Increase the reliability of the utilities by keeping the adequate spacing between boilers or generators.
  - Properly pressurize per NFPA 496 or separate electrical substations and motor control centers. Locate substations away from hazardous areas to increase the reliability of the power supplies should a loss occur. Bury electrical distribution cables limit their exposure to explosions, fires, storms, and vehicles and ease firefighting accessibility.

- **Control Rooms:**
  - Locate and construct control rooms, motor control centers, and other essential facilities to allow operators to shut down units under emergency conditions safely.
  - Locate the control building where it will not be exposed to fires or explosions. If separation is not feasible, design the building to withstand potential explosion overpressure. Where control rooms are exposed to fires or blast overpressures, locate the emergency loss control coordination center in a safe area.

- **Services:**
  - Keep warehouses, laboratories, shops, fire brigade stations, and offices away from process areas. Welding equipment, cars, trucks, and many people can become "uncontrollable ignition sources."

- **Loading and Unloading:**
  - Space loading racks, piers, and wharves well away from other areas due to large numbers of trucks, rail cars, barges, or ships carrying large amounts of flammable or combustible liquids.
  - Reduce plant traffic to ease emergency vehicle movement and limit accident hazards by locating loading and off-loading operations at the plant perimeter close to the entry gate.

- **Tank Farms:**
  - If there are adverse conditions, such as poor fire protection and water supply, difficult firefighting, poor accessibility, poor diking, or poor drainage, increase the spacing by at least 50%. Treat crude oil as a flammable liquid.
  - Do not group or dike different types of tanks and contents together.
  - Locate storage tanks at a lower elevation than other occupancies to prevent liquids or gases from flowing toward equipment or buildings and exposing them. Locate tanks downwind of other areas.
  - Arrange atmospheric storage tanks and pressure vessels in rows not more than two deep and adjacent to a road or accessway for adequate firefighting accessibility.
  - Since piping involved in ground fires usually fails within 10 or 15 minutes of initial exposure, locate an absolute minimum amount of piping, valves, and flanges within dikes. Install pumps, valve manifolds, and transfer piping outside dikes or impounding areas.
  - Where tanks over 500,000 bbl (80,000 m^3) are present, increase minimum distances to 1000 ft (305 m) spacing between them.

- **Atmospheric Storage Tanks:**
  - Classify internal floating roof tanks as floating roof tanks when internal pontoon floaters are provided. When plastic, aluminum, or steel pan is used in the construction of the internal floater, classify the tank as a cone roof tank for spacing purposes.
  - Floating roof tanks: Store crude oil and flammable liquids (Class I) in the floating roof or internal floating roof tanks. Arrange floating roof tanks over 300,000 barrels (47,700 m^3) in a single row. If multiple rows are necessary, space tanks farther than one diameter apart.
  - Cone roof tanks: Combustible liquids (Class II and III) may be stored in cone roof tanks with the following limitations or exceptions:

- Cone roof tanks over 300,000 barrels (47,700 m^3) present an unacceptable amount of potentially explosive vapor space, even if storing heavy oils. In such cases, use only floating roof tanks.
- Do not store liquids with boil-over characteristics in cone roof tanks larger than 150 ft (45.8 m) in diameter unless an inerting system is provided.
- Avoid storage of flammable liquids (Class I) in cone roof tanks. If cone roof tanks are used for flammable liquids storage, restrict the tank size to less than 150,000 barrels (23,850 m^3), provide an inert gas blanket, and increase the spacing.
- Space cone roof tanks storing Class IIIB liquids, operating at ambient temperatures, as "floating and cone roof tanks smaller than 3000 barrels (480 m^3)."
- Increase separation of cone roof tanks over 10,000 barrels (1590 m^3) containing combustible liquids stored at temperatures higher than 200°F (93°C).

