PROCESS SAFETY STUDIES IN OIL & GAS MAJOR PROJECTS

EGPC-PSM-GL-002

PSM GUIDELINES

The Egyptian Process Safety Management Steering Committee (PSM Egypt)
PSM TECHNICAL SUBCOMMITTEE (PSMTC)
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PSM Technical Subcommittee team members during the project comprised:

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

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Process Safety Consultants (in alphabetical order)

Bell Energy Services	Amey Kulkarni	Technical Director
DNV	Cees de Regt	Senior Principal Consultant
Process Safety & Reliability Group (PSRG)	Robert J. Weber	President/CEO
Risktec Solutions - TÜV Rheinland		

Major IOCs & EPCs (in alphabetical order)

ENI	Aladdin Elsonbati	HSE & Process Safety Manager
ENPPI	Karim Rasmy	Process Technology / Process Safety Section Supervisor

It should be noted that the above have not all been directly involved in the development of 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

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Approval

NAME	TITLE	DATE	SIGNATURE
Amr Moawad Hassan	PSM Senior Consultant - Methanex Egypt PSM Technical Subcommittee Team Leader	31-May-2022	Amr Hassan Digitally signed by Amr Hassan Date: 2022.06.09 10:01:18 +02'00'
Gamal Fathy	EGPC CEO Consultant for HSE		Gamal Fathy

Endorsement

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

Table of Contents

1. Introduction

The focus of this guideline is on proactively implementing process safety studies at the optimum timeframe, while also addressing reactively conducting a cold-eyed review to assure that nothing significant has been missed. This approach ensures that, if the right process safety studies are conducted at the right time, project leadership will have the right process safety information to be able to make the right risk management decisions regarding safety.

The intent of this guideline is not to describe in detail how to perform specific process safety studies, but rather to identify what needs to be addressed at each stage of a project.

The main aim of this guideline is to:

- Provide clarity regarding process safety input throughout the overall project phases from evaluation to project execution.
- Underline the main process safety studies during project phases, focusing on their interaction and scheduling inside the safety engineering discipline.
- Explain how process safety studies interact with other disciplines, inside and outside the engineering department.
- Articulate the role of process safety engineering inside the engineering department and how it is involved in the managing of process safety studies during project development.

2. Scope

The primary scope of this document is to provide guidance for addressing process safety studies required to support projects in the oil and gas and petrochemical industries and elaborating during the design phases on all the inputs coming from process safety.

Nothing herein contained shall exempt the document user from complying with the Arab Republic of Egypt (A.R.E.) Laws and Regulations regulate health, safety, and the environment. The process safety studies required in this document are complimentary to the legal requirements. The Egyptian Legal requirements are obligatory and not superseded by the requirements mentioned in this document. For most relevant Environmental and other legislations, you can refer to Annex- A.

The scope of this guideline applies to Egyptian General Petroleum Corporation (EGPC), the Egyptian Natural Gas Holding Company (EGAS), the Egyptian Petrochemical Holding Company (ECHEM), and the Ganoub ElWadi Holding Company (GANOPE) covering all of their operational subsidiaries, state-owned companies, affiliates and Joint Ventures across oil and gas segments, i.e., upstream, midstream and downstream.

This guideline covers projects for facilities such as oil & gas plants, refineries, chemical plants, and large fuel or chemical storage sites where hazardous materials are stored, handled, or processed and could lead to major accident hazards incidents with consequences such as fire, explosions, and toxic release resulting in serious danger to people inside or outside establishment or major environmental impact.

3. Project Phases

Projects are usually organized into phases that are determined by governance and control needs. These phases should follow a logical sequence, with a start and an end, and should use resources to provide deliverables. To manage the project efficiently and effectively during the entire project life cycle, a set of requirements should be performed in each phase.

The phases are divided by decision points, which can vary depending on the organizational environment. The decision points facilitate project governance.

Throughout this guideline, the project phases are commonly divided into four main phases as illustrated in Figure 1. All phases are distinct and separate from each other by a decision stage gate to evaluate the completeness, quality, and maturity of the decision made during that phase and provide approval either or against advancing to the next project phase.

During the project, process safety engineering interacts continually with all engineering disciplines involved in the project. In this context, process safety engineering receives, processes, and analyzes information coming from engineering disciplines and manages all Process Safety (PS) studies needed for the success of the project development.

For each project phase, relevant information received as input data from engineering disciplines is re-cycled back to them as output data and re-elaborated inside the project engineering team.

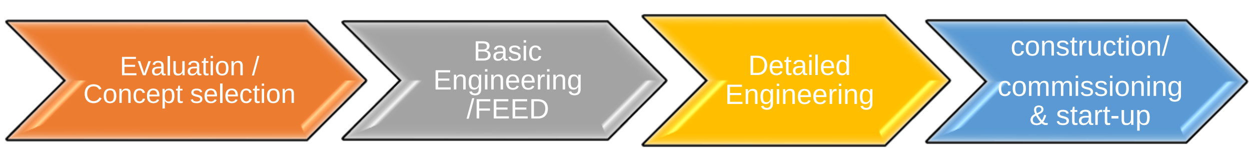

Figure 1. *Project Phases*

Throughout the lifetime of the project and during the different engineering phases, COMPANY shall ensure, through its engineering contractor, that the project has been developed considering engineering practices, requirements of relevant codes/standards (International /National /COMPANY standards), and any requirements stated as contractual requirements.

Accordingly, and before the starting of any engineering activities, it is crucial that both COMPANY and the engineering contractor identify/agree on which codes, standards, or any other requirements (e.g., contractual requirements, etc.) will apply to the new project. As a kind of register, these agreed codes, standards, contractual requirements, etc. might be listed in standalone documents as a part of the engineering deliverables.

In addition, COMPANY shall decide with its engineering contractor the order of precedence just to be followed in case of any conflicts between the different applied codes, standards, contractual requirements, etc.

Finally, any deviation from the agreed/approved list mentioned before shall be submitted to COMPANY for approval supported by robust justifications to support the deviation.

