GUIDELINES FOR

FACILITY SITING AND LAYOUT

CCPS
CENTER FOR CHEMICAL PROCESS SAFETY
An AIChE Industry Technology Alliance

Center for Chemical Process Safety
of the
American Institute of Chemical Engineers
3 Park Avenue, New York, New York 10016-5991

WILEY-INTERSCIENCE

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Preface

The Center for Chemical Process Safety (CCPS) The Center for Chemical Process Safety (CCPS) was established in 1985 by the American Institute of Chemical Engineers for the express purpose of assisting industry in avoiding or mitigating catastrophic chemical accidents. To achieve this goal, CCPS has focused its work on four areas:

- Establishing and publishing the latest scientific, engineering and management practices for prevention and mitigation of incidents involving toxic, flammable, and/or reactive materials
- Encouraging the use of such information by dissemination through publications, seminars, symposia, and continuing education programs for engineers
- Advancing the state of the art in engineering practices and technical management through research in prevention and mitigation of catastrophic events
- Developing and encouraging the use of undergraduate engineering curricula that will improve the safety knowledge and consciousness of engineers

This book outlines a process for finding an optimal location for a chemical or petroleum processing site and then arranging the units and equipment. It provides comprehensive guidelines on how to select a site, how to recognize and assess long-term risks, and how to lay out the facilities and equipment within that site. A survey guide is provided to aid site selection teams in obtaining necessary data to select a new site. Site layout and equipment spacing guidelines are provided based on historical and current data including industry practices and standards. Spacing tables are provided which can be used as a starting point in laying out a site. Case histories and examples are included to illustrate both the appropriate manner in which to address facility siting and layout as well as the consequences when the effort is inadequate.

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1 Introduction

1.1. Objectives

The cost, complexity, and safety of process operation and maintenance is highly dependent on site location and layout. Building inherent safety into a site generally reduces both the cost and complexity. Siting and layout are among the earliest steps in design, and are quite costly to modify once the site is constructed. Optimum siting and layout minimizes material and construction costs, but more importantly, minimizes the risk of losses throughout the site's life cycle.

What principles do you use to decide on the location and layout of a new or expanded site? What information do you need to consider before selecting a site location? How do you maximize inherently safer design with minimal impact on cost and schedule? How do you manage siting issues when limited space is available? How to you address security concerns in a new site?

This book addresses siting and layout in terms of the overall process of finding an optimal location for the site and then arranging the units and equipment. It provides comprehensive guidelines on how to select a site, how to recognize and assess long-term risks, and how to lay out the facilities and equipment within that site. Site layout and equipment spacing guidelines are provided based on current industry practices and standards.

This book is applicable to the following types of facilities.

- Large and small.
- Petroleum and chemical facilities and other industries using petroleum or chemical products
- Within and outside of the US.
- Grassroots sites, brownfield sites, and expansions within a site.
- Open air sites
- Processes enclosed in a building (in terms of siting the building, not in terms of process equipment layout inside of the building)

The objectives of these guidelines are to provide guidance on the following points.

- Approaching siting and layout from a safety perspective
- Assembling a site selection team, compiling the issues they need to consider, and determining what data they should collect (This information is needed for selecting a location for a new grassroots site, a brownfield site, or an expansion within a site.)
- Balancing infrastructure, environmental, security, population, and process risk considerations with each other in the site selection process.
- Anticipating outside factors that may affect the project cost and schedule.
- Fitting a new expansion within an existing unit and compensating for limited spacing by taking risk mitigation measures.
- Maximizing inherently safer design in siting and layout by gathering data and conducting hazard analysis in the conceptual design and layout stages of the site design.
- Maximizing ease of operations and maintenance as well as minimizing operating and maintenance risks to personnel and the surrounding site through layout and equipment spacing.

This book will benefit anyone responsible for making or advising on siting decisions. Project developers will find the information they need to collect and/or develop in order to select a site. Planners and those who evaluate the economic justification for a site will learn of the potential safety and risk impacts of siting decisions. Designers and engineers will appreciate the technical details included in specifics given on plant and equipment layout and spacing.

1.2. How To Use This Book

This book may be considered the starting point for establishing the criteria needed to make decisions on the location of a grass roots site or new unit within an existing site, as well as the basic equipment layout and spacing within the site. This book discusses the sequential steps taken in this process as outlined in Figure. 1-1.