- **Pressurized and Refrigerated Storage Tanks:**
  - Spheres and spheroids: Provide spacing between groups of vessels of at least 100 ft (30 m) or the largest tank diameter. Limit each tank group to a maximum of six vessels.
  - Drums and bullets: Limit horizontal pressurized storage vessels to not more than six vessels or 300,000 gals (1136 m^3) combined capacity in any one group. Provide at least 100 ft (30 m) or the largest tank diameter between groups. Align vessels, so their ends are not pointed toward process areas or other storage areas, as these vessels tend to rocket if they fail during a fire. Avoid multiple-row configurations. Do not locate pressurized storage vessels above each other.
- **Refrigerated dome roof tanks**:
  - Provide spacing between groups of vessels of at least 100 ft (30 m) or the largest tank diameter. Limit each tank group to a maximum of six vessels.
  - Provide greater spacing if exposed combustible insulation is used on the tanks.

10. References

[1] Jung S. Facility siting and plant layout optimization for chemical process safety. Korean Journal of Chemical Engineering. 2016 Jan; 33(1):1-7.

[2] Center for Chemical Process Safety (CCPS). Guidelines for Integrating Process Safety into Engineering Projects. New York, NY: American Institute of Chemical Engineers; 2018.

[3] API R. 752: Management of Hazards Associated with Location of Process Plant Permanent Buildings. Washington: API. 2009 Dec.

[4] Marx JD, Ishii BR. A comprehensive approach to API RP 752 and 753 building siting studies. Journal of Loss Prevention in the Process Industries. 2016 Nov 1; 44:748-54.

[5] Chemical Industries Association, Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites, Fourth Edition, 2020.

[6] API R. 753: Management of Hazards Associated with Location of Process Plant Portable Buildings. Washington: API. 2007 Jun.

[7] Sutton I. Plant design and operations. Gulf Professional Publishing; 2017 Jun 14.

[8] CCPS. Guidelines for Siting and Layout of Facilities. New York, NU, USA: Wiley; 2018.

[9] Vilas KR, Hereña PG, Shah JN. A vision of facility siting possibilities. Process Safety Progress. 2020 Sep; 39(3):e12180.

[10] Mannan S. Lees' Process Safety Essentials: Hazard Identification, Assessment, and Control. Butterworth-Heinemann; 2013 Nov 12.

[11] Klein JA, Vaughen BK. Process Safety: Key Concepts and Practical Approaches. CRC Press; 2017 Jun 1.

[12] Moran S. Process plant layout. Butterworth-Heinemann; 2016 Nov 16.

[13] Anderson TH, Hodge PR. A method to utilize facility siting techniques in the early phases of capital projects to reduce risks and safety spending. Journal of Loss Prevention in the Process Industries. 2017 Sep 1; 49:310-8.

[14] Prophet N. The benefits of a risk-based approach to facility siting. Process Safety Progress. 2012 Dec; 31(4):377-80.

[15] Shah JN, Shaffer DM. Risk-based approach for evaluating safety events in large plants. Process Safety Progress. 2012 Sep; 31(3):287-90.

[16] Ashiofu A, Bruce-Black J, Dyer J. Leveraging facility siting to optimize mitigation decisions. Process Safety Progress. 2020 Sep; 39(3):e12188.

[17] Mander TJ, Sarrack A, Diakow P, Bruce-Black J. Current state of the practice for facility siting studies. Process Safety Progress. 2020 Sep; 39(3):e12181.

[18] Martinez-Gomez J, Nápoles-Rivera F, Ponce-Ortega JM, Serna-González M, El-Halwagi MM. Siting optimization of facility and unit relocation with the simultaneous consideration of economic and safety issues. Industrial & Engineering Chemistry Research. 2014 Mar 12; 53(10):3950-8.

[19] Centre for Chemical Process Safety. Guidelines for Evaluating Process Plant Buildings for External Explosions, Fires, and Toxic Releases. John Wiley & Sons (US); 2012.

[20] Basheer A, Tauseef SM, Abbasi T, Abbasi SA. A new method for siting hazardous units in chemical process facilities which minimizes risk at least cost: RIDIMPUS. Journal of Failure Analysis and Prevention. 2018 Feb; 18(1):83-91.

[21] Michael W. The Facility Siting Cycle (Revalidation). 13th Global Congress on process safety. 2017.

[22] GAP.2.5.2: Oil and Chemical Plant Layout and Spacing. A Publication of Global Asset Protection Services LLC, 2015.

[23] PIP PNE00003: Process Unit and Offsites Layout Guide, 2019.