3.1. Evaluation/Concept Selection Phase

Evaluation estimates the development opportunity of a project. The opportunity study in this phase is based on considerations linked to economic, environmental, and social sustainability. To define project development alternatives, during the Evaluation, a series of process concepts are proposed and studied from a technical point of view through the preliminary definition of the process, main utility items, flowlines, and/or sealines. Evaluation is a phase characterized by great uncertainties.

Concept Selection represents the feasibility phase. Following the Evaluation step, Concept Selection deepens and compares different development concepts and alternatives, selecting and refining the best one based on technical, economical, risk, and procurement strategies. The alternatives developed during this phase are qualitatively studied and identified in terms of hazards from the safety point of view. During Concept Selection for each alternative, the process is better defined and a preliminary design of equipment, infrastructures, flowlines, sealines, and/or ancillary systems is realized.

In this context process safety engineering, together with engineering disciplines, contribute mainly to identifying the hazards and carrying out the risk assessment studies and philosophies. The main objective is to select or support a concept that is As Low As Reasonably Practicable (ALARP).

3.2. Basic Engineering/Front End Engineering Design (FEED)

This phase defines, details, and refines the concept selected previously during Evaluation / Concept Selection phase.

The engineering activities performed during this phase become increasingly specific and detailed. Consequently, all process safety requirements are expected to be developed mainly in this phase due to the increased detail of project information in terms of relevant deliverables (e.g., Block Flow Diagram (BFD), Process Flow Diagrams (PFDs), Piping and Instrumentation Diagrams (P&IDs), Utility Flow Diagrams, Cause & Effect Matrices, Units & General Layouts, and Equipment Datasheets) available to feed them.

Engineering in this phase ends with the development of a well-defined plant solution and the realization of cost estimation. The cost estimation is of fundamental importance since it allows, at the end of the phase as gate approval, the achievement of the final investment decision.

3.3. Detailed Engineering

Detailed Engineering or Design involves the completion of detailed engineering of the defined scope (FEED package). This addresses the layout and detailed engineering of individual items of equipment. Change management is introduced following the final HIRA (Hazard Identification & Risk Analysis) studies and process knowledge management information is documented and compiled.

Other important activities during this phase include management of any scope changes, planning for procurement of materials and equipment, planning for construction and commissioning, and interface management between multiple organizations including contractors, fabricators, vendors, and suppliers. The goal is to resolve the remaining project risks and uncertainties and complete a design package that includes all necessary information required for construction to stay on schedule and facilitate efficient commissioning and handover.

3.4. Construction, Commissioning, and Start-up

This project phase covers the construction activities including the pre-commissioning, commissioning, and start-up activities.

Construction activities mainly focus on safely building the facility in accordance with the design. This includes construction plans and management, procurement of equipment & materials, fabrication, installation, management of engineering, and integrity baseline documentation. Moreover, it involves interfaces with fabricators, contractors, sub-contractors, suppliers, and vendors that require good management and regular performance reporting.

Following construction (including pre-commissioning and mechanical completion of the facilities), the project moves into commissioning and start-up. Commissioning is the process of assuring that all systems and equipment are tested and operated in a safe environment to verify the facility will operate as intended when process chemicals are introduced. On the other hand, a start-up is a process of introducing process chemicals to the facility to establish operation.

4. Process Safety Management during Project Phases

Proper management of process safety during project phases would help a lot in respecting the project planning and scheduling. The key points for successful implementation of process safety in projects are to identify and plan the required process safety studies at an early stage and link it with other engineering activities in the overall project schedule, even during the proposal stage if possible. In addition, it is essential to get competent resources to perform or coordinate the technical process safety studies. This is likely to require engagement with process safety specialists at the right time. Finally, if these steps are followed, process safety would be more likely to be embedded in the project and support the overall project schedule and budget objectives.

In general, the execution and management of systematic and structured process safety studies during various project phases would be beneficial for the development of the project, avoiding negative impacts on the project schedule and costs.

For each project phase, process safety studies can be classified according to Table 1 which illustrates the studies belonging to each phase. All studies, including the main deliverables/families of documents belonging to each project phase, are described in detail in the following sections.

It is important to mention here that the ordering of the different process safety studies mentioned in this guideline is not intended to be in a chronological pattern, while it was left for the COMPANY (in conjunction with its engineering contractor) to order it based on the project progress, scheduling, and availability of data.

***Table 1.** Process safety studied for different project phases*

Category	Evaluation / Concept selection	Basic Engineering /FEED	Detailed Engineering	Construction/ Commissioning / Start-Up
Hazard identification	Preliminary HAZID	HAZID		
		HAZOP (Basic Engineering)	HAZOP (Detailed Engineering)	
Consequence assessments		Facility siting study	Final/Updated Facility siting study	
		Flare radiation and gas dispersion study		
		Vent to a safe location (Dispersion modelling)	Final/Updated Vent to a safe location (Dispersion modelling)	
Safety assessments	Preliminary Inherent safer design review	Inherent safer design Review		
	Preliminary layout review	Hazardous area classification	Final/Updated Hazardous Area Classification	
		SCEs & Performance Standard Management in Design		SCE's Identification & Performance Standards in Operation
		Evacuation, Escape, and Rescue Analysis (EERA)	Final/Updated Evacuation, Escape, and Rescue Analysis (EERA)	SIMOPS
Risk assessments	Preliminary Risk studies	Quantitative Risk assessment (QRA)	Final/Updated Quantitative Risk Analysis (QRA)	
		Fire & explosion Risk analysis (FERA)	Final/Updated Fire & Explosion Risk Analysis (FERA)	
		Dropped Object study *		
		Ship collision assessment *		
		Temporary Refuge Impairment assessment *		
Risk Mitigation		Emergency Shutdown & blowdown philosophy		
		Fire & Gas Detection Philosophy		
		Fire protection philosophy		
		Process Isolation philosophy		
		Drainage & venting philosophy		
		Fire & Gas 3D mapping study	Final/Updated Fire & Gas 3D mapping study	
			Safety Integrity Level classification/assessment study (SIL study)	
			Safety Integrity Level Verification (SIL Verification)	
		Active firefighting calculation study	Final/Updated Active firefighting calculation report	
		Passive fire protection study		
Regulatory studies		Design safety case		Operation safety case
Stage gate review	Evaluation /Concept Selection Gate review	Basic/FEED Gate Review	Detailed Engineering Gate review	Construction/commissioning & start up Gate review