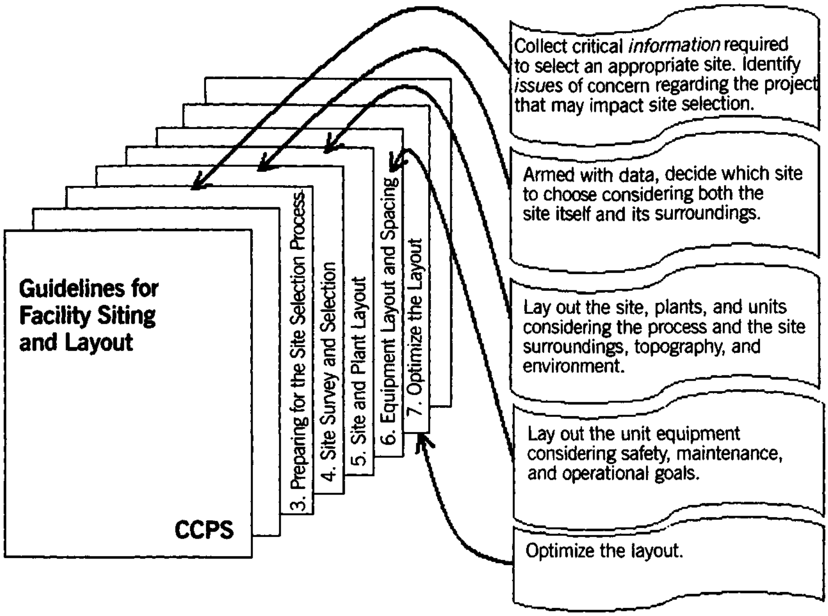

Figure 1-1. *Guidelines Book Flowchart*

It is important to use consistent vocabulary when discussing the components and subcomponents of a process complex. Figure 1-2 shows the terminology used in this book.

A **unit** is a collection of process and/or manufacturing equipment that is focused on a single operation. For example, a refrigeration unit supplying a frozen food plant, a crude distillation unit, a water treating unit chlorinating waste-water effluent from a waste disposal facility, a polyethylene unit, or a batch reactor train.

A **plant** is a collection of process units with similar process parameters or related by feeding or taking feed from each other. For example, a fuels plant which produces materials for blending gasoline, a lubricating oil blending plant, a tank farm area supporting a refinery, chemical site or both, a wharf receiving raw materials and loading products, a polypropylene processing and plastic pellet silo storage area, a pipeline pumping station.

A **site** is a collection of **plants** typically owned by a single entity. A site may have its own support facilities or share them with another site. Support facilities may include parking, offices, maintenance, and warehousing facilities, firehouse, medical, transportation, and security facilities. Examples of

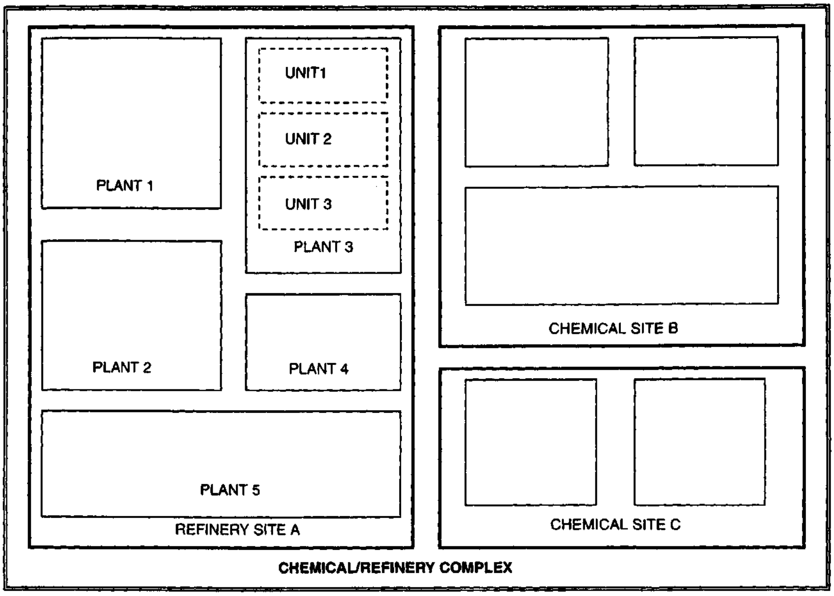

Figure 1-2 *. Guidelines Terminology*

a site may include a petroleum refinery, or a manufacturing facility that produces a variety of products such as paints, synthetic rubbers for tire manufacturing, or petrochemicals.