[24] Pemberton AW. Plant layout and materials handling. Macmillan International Higher Education; 2016.

[25] Barker GB. The engineer's guide to plant layout and piping design for the Oil and Gas Industries. Gulf Professional Publishing; 2018.

[26] NFPA 30 - Flammable and Combustible Liquids Code, 2021.

Annex A - CCPS Recommended Distance Tables for Siting and Layout of Facilities

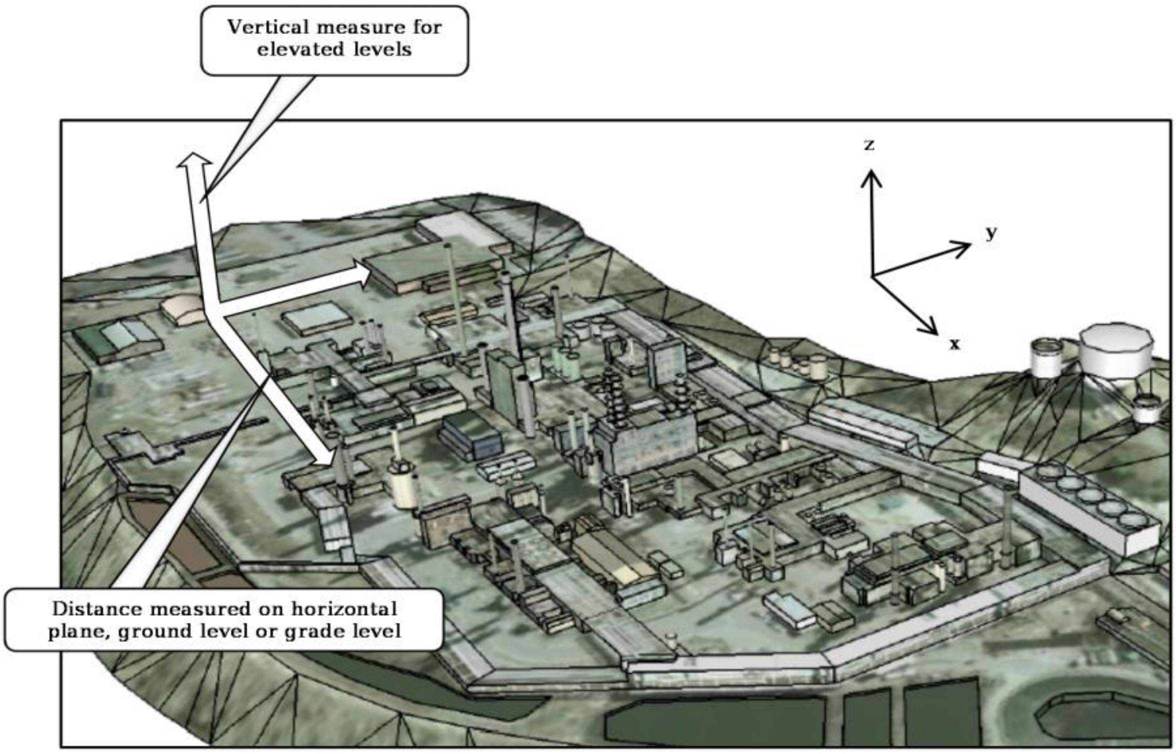

Figure A1. *A depiction of how distances are measured using the tables in Annex A.*

Reference: Center for Chemical Process Safety (CCPS), Guidelines for Siting and Layout of Facilities, 2018.

Table A1. *Typical facility and layout distances between process unit equipment for fire consequences.*

Metric Units - Issued 06-Apr-2018
CCPS Guidelines for Siting and Layout of Facilities

Ground level, horizontal plane, or grade distance (m.)