* Offshore

5. Process Safety Studies in Evaluation/Concept Selection Phase

5.1. Preliminary HAZID

A HAZID (Hazard Identification study) is a team-based brainstorming analysis used to identify potential major process and non-process hazards. HAZID studies may be broad in their scope and thus have wide applicability. HAZID typically examines all reasonably possible sources of hazard, including the process design itself and hazards external to the process design.

A preliminary hazard identification (Preliminary HAZID) should be conducted on each of the options being considered by the project management team. Taking into consideration that at this early stage of the project, only basic information shall be available.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Location and nature of the terrain and environmental conditions
- Principal operations and other activities
- Chemical and materials/equipment handling
- Process type/design and utility data, such as process flow diagrams (PFDs), and operating envelopes
- Accident history for similar units
- Emergency response plans
- Description of neighbouring facilities, operations, and areas of occupancy

Output data

- HAZID Report
- Hazard/risk register
- HAZID Follow-Up/Close-out Report

5.2. Preliminary Inherent Safer Design Review

An inherently safer design avoids hazards instead of controlling them, particularly by reducing the amount of hazardous material, designing equipment for worst-case conditions, and reducing the number of hazardous operations in the facility.

The application of Inherently Safer Design (ISD) is most effective at the earliest stages of a project. Although opportunities to apply ISD exist in later stages, there is likely to be less flexibility or a significant cost impact. Therefore, each project should consider ISD principles when developing each of the alternative options.

ISD has four principles:

- **Minimize**: reduce the quantity of hazardous material.
- **Substitute**: substitute hazardous material with the less hazardous material.
- **Moderate**: use less hazardous conditions, less hazardous forms of material, or facilities that minimize the impact of a release of hazardous material.
- **Simplify** design facilities that eliminate unnecessary complexity to make operating errors less likely, and that is more forgiving of errors that are made.

The reviews are generally based upon a combination of What-If analysis, checklist, and/or brainstorming.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- The design basis for proposed options
- Plot area allocated to project
- Details of neighbouring facilities, operations, and areas of occupancy

Output data

- Preferred design option
- Recommendation for potential risk reduction measures

5.3. Preliminary Layout Review

Site layout and spacing of process units, other equipment, and buildings should have been evaluated in the concept selection phase and a preliminary layout should be developed accordingly to ensure that the layout and spacing of plant equipment are designed in a safe, cost-effective, and consistent manner to avoid any potential impact to the specification of design safety measures.

The purpose of having minimum spacing distances between the equipment and proper plant layout is to:

- Minimize the likelihood of ignition such that fugitive hydrocarbon releases do not lead to fires or major accident hazards
- Safely separate plant and equipment areas
- Provide confinement of liquid leaks and spills
- Allow access to operations and maintenance

- Minimize congestion to minimize the chance of an explosion
- Provide suitable means for escape and evacuation.

Plant layout should be further reviewed and revalidated in FEED/Basic Engineering utilizing quantitative study “facility siting” where consequence modelling or risk-based approach is performed to evaluate the impact of various consequence or risk counters on people and occupied buildings.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Preliminarily risk studies if available
- Initial/General layout or plot plan
- Details of neighbouring facilities, operations, and areas of occupancy

Output data

- Preliminarily plant layout and Spacing Report

5.4. Preliminary Risk Studies

The Preliminary Risk Studies are a simplified form of quantitative risk analysis (QRA and if required FERA), based upon a combination of generic technology/process data and site-specific data. Due to the basic nature of the available information on the technologies and processes at this stage of the project, the analysis uses industry data, such as the likelihood of fires/explosions for similar facilities. The consequence part of the analysis may use either estimate for inventories and process conditions or generic industry data from similar facilities. These Preliminary Risk studies are unlikely to be as accurate in absolute terms as quantitative risk analysis studies conducted at later stages of the project when the detailed design has evolved. However, the application of Preliminary Risk Studies to multiple options in a comparison approach largely overcomes the problem of inaccuracies in the assumptions used in the absence of definitive data. The difference in risk between options is the important factor, not the absolute level of risk. This allows the project management team to compare the safety risks between options and rank them accordingly. It can also provide insights into potential business interruption and property damage-related risks between options. All risks should be captured in a risk register. The Preliminary Risk Studies should be conducted by a competent and experienced risk analyst familiar with the sensitivity of using estimates and assumptions in place of definitive data. The risk analyst requires input from personnel familiar with the technologies and processes of each development option. The project management team should carefully weigh each development option's commercial and technical attributes together with their associated risks.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Site-specific data
- Estimated inventories and process conditions or generic industry data from similar facilities
- Preliminary plant layout
- Preliminary PFDs
- Preliminary P&IDs
- Preliminary heat and material balance.

Output data

- Preliminarily risk study report

5.5. Evaluation/Concept Selection Stage-Gate Review

Stage gate review is a requirement that is required at key milestones/phases during the life cycle of capital projects to ensure that the process safety requirements are properly completed and achieved its objectives.

The stage-gate review is conducted by an independent and experienced multi-discipline team familiar with the relevant facility/process and technology. This team assesses whether the project management team has fulfilled its process safety objectives (requirements and deliverables) for the current project phase. At the conclusion of the review, the review team shall make recommendations for any improvements needed, and indicate to the Gate Keeper, based on process safety, whether the project is ready to proceed to the next stage.