A **complex** is a collection of **sites** that may or may not be owned by the same business entity. A site within a complex may feed or take feed from another site within the same complex or be totally independent.

This book provides a selection of examples throughout the text and case histories in Chapter 8. These case histories and examples serve to illustrate both the appropriate manner in which to address facility siting and layout as well as the consequences when the effort is inadequate. These case histories include actual events, scenarios based on real events but modified to emphasize a point, and purely illustrative examples.

1.3. Layers of Safety

Siting and layout provide a fundamental aspect of risk management. It separates sources of potential fire, explosion, or toxic incidents from adjacent areas that might become involved in the incident or be harmed by its potential consequences. This is also a key component in inherently safer design.

Inherently safer strategies can impact a potential incident at various stages. The most effective strategy will prevent initiation of the incident. Inherently safer design can also reduce the potential for an incident to escalate. Lastly, an inherently safer strategy can limit the incident sequence before there are major impacts on people, property, or the environment. (CCPS, 1996, no. 23)

There are many challenges to the ability to site and lay out a plant as will be discussed in these guidelines. Layers of safety are utilized to compensate for less than desired spacing and to implement additional aspects of inherently safer design. This use of layers of safety or layers of protection is a traditional risk management approach and is illustrated in Figure 1-3. These layers may include the inherently safer strategies of preventing the incident, minimizing escalation, and minimizing impact. The layers may include using a less hazardous process, separation distances, operator supervision, control systems, alarms, interlocks, physical protection devices, and emergency response systems (CCPS, 2001).

Consider layers from inside to outside following inherently safer concepts:

1. Process design
2. Separation distance
3. Safety and process devices, instruments, alarms, and controls
4. Administrative processes and controls

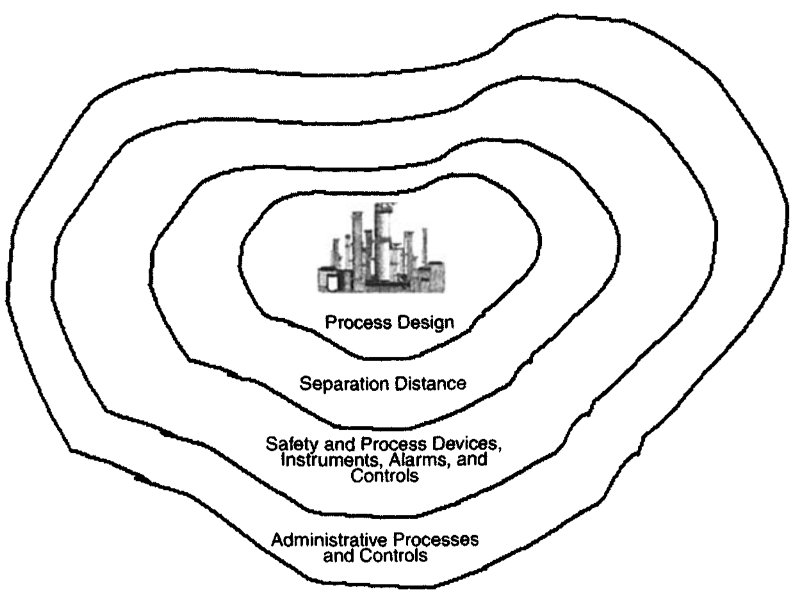

Figure 1-3. Layers of Safety

1.4. References

1.4.1. CCPS Publications

Where appropriate, reference is made to other CCPS books for additional guidelines and methodology for specific applications. The most relevant CCPS Publications are listed here.

Guidelines for Evaluating Process Plant Buildings for External Explosions and Fires. Chapter 5 provides general guidance on locating buildings within the site with relation to other facilities (CCPS, 1996, no. 22).

Guidelines for Chemical Process Quantitative Risk Assessment and *Guidelines for Hazard Evaluation Procedures* provide additional guidance on conducting risk assessments. Risk assessment may be applied in many siting decisions (CCPS, 2000 and CCPS, 1992).