Distances

Changes are noted for the 2018 Edition with ***bold italicized*** distances

Distances	(Another) Process Unit Battery Limit	Property	ESD Valves - Manual	Fire Pumps	Hydrants, Monitors	Water Spray & ESD Activation Switches	Equip handling non-flammable, non-combustible, non-toxic materials	Reactors and Desalters	(Another) Tower, Drum, Knock Out Pot, or In-process Storage Tank	Air cooled heat exchangers - process	Boilers, Air Compressors, Power Generation (Utility Area)	(Another) Cooling Tower	Heat Exchangers	Fired Heaters, Cracking Furnaces	Gas Compressor, Expanders	Pumps handling Flammables > autoignition or self-igniting	Pumps handling Flammables < autoignition or non-self-igniting	Central Loading Racks for Trucks and Rail Cars	Liquefied Flammable Gas (LFG) Loading Racks for Trucks and Rail Cars	Main Pipe racks (piping not associated with unit)
Boundaries																				
Process Unit Battery Limit	***30***																			
Property	60																			
Emergency Equipment																				
ESD Valves - Manual	15	NM																		
Fire Pumps	***75***	NM	NM																	
Hydrants, Monitors	NM	NM	NM	NM																
Water Spray & ESD Activation Switches	15	NM	NM	NM	NM															
Process Vessels / Equipment																				
Equip handling non-flammable, non-combustible, non-toxic materials	NA	NM	NM	NM	NM	NM														
Reactors and Desalters	NA	60	15	60	15	15	NM													
Towers, Drums, Knock Out Pots, In-process Storage Tanks	NA	60	15	60	15	15	NM	***8***	***8***											
Heat Transfer Equipment																				
Air cooled heat exchangers - process	NA	60	15	60	15	15	NM	***6***	***6***											
Boilers, Air Compressors, Power Generation (Utility Area)	30	30	15	***30***	15	15	NM	30	30	30										
Cooling Towers	***30***	30	15	***30***	15	15	NM	30	30	30	30	***15***								
Heat Exchangers	NA	60	15	60	15	15	NM	***8***	***8***	5	30	30								
Fired Heaters, Cracking Furnaces	NA	60	15	60	15	15	NM	15	15	15	30	30	15							
Rotating Equipment																				
Gas Compressor, Expanders	NA	60	15	60	15	15	NM	***8***	***6***	***6***	30	30	5	***15***						
Pumps handling Flammables (> autoignition or self-igniting materials)	NA	60	15	60	15	15	NM	5	5	5	30	30	5	15	5					
Pumps handling Flammables (< autoignition or non-self-igniting materials)	NA	60	15	60	15	15	NM	5	5	5	30	30	5	15	5	NM				
Transfer Equipment (Structures)																				
Central Loading Racks for Trucks and Rail Cars (see Liquid Flammable Gas below)	***75***	30	15	60	15	15	NM	60	60	60	60	50	30	60	60	60	***60***			
Liquefied Flammable Gas (LFG) Loading Racks for Trucks and Rail Cars	***75***	110	15	***75***	15	15	NM	***75***	***75***	75	75	75	75	75	75	75	***75***	***50***		
Main Pipe Racks (piping not associated with unit)	NM	30	NM	15	NM	NM	NM	15	15	NM	15	15	5	15	15	15	15	15	15	
Process Pipe Racks	NM	60	NM	60	NM	NM	NM	***5***	***5***	NM	30	30	***5***	15	***6***	5	***5***	60	60	NM

Notes for Table A1. Typical facility and layout distances between process unit equipment for fire consequences	
1	Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
1a	Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. (This could be on the corner of a block.)
1b	Distances between equipment to equipment: Measure the shortest distance between "points" or closest edge.
2	These tables do not apply to enclosed process units.
3	The typical distances cited in Table A1 are based on potential fire consequences and processes with "Intermediate Hazards" [GAP 2.5.2.A]. Greater distances may be required based on modeled explosions and toxic releases.
4	Different distances may be warranted based on site-specific hazards and risks. Distances may be reduced or increased based on risk analysis or when additional layers of protection are implemented (such as fire protection or emergency shutdown systems). Where unusual conditions require closer distances, appropriate risk reduction measures should be considered.
NA	Not applicable.
NM	No minimum distance requirement has been established for fire consequences. Use engineering judgment for distances and provide sufficient space for maintenance and firefighting access.