The key objectives of the Evaluation/Selection Stage Gate Review are to evaluate and assure that all the objectives of process safety during this project phase have been achieved. These objectives shall include but are not limited to the following:

- Determine whether there are any potential process safety risks associated with the options being considered, such as novel technology or processes.
- Ensure that inherently safer design (ISD) principles are considered when developing each option.
- Assess the proposed location(s) for any process safety issues, such as potential impacts on local communities, the environment, and other industries.

- Identify all process safety concerns (significant hazards, uncertainties, etc.) relating to the full life cycle of the facility, novel/unproven technology, and characteristics of the location.
- Identify all applicable process safety regulations, standards, and relevant corporate expectations.
- Establish a risk management strategy, including future Hazard Identification and Risk Analysis (HIRA) studies.

6. Process Safety Studies in Basic Engineering/FEED Phase

6.1. Emergency Shutdown & Blowdown Philosophy

The Emergency Shutdown (ESD) system prevents the development of dangerous events generated by the deviation of operating variables (such as the pressure inside the equipment), human errors, or external events (such as a fire). The ESD system is designed typically to act on three hierarchical levels of intervention depending on the severity of the anomaly: Emergency shutdown (ESD), Process Shutdown (PSD), and Local Shutdown (LSD).

The blowdown system has the purpose of reducing the magnitude of major accidents by disposing of the process fluids toward a safer place, reducing the pressure inside the piping and process equipment, and hence globally reducing the risk of ruptures and escalation.

In terms of inputs/outputs of such a philosophy, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- PFDs
- P&IDs
- Heat and Material Balance
- Layout with the equipment list
- Process description
- Design basis

Output data

- Emergency Shutdown & Blowdown Philosophy

6.2. Fire & Gas Detection Philosophy

Fire and Gas (F&G) detection has the purpose to find and detect the presence of fire and flammable gases and, if any, toxic substances released from equipment. The continuous monitoring of the presence of fire and gases in the atmospheres is realized through the selection and design of correct positioning and appropriate voting logic of detectors. The technology of detectors to be used depends greatly on the place of installation (inside buildings or open space) and on the substance to be detected (only flammable or even toxic substances).

A proper design activity guarantees that the F&G detection system acts properly: alerting all personnel in the areas involved and initiating immediate executive actions against fire and gas, including appropriate levels of emergency and shutdown actions.

In terms of inputs/outputs of such a philosophy, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Basis of Design
- Block flow diagram
- PFDs
- Utility flow diagram
- HSE Philosophy
- Firefighting Philosophy

Output data

- Fire & Gas Detection Philosophy

6.3. Fire Protection Philosophy

The layout of and distances between fire-hazardous equipment shall be such that in the event of a fire the probability of escalation is reduced to tolerable levels. However, since it is not always feasible to achieve complete separation of individual pieces of equipment, within an operational complex, additional precautionary fire protection measures may be necessary. The basic objective of fire protection is to limit or prevent the escalation of fire, avoid risk to life, and minimize material damage. Where fire protection is deemed necessary, passive fire protection measures shall be provided where feasible. Passive fire protection performs its function without relying on activation. The prime function of passive fire protection is to retard the rate of temperature increase of a given substrate.

On the other hand, an active fire protection system is a dormant system that requires to be activated to perform its function (e.g., water spray systems, deluge systems, sprinkler systems, firewater monitors, and steam rings around flanges). Such systems are activated once the information is received from the scene of the fire that protection is required. Their function is to protect against the escalation of the fire emergency and avoid the need for manual intervention in the fire area.

The scope of this philosophy is to define the design criteria and the requirements to be applied for the active and passive fire protection systems.

In terms of inputs/outputs of such a philosophy, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Basis of Design
- Block flow diagram
- PFDs
- Utility flow diagram
- HSE Philosophy
- Fire & Gas Detection Philosophy

Output data

- Fire Protection Philosophy

6.4. Process Isolation Philosophy

The objective of this document is to define the valving and isolation philosophy to be used in the design. This philosophy describes methods for isolating sections of the plant to permit safe operation and provide access for maintenance or inspection. Isolation requirements are generally dependent on the extent of the shutdown, the hazardous nature of contained fluids, and the pressure rating of the piping system. All isolation of plant, breaking of containment, and vessel entry must be strictly controlled by the permit to work system.

The isolation philosophy covers the mandatory administration and mechanical isolation of process equipment before maintenance or engineering work.

In terms of inputs/outputs of such a philosophy, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- P&IDs
- Layout with the equipment list
- Process description
- Design basis

Output data

- Process Isolation Philosophy

6.5. Drainage & Venting Philosophy

The purpose of this document is to address the requirements to ensure that drain systems are:

- The drain systems shall be designed to allow the disposal of liquid inventory and surface water run-off in a safe and environmentally acceptable manner.
- Drain systems shall be designed to ensure proper handling of any contaminants that may accidentally enter the system, e.g., due to spillages or inadvertent operations.
- Drainage shall be at low points to allow maximum natural drainage of isolated fluids.
- Non-hazardous effluent (oil-free storm water) shall be routed using a drainage network, which comprises of open drain and an underground pipe network connected through manholes.
- There shall be no interconnection of Drain Systems; the Closed Drains are not connected to Open Drain.
- Prevent migration of flammable liquids or vapours from one hazardous area to another or a non-hazardous area.

On the other hand, the venting system shall avoid the emission of gases and vapours to the atmosphere that is flammable, toxic, or harmful to the environment where practicable and economically possible. Where unavoidable, venting shall be directed to a safe location to ensure proper dispersion and avoid jeopardizing the safety and occupational health of personnel. Suitable size and appropriate location of purge and vent connection on equipment and piping shall be provided to allow hydrocarbon gas removal.

In terms of inputs/outputs of such a philosophy, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- PFDs
- P&IDs
- Heat & Material Balance
- Hazardous Area Layout Drawings
- Equipment list/ Layout Drawings / Plot Plans
- Local Legislation / Regulations (If any)

Output data

- Drainage & Venting Philosophy

6.6. HAZID

At this project phase, more information shall be available than was available at the Evaluation/Concept selection phase. If preliminary HAZIDs were previously prepared, they should be updated using the available data. If a preliminary HAZID was not conducted previously, the HAZID should focus on the hazardous materials and major process areas of the facility, where there are potential major accident hazards that can impact people, the environment, and/or property.