Inherently Safer Chemical Processes—A Life Cycle Approach discusses inherently safer design (CCPS, 1996, no. 23).

Layer of Protection Analysis: Simplified Process Risk Assessment describes layer of protection analysis (CCPS, 2001).

Guidelines for Analyzing and Managing Security Vulnerabilities of Fixed Chemical Sites describes security measures and analysis techniques (CCPS, 2002).

Guidelines for Fire Protection in Chemical, Petrochemical, and Hydrocarbon Processing Facilities describes fire protection measures that may be applied to the site and the equipment on the site (CCPS, 2003, no.29).

1.4.2. Other References

Where appropriate, this book references pertinent American Petroleum Institute (API) Practices, National Fire Protection Association (NFPA) Codes, and American Society of Mechanical Engineers (ASME) Codes. References are generally made to US codes and practices; recognizing that when the site is located outside the United States, there may be non-US codes and regulations that override the references in this book. A complete list of all referenced industry practices, including applicable CCPS books, is included in the References at the end of this book.

2 Management Overview

Example

In 1969, the site started to produce the pesticide SEVIN. Methyl isocyanate (MIC), an intermediate chemical, was imported from another location. In the late 1970s, the site added a MIC production unit. [Originally] the site was located approximately 3–4 miles outside the city center. At the time of the incident, the site employed 630 people. The city had a population of 900,000 people with a community of squatters situated immediately outside of the site boundary. Just after midnight there was an accidental release of approximately 40 metric tons of MIC into the atmosphere. Thousands of people lost their lives, hundreds of thousands were injured, and significant damage was done to livestock and crops. The plant was located in Bhopal, India.

[Reproduced with the permission of the United States Chemical Safety and Hazard Investigation Board, CSB, 1999.]

Lesson

The siting of a new facility and the purchase of surrounding land to control community encroachment is critical to risk management.

2.1. Implications of Siting and Layout

Appropriate siting and layout establishes a foundation for a safe and secure site. A site that is well laid out will have a lower risk level than a poorly laid out site. The potential for toxic impacts, fire escalation, and explosion damage will be lower. The risk to personnel and the surrounding community will be reduced. Additionally, maintenance will be easier and safer to perform. However, these benefits do not come without associated costs. Separation distances translate to real estate that costs money. Tradeoffs between initial capital investment, life cycle costs, and risk reduction are inherent in siting and layout decisions.

2.2. Management of Risks

Consideration of siting and layout is an important aspect of risk management. Managers must address several types of business risks, including the risks from costly potential incidents. The approach in this book is to find a site location and layout that will minimize risk to site and community personnel and property while maximizing the ease of safe operation and maintenance. This approach may reduce the total life cycle cost. The guidance in this book is aimed at maximizing the use of inherently safer strategies in the design to build in safety and risk reduction.

Inherently safer design strategies may prevent initiation of an incident, reduce the potential for incident escalation, and limit the incident consequence before there are major impacts on people, property, or the environment (CCPS, 1996, no. 23). Appropriate siting and layout separates sources of potential fire, explosion, or toxic incidents from adjacent areas that might become involved in the incident or be harmed by its potential consequences. Thus, siting and layout not only provide for a fundamental aspect of risk management but are also key components in inherently safer design.

The many challenges associated with plant siting and layout are discussed in this book. Layers of safety are utilized to compensate for less than desired spacing and to implement additional aspects of inherently safer design. This use of layers of safety or layers of protection is a traditional risk management approach and is illustrated in Figure 1-3. These layers include the inherently safer strategies of preventing the incident, minimizing escalation, and minimizing impact. The layers may include using a less hazardous process, separation distances, operator supervision, control systems, alarms, interlocks, physical protection devices, and emergency response systems. Although safety protective systems are often necessary, they are less reliable and more costly to maintain than the protection afforded by inherently safer design strategies (CCPS, 2001).

2.3. Basis for Facility Siting and Layout

Building a new site or adding equipment to an existing one is often an exciting, but daunting, proposition. If it is done well, capital is well invested, goals are met, and the future looks promising. If it is done poorly, money may be wasted, goals unachieved, and the future could be unwittingly compromised.