Table A2. *Typical facility and layout distances between tanks and process unit equipment for fire consequences.*

Metric Units - Issued 06-Apr-2018 *CCPS Guidelines for Siting and Layout of Facilities*	**Ground level, horizontal plane, or grade distance (m.)**							
						Portable Containers		
Distances Changes are noted for the 2018 Edition with ***bold italicized*** distances	Atmospheric and Low Pressure Storage (non-boilover) less than 40,000 L	Atmospheric and Low Pressure Storage (non-boilover) greater than 40,000 L	Atmospheric Storage (boilover potential)	Pressurized Storage	Refrigerated Flammable Storage	Pressurized flammable gases (e.g. LPG and LFG) < 250 kg. total storage	Pressurized flammable gases (e.g. LPG and LFG) 250 kg. to 1 tonne total storage	Pressurized flammable gases (e.g. LPG and LFG) 1 to 5 tonne total storage *
Boundary to Tank Distances								
Property Line or Boundary with adjacent industry	8	30	60	60	60	3	15	30
Public Access Right of Way (e.g., roads, rail lines, and parks)	15	30	60	75	75	3	15	30
Off-site populations (e.g., businesses/offices, residential housing)	15	75	150	110	75	8	30	75
Process Unit Battery Limits (except portable containers related to the process)	8	***60***	***60***	***90***	***60***	8	15	30
Utility Battery Limits (except portable containers related to the utility)	8	***60***	***60***	***90***	***60***	8	15	30
Equipment to Tank Distances								
Fire water pumps (except the fuel source for the pump)	15	***75***	***75***	***90***	***75***	30	60	60
ESD and mitigation system activation points (activation point must be outside of tank diked area.)	15	15	15	15	15	15	15	15

* Greater than 5 tonnes should be treated as Pressurized Storage

Notes for Table A2. Typical facility and layout distances between tanks and process unit equipment for fire consequences	
1	Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
1a	Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. (This could be on the corner of a block.)
1b	Distances between equipment to equipment: Measure the shortest distance between "points" or closest edge.
2	These tables do not apply to enclosed process units.
3	The typical distances cited in Table A2 are based on potential fire consequences and processes with "Intermediate Hazards" [GAP 2.5.2.A]. Greater distances may be required based on modeled explosions and toxic releases.
4	Different distances may be warranted based on site-specific hazards and risks. Distances may be reduced or increased based on risk analysis or when additional layers of protection are implemented (such as fire protection or emergency shutdown systems). Where unusual conditions require closer distances, appropriate risk reduction measures should be considered.
NA	Not applicable.
NM	No minimum distance requirement has been established for fire consequences. Use engineering judgment for distances and provide sufficient space for maintenance and firefighting access.

Table A3. *Typical facility and layout distances between tanks of hazardous materials for fire consequences.*

	D = Diameter (larger of two tanks); Ground level, horizontal plane, or grade distance (m.)									
Tank Type Changes are noted for the 2018 Edition with ***bold italicized*** distances	Floating & Cone Roof Tanks (< 3,000 bbl.)	Floating & Cone Roof Tanks (3,000 to10,000 bbl.)	Floating Roof Tanks (10,000 to 300,000 bbl.)	Cone Roof Tanks, Inerted Class I prod. (10,000 to 300,000 bbl.) *	Cone Roof Tanks, Class II & III Product (10,000 to 300,000 bbl.)	Floating & Cone Roof Tanks (>300,000 bbl.)	Low Pressure Storage (up to 100,000 Pa) < 40,000 L	Low Pressure Storage (up to 100,000 Pa) > 40,000 L	High Pressure Storage (Bullet, Spheres)	Refrigerated Dome Roof Storage Tanks
Floating & Cone Roof Tanks (< 3,000 bbl.)	0.5 x D									
Floating & Cone Roof Tanks (3,000 to10,000 bbl.)	0.5 x D	0.5 x D								
Floating Roof Tanks (10,000 to 300,000 bbl.)	1 x D	1 x D	1 x D							
Cone Roof Tanks, Inerted Class I Prod. (10,000 to 300,000 bbl.)	1 x D	1 x D	1 x D	1 x D						
Cone Roof Tanks, Class II & III Product (10,000 to 300,000 bbl.)	0.5 D	0.5 D	1 x D	1 x D	0.5 D					
Floating & Cone Roof Tanks (>300,000 bbl.)	1 x D	1 x D	1 x D	1 x D	1 x D	1 x D				
Low Pressure Storage (up to 100,000 Pa) < 40,000 L	1 x D 15 m. min	1 x D 15 m. min	1 x D 15 m. min	1 x D 15 m. min	1 x D 15 m. min	1 x D 15 m. min	1 x D 15 m. min			
Low Pressure Storage (up to 100,000 Pa) > 40,000 L	1.5 x D 30 m. min	1.5 x D 30 m. min	1.5 x D 30 m. min	1.5 x D 30 m. min	1.5 x D 30 m. min	2 X D	1 x D 15 m. min	1 x D 15 m. min		
High Pressure Storage (Bullet, Spheres)	2 x D 30 m. min	2 x D 30 m. min	2 x D 30 m. min	2 x D 30 m. min	2 x D 30 m. min	2 X D	2 x D 30 m. min	2 x D 30 m. min	1 x D **30 m. min**	
Refrigerated Dome Roof Storage Tanks	2 x D **50 m. min**	2 x D **50 m. min**	2 x D **50 m. min**	2 x D **50 m. min**	2 x D **50 m. min**	2 X D	2 x D 30 m. min	2 x D 30 m. min	1 x D 30 m. min	1 x D 30 m. min