The main purpose of HAZID is to:

- Identify potential hazards as defined in the Terms of Reference (TOR) for the HAZID study, including the identification of Major Accident Hazard (MAH).
- Consider the consequences of the hazards.
- Evaluate Risk.
- Identify safeguards that are in place to provide hazard prevention or mitigation.
- Propose recommendations, as needed, to eliminate, prevent, control, or mitigate hazards.
- Assist facility management in its efforts to manage risks.
- Support objectives of ISD.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Facility layout, including the location of major equipment and occupied buildings
- Location and nature of the terrain and environmental conditions
- Principal operations and other activities
- Details of hazardous inventories
- Chemical and materials/equipment handling
- Process type/design and utility data, such as PFDs, P&IDs, and operating envelopes
- Design philosophies, including manning, operating, maintenance, and safety
- Findings of any prior HAZID studies
- Accident history for similar units
- Emergency response plans
- Plans for construction, transportation, and installation activities
- Hazard and risk register
- Description of neighbouring facilities, operations, and areas of occupancy

Output data

- HAZID Report
- Hazard/risk register
- HAZID Follow-Up/Close-out Report

6.7. HAZOP (Basic Engineering)

A HAZOP study is a structured analysis of a system, process, or operation for which design information is available, carried out by a multidisciplinary team. The team proceeds on a line-by-line or stage-by-stage examination of a firm design for the process or operation. While being systematic and rigorous, the analysis also aims to be open and creative. This is done by using a set of guidewords in combination with the system parameters to seek meaningful deviations from the design intention. A meaningful deviation is one that is physically possible for example no flow, high pressure, or reverses flow. Deviations such as no temperature or reverse viscosity have no sensible physical meaning and are not considered. The team concentrates on those deviations that could lead to potential hazards to safety, health, environment, asset, or reputation.

In addition to the identification of hazards, it is common practice for the team to search for potential operating problems. These may concern security, human factors, quality, financial loss, or design defects. Where causes of a deviation are found, the team evaluates the consequences using experience and judgment. If the existing safeguards are adjudged to be inadequate, then the team recommends action for change or calls for further investigation of the problem. The HAZOP scenarios and related actions shall be risk-ranked. The analysis is recorded and presented as a written report which is used in the implementation of the actions.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- P&IDs
- PFDs
- Process description and process chemistry
- Pressure relief (or safety) valves datasheets
- Previous HAZID or LOPA Follow-Up/Close-out Report
- Alarm and trip settings
- Control system philosophy and description
- Cause and effect diagrams

- Changes to design since the last HAZOP
- Operating procedures (start-up, operating, shut down, emergency)
- Previous process safety accident/ incident/ near-miss reports
- Facility plots plan/Unit layout drawings
- Other documents as required such as general HSE guidelines, safety data sheets (SDS), equipment datasheets, and fire-fighting philosophy

Output data

- HAZOP Report
- HAZOP Follow-Up/Close-out Report

6.8. Facility Siting Study

Site layout and spacing can influence material and construction costs, major accident risks, and the safety of future operations. A Facility Siting Study (FSS) should be conducted to address both off-site and on-site impacts from potential fire, explosion, and toxic hazards.

Adequate layout and spacing are necessary to prevent a fire or explosion from impacting adjacent people, property, and equipment, and can minimize the risk of fire or explosion by separating sources of fuel from potential sources of ignition. Proximity to local communities, other industries, offices, shops, public roads, and other receptors should be evaluated to reduce risks. Proper spacing of equipment is one of the most important design considerations for limiting the impact of hazards, operability, and maintainability as well as facilitating emergency egress and emergency response. Siting of permanent and temporary buildings in process areas requires careful consideration of the potential effects of explosions, fires, and toxic vapours arising from the accidental release of hazardous materials.

Spacing tables (i.e., GAP, PIP, NFPA, etc.) are available for specifying the minimum distance between process equipment. Spacing tables are conservative techniques, a facility siting study where consequence modelling is being performed to the selected design should be conducted to assess potential explosion, flammable, and toxic hazards associated with the operation and the impact of these hazards to both off-site & on-site personnel and buildings.

Facility siting study results identify hazard vulnerabilities to aid with the identification of potential mitigation strategies. Since the layout and equipment may change, this process is designed to be iterative (throughout the Basic/FEED and Detailed Engineering stages) to assist the project team with layout decisions from a safety perspective.

In special cases where consequence modelling data is not enough to provide solid technical support to the project team to finalize the layout, a risk-based approach shall be applied by performing a Quantitative Risk Analysis (QRA).

When consequence data and counters are available from other studies such as QRA or FERA, the facility siting study shall utilize the available data with no requirement to repeat the consequence modelling.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Plant proposed layout
- Details of neighbouring facilities, operations, and areas of occupancy
- Basic Engineering Design Data
- Process Heat and Material Balance
- Equipment list
- General Site Layout
- Relief and Blowdown Philosophy
- PFDs
- P&IDs
- Process description

Output data

- Facility Siting Study report

6.9. Flare Radiation & Gas Dispersion (Flameout) Study

The objectives of the Flare Radiation and Gas Dispersion Study are to:

- Evaluate the adequacy of the flare height and assess the extent of heat radiation levels during flaring and burning, and the extent of flammable and toxic gas dispersion in the event of flameout.
- Ensure the safety of personnel based on the assessment and identification of potential flammable and toxic gas hazards on-site and outside of the facility fence line to ensure that the sterile area and Ground Level Concentration (GLC) criteria are met.

The COMPANY/OPERATOR shall set the acceptance criteria (onsite/onsite) for thermal radiation, sterile area radius, and flammable and toxic gas concentrations in case of the gas dispersion for a flameout scenario.