Notes for Table A3. Typical facility and layout distances between tanks of hazardous materials for fire consequences	
1	Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
1a	Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. (This could be on the corner of a block.)
1b	Distances between equipment to equipment: Measure the shortest distance between "points" or closest edge. (For distances between tanks and vessels, measure the shortest distance from shell to the shell)
2	These tables do not apply to enclosed process units.
3	The typical distances cited in Table A3 are based on potential fire consequences and processes with "Intermediate Hazards" [GAP 2.5.2.A]. Greater distances may be required based on modeled explosions and toxic releases.
4	Different distances may be warranted based on site-specific hazards and risks. Distances may be reduced or increased based on risk analysis or when additional layers of protection are implemented (such as fire protection or emergency shutdown systems). Where unusual conditions require closer distances, appropriate risk reduction measures should be considered.

Table A4. *Typical facility and layout distances between onsite buildings for fire consequences.*

	Ground level, horizontal plane, or grade distance (m.)											
On-Site Building	Property Line or Boundary	Process Unit containing flammables	Utilities	Process Equipment	Main Pipe Racks	Process Unit Pipe Racks	Atmospheric & Low Pressure Flammable & Combustible Storage Tanks (up to 100,000 Pa) <40,000 L	Atmospheric & Low Pressure Flammable and Combustible Storage Tanks (up to 100,000 Pa) >40,000 L	High Pressure Flammable Storage	Any Loading and Unloading Racks (non-LPG and LFG)	Any LPG and LFG Loading and Unloading Racks	***Refrigerated Storage***
Office, Lab, Maintenance, Warehouse	NM	***60***	30	60	30	30	***60***	75	110	***60***	***110***	***60***
Fire Station, Medical, Emergency Command Center	NM	***60***	***30***	60	30	30	***60***	***90***	110	***60***	***110***	***60***
Substation, Motor Control - Main (Note 5)	15	***30***	***30***	60	30	30	***60***	***90***	110	***60***	***110***	***110***
Substation, Motor Control - More than One Process Unit (Notes 5, 6)	15	***30***	***30***	15	8	8	30	75	75	***60***	***75***	***110***
Substation, Motor Control - One Process Unit (Note 5)	15	***30***	***30***	15	***8***	***8***	15	75	75	***60***	***75***	***110***
Control Room - Main	NM	***60***	30	***60***	30	30	***60***	75	110	***60***	***110***	***110***
Control Room - More than One Process Unit	NM	***60***	30	30	10	30	30	75	110	***60***	***110***	-
Control Room - One Process Unit	NM	***60***	30	15	***10***	***10***	15	75	75	***60***	***75***	-
Satellite Instrument House (SIH) - More than One Process Unit (Note 5)	NM	***30***	30	30	10	30	30	75	110	***60***	***110***	-
Satellite Instrument House (SIH) - One Process Unit (Note 5)	NM	***30***	30	15	3	3	15	75	75	***60***	***75***	-
Shelter (operations weather overhang) (Note 7)	NM	15	-	-	-	-	-	-	-	-	-	-
Shelter (dedicated to truck or barge unloading, sampling stations) (Note 7)	NM	15	-	-	-	-	-	-	-	-	-	-
Portable buildings	*Industry guidance on the siting of portable buildings and tents is provided in the literature [i.e., API RP 753, API RP 756, and API TR 756-1]. (Note: Portable buildings include temporary buildings or trailers used to house people or store equipment.)*											