However, the study shall consider the following to ensure accurate results:

- Calculation shall take into consideration the solar radiation when setting the acceptance criteria for the safe thermal radiation limits.
- Worst case weather condition for flare dispersion (calm weather condition).
- Addressing acceptance criteria for both onsite (workers) and offsite population (public).

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Heat & material balance
- Shutdown and blowdown philosophy
- Blowdown calculation study

Output data

- Flare Radiation & Gas Dispersion Study Report

6.10. Vent to Safe Location (Dispersion Modelling)

The study objectives are to:

- Ensure safe dispersion of toxic and flammable hydrocarbon gas from the vent(s) directed to the atmosphere (Vent to a safe location) and during emergency discharges from Pressure Safety Valves (PSVs) and manual depressurization directed to the atmosphere.
- Evaluate the adequacy of the Vent(s) and PSVs directed to the atmosphere to ensure the safety of personnel based on the assessment and identification of potential flammable and toxic gas hazards on-site and outside of the facility fence line to ensure that the sterile area and Ground Level Concentration (GLC) criteria are met.

The COMPANY/OPERATOR shall set the acceptance criteria for flammable and toxic gas concentrations (safe acceptance criteria). However, the study shall consider the following to ensure accurate results:

- Worst case weather condition (calm weather condition).
- Addressing acceptance criteria for both onsite (workers) and offsite population (public).
- Special attention where the Vent(s) and PSV(s) are directed to the atmosphere near occupied buildings.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Drainage and venting philosophy
- List of Vents and PSV (s) to a safe location with release sizes
- Compositions and operating parameters (temperature & pressure) for all vents / PSV(S) for worst-case scenario
- In case of sensitivity analysis is required for release cases, different compositions, and operating parameters (temperature & pressure) to be provided for respective cases
- All vents and PSV(S) plotted on plot plan and in 3D model with physical dominations
- Meteorological/weather Conditions to be used for modelling (recommended 2F, 6D, 10D)
- Hydrocarbon & toxic gases acceptance criteria

Output data

- Vent to a safe location study report

6.11. Inherent Safer Design Review

The same principles that have been discussed in **section-5.2** shall be applied, considering the level of the engineering development/detail and the availability of design data/information.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Process description
- Design basis
- PFDs
- Preliminary Layout
- HAZID if available
- Details of neighbouring facilities, operations, and areas of occupancy

Output data

- Recommendation for potential risk reduction measures

6.12. Hazardous Area Classification

A hazardous area classification (HAC) assessment should be conducted in the Basic/FEED phase to determine classified areas. The assessment identifies areas within the facility where electrical equipment may need to be appropriately classified to prevent ignition and can be used to optimize plot plan layout in terms of potential classified equipment cost. HAC does not apply to catastrophic failures, e.g., vessel or piping rupture.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- The flammable materials that may be present
- The physical properties and characteristics of each of the flammable materials
- The source of potential releases and how they can form explosive atmospheres
- Prevailing operating temperatures and pressures
- Presence, degree, and availability of ventilation (forced and natural)
- Dispersion of released vapours to below flammable limits
- The probability of each release scenario
- P&IDs
- PFDs
- Process unit layouts
- HVAC

Output data

- HAC Report/Schedule
- HAC layout

6.13. Safety-Critical Elements and Performance Standard Management in Design

The prevention and mitigation of major accidents rely upon appropriate barriers working on demand. Identifying the subset of equipment that is critical to the management of major accident hazards, and therefore requires high reliability, is the foundation for managing the Major Accidental Hazard scenario. These items are known as Safety Critical Elements (SCE) which might be systems or equipment. The purpose of this categorization is to indicate which barriers need additional focus and attention on that barrier.

For each SCE identified during the bowtie workshop or any other applicable approach, a performance standard must be developed which sets out the levels of performance it must achieve in terms of functionality, availability, reliability, survivability, and interdependency. This ensures that the critical barriers remain in place and effectively continue to manage the Major Hazard over time.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- MAHs (Hazard Register)
- The SCEs inherent design is the engineering design (definition, sizing, etc.) of each SCE identified (in terms of Philosophies, Layout Drawings, P&IDs, Data Sheets, Diagrams, Demand Report/Calculation Reports, Specifications, FERA Report, Procedures, etc.)

Output data

- SCEs & Performance Standard Report

For more details, you can refer to Major Accident Hazard Management (MAHM) Guideline, document number EGPC-PSM-GL-006.

6.14. Evacuation, Escape, & Rescue Analysis (EERA)

Evacuation, Escape, & Rescue Analysis (EERA) ensures that personnel can leave safely all dangerous areas in case of incidents. EERA implies that the escape, evacuation, and rescue system is identified and properly designed. The design of the escape, evacuation and rescue system enables personnel to reach safely the muster area. The design also considers the realization of an area insulated from the effects of all incidents for all the time necessary for the evacuation procedure. EERA study should be conducted to evaluate the performance of the emergency response facilities and procedures. The EERA study addresses the following emergency response equipment:

- Escape routes (including bridge links to other installations, if appropriate).
- Muster area(s) and facilities in the temporary refuge.
- Evacuation equipment (including helicopter and helideck operation, lifeboats, life rafts, and escape chutes).
- Rescue arrangements, such as stand-by boats, Search and Rescue (SAR) helicopters, and non-specific marine craft in the locality.

The EERA study is typically undertaken in conjunction with appropriate quantitative risk analysis and consists of a structured review of the performance of the escape, evacuation, and rescue facilities and procedures under representative scenarios.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- General site layout
- Facility siting study
- HSE philosophy
- QRA study Report
- FERA Study Report
- Equipment Summary
- Shutdown and blowdown philosophy
- Preliminary emergency response plan

Output data

- EERA Study Report
- EERA layout

6.15. Quantitative Risk Assessment (QRA)

QRA provides a numerical estimate of onsite and/or offsite risk exposures to people. This allows risk levels to be compared with corporate risk tolerance criteria and provides input where risk reduction measures are required to demonstrate ALARP on decisions regarding strategies to mitigate risk, such as potential issues with plant layout, building locations, structural blast resistance, etc., which need to be resolved before the detailed design stage of the project.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Basic Engineering Design Data
- Process Heat and Material Balance
- Equipment Summary
- General Site Layout
- Relief and Blowdown Philosophy
- Fire and Explosion Risk Assessment (FERA) Report if available
- QRA scope of work (SOW)
- Details of neighbouring facilities, operations, and areas of occupancy
- HAZID Study
- HAZOP study
- PFDs

- P&IDs
- Isolatable sections inventory
- Blowdown flow orifices
- Isolation times
- Metrological data
- Sea conditions (for offshore sites)
- Manning distribution and shift pattern

Output data

- QRA study report

For more details, you can refer to the Quantitative Risk Assessment (QRA) guideline, document number EGPC-PSM-GL-008.

6.16. Fire & Explosion Risk Analysis (FERA)

The aim of FERA is the quantification of the risk for the asset associated with uncontrolled hydrocarbon releases from process equipment. The quantification of the risk is performed through the calculation of the frequencies and consequences of final incidental scenarios. Risk management is performed according to the criteria of tolerability reported in international and company standards.

The results coming from FERA studies are used to optimize the layout of the plant and, according to the associated philosophies, the design of the fire protection system (passive/active).

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Equipment Summary
- FERA scope of work (SOW)
- Basic Engineering Design Data
- Process Heat and Material Balance
- HAZID Study
- HAZOP study
- Layouts/ 3D model (recommended)
- PFDs
- P&IDs
- Isolatable sections inventory

- Blowdown flow orifices
- Isolation times
- Weather conditions
- Sea conditions (for offshore sites)

Output data

- FERA study Report

6.17. Dropped Object Study

A dropped object study involves a qualitative or quantitative risk assessment of impacts caused by accidentally dropped object loads (or dragging anchors) within the safety zone of an offshore installation. The goal of the study is to ensure that the risks to subsea wellheads and pipelines, and topsides equipment and structures by dropped objects are understood. Where pipelines and facilities contain hydrocarbons, any loss of containment (LOC) could have potentially catastrophic consequences. The study highlights areas of concern (i.e., risks that exceed jurisdiction or corporate tolerance criteria) and assists decision-making on the most efficient risk reduction measures. A dropped object study may also be performed for an onshore facility.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Lifting Manifest (Lifting Plan) – Weight, Height, Volume, Dimensions, and number of lifts per year
- Pipeline Approach Drawings
- Layout
- Crane Specs
- Riser Locations
- Simultaneous operations (SIMOPS)
- Removable hatch locations

Output data

- Dropped Object Study Report with recommendations for impact protections, pipeline & riser protections

6.18. Ship Collision Assessment

Offshore facilities typically have several vessels working in their immediate vicinity or are located close to major shipping lanes. Collisions with vessels are therefore a constant threat. To keep the risk of collision at a sufficiently low level, all the offshore installations shall be designed to withstand impacts with ships of a given size and speed. The worst expected consequence may be used as design criteria, but this is normally over onerous in terms of cost of implementation or even impracticable. A risk-based approach for the design criteria definition turns out convenient to obtain risks characterized by an ALARP level.

A Boat Impact Study shall aim to supply data on Offshore Structures (including risers, umbilical, flowlines, and subsea installations) to be used to determine ship collision risks on personnel and asset. In case they are significant, proper risk reduction measures shall be applied.

During this phase, the Boat Impact Assessment shall exhaustively address the identification of all risk reduction actions (first preventive and then mitigating) required to minimize collision effects, due to Incident Scenarios.

The Study shall provide support in:

- Layout Optimization.
- Collision loads design.
- Identification of additional risk reduction measures.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Meteorological data including wind distribution and sea conditions (wave height, water depth, currents velocities and distribution, sea temperature).
- Shipping traffic data for the relevant geographical area.
- Collision incidents databases.

Output data

- Ship collision assessment report

6.19. Temporary Refuge Impairment Assessment

Temporary Refuge for offshore platforms/facilities is a place provided where personnel can take refuge for a predetermined period whilst emergency response and evacuation preparations are undertaken. Smoke and Gas Ingress Analysis (SGIA) should be performed to ensure that in an emergency a Temporary Refuge (TR) can provide life support for a while until complete evacuation can occur. The study should evaluate whether the temporary refuge is designed for the relevant accident scenarios (e.g., fires, smoke, and blasts) and the levels of explosion overpressure, thermal radiation, smoke, and toxic gas to which it could be exposed. It also ensures that breathable air is maintained in the TR by limiting the ingress of smoke, gases, and other combustion productions resulting from external fires, and ensures that smoke does not hinder full and safe evacuation of the installation, SGIA study should evaluate:

- Thermal radiation.
- Building porosity/tightness (i.e., closure of doors, windows, HVAC louvers, penetrations, holes).
- Requirement for positive pressure.
- Detection of products of combustion (particulates, carbon monoxide, carbon dioxide, etc.) and flammable/toxic vapours in the HVAC inlet.
- Isolation of HVAC and ventilation systems.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Building Type
- Dispersion Analysis
- QRA Study
- Layout with the equipment list
- PFDs
- P&IDs
- 3D Model
- Emergency Response Plan (ERP)

Output data

- Temporary Refuge Impairment Assessment report with recommendations to ensure temporary refuge (TR) can provide life support for a period of time until complete evacuation can occur.

6.20. Fire & Gas 3D Mapping Study

The objectives of the Fire & Gas 3D mapping study are as follows:

- To simulate several gas dispersion scenarios to evaluate the gas dispersion occurrence maps for the regions of interest.
- Design detectors layout for the gas detection system, by optimizing the number and location of flammable gases detectors.

- To determine the location and quantity of flame detectors, cover the most critical equipment, and avoid obstacles & shadowing effects based on the 3D model.