Notes for Table A4. Typical facility and layout distances between onsite buildings for fire consequences	
1	Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
1a	Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. (This could be on the corner of a block.)
1b	Distances between equipment to equipment: Measure the shortest distance between "points" or closest edge.
2	These tables do not apply to enclosed process units.
3	The typical distances cited in Table A4 are based on potential fire consequences and processes with "Intermediate Hazards" [GAP 2.5.2.A]. Greater distances may be required based on modeled explosions and toxic releases.
4	Different distances may be warranted based on site-specific hazards and risks. Distances may be reduced or increased based on risk analysis or when additional layers of protection are implemented (such as fire protection or emergency shutdown systems). Where unusual conditions require closer distances, appropriate risk reduction measures should be considered.
5	Substations and Satellite Instrument Houses (SIH) - normally temperature controlled (i.e., air-conditioned) buildings. Caution: SIHs are typically considered "unoccupied" for facility siting studies. If personnel use Substations or SIHs, evaluate them as "occupied."
6	No direct comparable table for Substations in GAP 2.5.2. Interpretation for "More Than One Process Unit" is the same as "Main."
7	The distinction between shelters: a simple weather overhang typically has three walls, a roof, and no windows or doors, whereas truck, railcar, and barge unloading "shelters" are used for the paperwork and protection of the unloading personnel from the weather during the transfer of the materials (rain, cold or hot temperatures).
NM	No minimum distance requirement has been established for fire consequences. Use engineering judgment for distances and provide sufficient space for maintenance and firefighting access.

A5. *Typical facility and layout distances between other types of equipment and operations for fire consequences.*

Ground level, horizontal plane, or grade distance (m.)		
Spacing From	**To**	**Minimum** Distances
Process-unit battery limit	On-site unrestricted roadway	15
Emergency shutdown valve, manually operated	Edge of a potential pool fire involving the equipment the valve is isolating	15
Wastewater separators	Equipment handling flammables, continuous ignition sources	30
Multi-unit blowdown drums (Note: due to historical accidents associated with these, the current trend is to seek alternate, safer designs)	Process Unit Battery Limits	30
	All other facilities	60
Transfer pumps, Out Side Battery Limits (OSBL), handling flammable and combustible liquids	Unit Substation (Single Unit)	***15***
	Unit Substation (Multiple Units)	***30***
	Main Substation	***60***
Off-property main railway	Equipment and storage tanks handling flammables	60
On-property main railway	Equipment and storage tanks handling flammables	30
On-property railway loading or platform	Equipment and storage tanks handling flammables	***60***
On-property railway spur	Equipment and on-site storage tanks handling flammables	8
	Off-site storage tanks handling flammables	30
Wharves handling flammable liquids	Equipment handling flammables	60
	Continuous sources of ignition	75
Wharves handling LPG and LFG	All other facilities	75
Cooling Tower (large, multi-cell, combustible)	Office, Lab, ***Warehouse,*** Emergency Center, Main Substation, Main Control Room	***60***
	Single or Multi-Unit Substation, Single or Multi-Unit Control Room, or Satellite Instrument House	***30***
	Flares	***See Table A7***
Unit Substations	Process equipment handling Flammables	***30***
Electrical switch racks supporting shutdown or emergency functions	Equipment handling flammables	6
	Fired heaters or gas compressors	15
Fire training areas	All other facilities	60

Notes for Table A5: Typical facility and layout distances between other types of equipment and operations for fire consequences	
1	Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
1a	Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. (This could be on the corner of a block.)
1b	Distances between equipment to equipment: Measure the shortest distance between "points" or closest edge
2	These tables do not apply to enclosed process units
3	The typical distances cited in Table A5 are based on potential fire consequences and processes with "Intermediate Hazards" [GAP 2.5.2.A]. Greater distances may be required based on modeled explosions and toxic releases.
4	Different distances may be warranted based on site-specific hazards and risks. Distances may be reduced or increased based on risk analysis or when additional layers of protection are implemented (such as fire protection or emergency shutdown systems). Where unusual conditions require closer distances, appropriate risk reduction measures should be considered.
NA	Not applicable.
NM	No minimum distance requirement has been established for fire consequences. Use engineering judgment for distances and provide sufficient space for maintenance and firefighting access.

Table A6. *Typical facility and layout distances for emergency response and operations accessibility.*

Ground level, horizontal plane, or grade distance		
Spacing From	**To**	**Maximum Distances (meter)**
One process unit access way	Another access way	60
Fire hydrants protecting process units	Another fire hydrant	60
Fire hydrants in tank farms	Another fire hydrant	60
Firewater Monitors	Fire risk area	15
Access way	Access way	30
Note: Access way should be at least 6 m. wide; Basis for this is a distance of a typical fire hose length of 30 m.		

Notes for Table A6. Typical facility and layout distances for emergency response and operations accessibility	
1	Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
1a	Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. (This could be on the corner of a block.)
1b	Distances between equipment to equipment: Measure the shortest distance between "points" or closest edge
2	Different distances may be warranted based on site-specific hazards and risks. Distances may be reduced or increased based on risk analysis or when additional layers of protection are implemented (such as fire protection or emergency shutdown systems). Where unusual conditions require closer distances, appropriate risk reduction measures should be considered.

Table A7. *Typical facility and layout distances for flare systems.*

Ground level, horizontal plane, or grade distance		
Spacing From	**To**	**Minimum Distances (meter)**
Elevated and grade level flares and burn pits (if radiation level calculations do not exist)	All other facilities	150
Enclosed ground flares	Property line, equipment handling flammables	30

Table A7. *Continued.*

Guidelines for Radiant Heat Calculations	
Permissible design level kW/m2 (Btu/h·ft2)	**Conditions**
1.58 (500)	Maximum radiant heat intensity at any location where personnel with *appropriate clothing* (Note 1) can be continuously exposed
4.73 (1,500)	Maximum radiant heat intensity in areas where emergency actions lasting 2 min to 3 min can be required by personnel without shielding but with *appropriate clothing* (Note 1)
6.31 (2,000)	Maximum radiant heat intensity in areas where emergency actions lasting up to 30 s can be required by personnel without shielding but with *appropriate clothing* (Note 1)
9.46 (3,000)	Maximum radiant heat intensity at any location where urgent emergency action by personnel is required. When personnel enter or work in an area with the potential for radiant heat intensity greater than 6,31 kW/m2 (2 000 Btu/h·ft2), then radiation shielding and/or special protective apparel (e.g. a fire approach suit) should be considered.
	SAFETY PRECAUTION — It is important to recognize that personnel with *appropriate clothing* (Note 1) cannot tolerate thermal radiation at 6.31 kW/m2 (2,000 Btu/h·ft2) for more than a few seconds.

Note for Radiant Heat Calculation Guidelines
Appropriate clothing consists of a hard hat, long-sleeved shirts with buttoned cuffs, work gloves, long-legged pants, and work shoes. Appropriate clothing minimizes direct skin exposure to thermal radiation.

Table A7. *Continued.*

Thermal Radiation kW/m2 (Btu/h·ft2)	**Effect**
1.5 (500)	Fire fighters can operate for long duration under normal conditions
5 (1,500)	Fire fighters can fight fire with normal protective clothing for a short time
8 (2,500)	Fire fighters can fight fire for short time if special cooled protective clothing is worn
	Fire unlikely to propagate beyond this point, even if no fire water applied
12 to 30 (4,000 to 9,500)	Fire should not propagate beyond this point if sufficient fire water applied
36 (11,000)	Fire likely to propagate no matter how much fire water applied

Notes Typical facility and layout distances for flare systems
Distances are measured with the shortest line from one point to another point at ground level, horizontal plane, or grade. Refer to Figure A1 for the "x,y,z" perspective. The "points" defined for measuring the distances are as follows:
Distances between one block (e.g., a building or structure) to another block or boundary: Measure the shortest distance between the edge of the block and the other block or boundary. This could be on the corner of a block. For Flare calculations, the distance is measured from the perimeter of the calculated circle.