Methodology for gas detectors: For gas detection numbers and distribution methodology, a computational fluid dynamics (CFD) simulation software should be used to determine the probability of detection given the occurrence of gas leaks in the plant areas. Following the definition of leak points and process conditions for selecting the dispersion scenarios, a criterion using software is required to ensure that the detectors are allocated in positions that be able to provide the best optimization and most effective coverage.

Methodology for flame detectors: Flame Detectors Allocation Analysis is performed without CFD simulations. A criterion shall be used to allocate the detectors taking into account the sight view of the detector and the vertical and horizontal range of the detector angle of view to define the maximum coverage of an equipment/area. Each detector has a cone of coverage/detection, and it is calculated based on the orientation. A geometric approach to identify the most recommended spots for flame detector placement. The approach shall aim to guarantee that the equipment is covered by fire detectors avoiding any obstacles and shadowing effects by analyzing the real geometry model.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- Fire & Gas Layout Drawings (If available for existing sites)
- Equipment list/ Layout Drawings / Plot Plans
- Fire and Gas Cause & Effect Charts
- Hazardous and Non-hazardous areas
- PFDs
- P&IDs
- Heat & Material Balance Sheets / Stream compositions (corresponding to PFDs)
- Detectors Data Sheets for all detector types (and current settings if applicable)
- Performance Targets if available
- Fire and Gas Philosophy
- Plant 3D Model
- Required gas mapping study approach (Recommended scenario-based approach based on CFD for gas detection mapping)
- Required percentage coverage for F&G detection
- Local Legislation / Regulations (If Any)

Output data

- Fire & Gas 3D mapping study

N.B. supplement families of the document shall be developed once the Fire & Gas 3D mapping study has been delivered e.g.:

- Fire & Gas detection layout
- Fire and Gas Cause & Effect Charts

6.21. Active Firefighting Calculation Study

The scope of this study is to define the maximum water demand to be applied for the design of the firefighting system. The calculation shall be realized according to fire protection criteria, requirements defined in the "Fire Protection Philosophy" (refer to **section-6.3**), and results of the Fire and Explosion Risk Analysis FERA (refer to **section-6.16**). The water requirements for fire extinguishing and cooling facilities should then be calculated, according to standards requirements, for the worst possible fire scenario. Moreover, the firefighting system should be designed to ensure fire protection for an adequate time as required by relevant standards.

In addition, hydraulic calculations should be applied to the firewater network according to the calculated water demands to define the required deluge/pipe/nozzles sizes and quantities for plant deluge valves and water spray systems. The objectives of the hydraulic analysis are:

- Identifying minimum residual pressure requirements, pipe sizing of the system, and water velocity.
- Evaluation of the outcome of the hydraulic calculations for the required firewater delivery pressure and flow at the nozzles.
- Providing adequate coverage layout to the equipment protected by firewater Spray.

Hydraulic Transient Analysis (HTA) also will be considered to evaluate the potential of water hammering and cavitation hammering. Transient pressures can create serious risks for piping integrity including pipe rupture, pipe collapse, cavitation, and check valve slam.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- FERA study
- QRA Study
- Plot plan/layout
- Fire protection Philosophy

Output data

- Active firefighting calculation report

N.B. supplement families of the document shall be developed once the active firefighting study has been delivered e.g.:

- Fire protection system location on plants and master plan
- Layouts of fire areas
- Firefighting system layouts with equipment details and isometric view
- Fire water system and foam system layouts diagrams
- Fixed firefighting systems simplified P&IDs
- Fixed firefighting systems P&IDs

6.22. Passive Fire Protection Study

Passive fire protection is a system/distance that, in the event of a fire, provides thermal protection to restrict the rate at which heat is transmitted to the object or area being protected.

Passive fire protection is defined as any fire protection system that, by its nature, plays an inactive role in protecting property from damage by fire and protecting personnel where escalation scenarios are foreseen. Passive fire protection is generically referred to as structural fire protection, particularly in governmental regulations, and includes firewalls.

The fireproofing process mainly depends on developing fire scenarios from which fireproofing needs are determined, and this process includes the following:

- Hazard evaluation, including quantification of inventories of potential fuels.
- Development of fire scenarios including potential release rates and determining the dimensions of fire scenario envelopes.
- Determining fireproofing needs based on the probability of an incident considering a company or industry experience, the potential impact of damage for each fire-scenario envelope, and technical, economic, environmental, regulatory, and personnel risk factors.
- Choosing the level of protection (based on appropriate standard test procedures) which should be provided by fireproofing material for specific equipment based on the needs analysis.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- FERA study

- QRA Study
- Plot plan/layout
- Fire protection Philosophy

Output data

- Passive Fire Protection Study Report

N.B. supplement families of the document shall be developed once the active firefighting study has been delivered e.g.:

- Fireproofing criteria
- Fireproofing layouts

6.23. Design Safety Case

Design Safety Case is required during the FEED/Basic Engineering phase to identify and report major accident hazards (MAH) associated with the facility, the process safety studies undertaken to evaluate their risks, and the measures employed to manage the risks or mitigate their potential consequences. It is a great tool to identify & manage the MAH, including specifications and performance standards of all the design safety measures. Failure to understand and maintain these measures throughout the facility life cycle would increase risks that might result in a major accident.

Preparation of a Safety Case during basic/FEED phases requires all the design elements from each source to be compiled into a single integrated user-friendly document to provide operations with a diverse range of design safety information. This has the following benefits: improved understanding of hazards and risks, enhanced knowledge of risk reduction measures, and likely reduction in major accidents or their consequences.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- The latest versions of relevant Company standards, if any
- Process description with accompanying process block diagrams for all equipment
- Scaled plot plan(s) for the facilities showing the location of the plant equipment and location and dimensions of the site
- Equipment lists and layouts drawings
- PFDs
- P&IDs

- The company preferred international codes & standards

Output data

- Design safety case including:
  1. Introduction & facility description
  2. Formal safety assessment including QRA and Bowtie for Major Accident Hazards
  3. Design performance standard

6.24. Basic Engineering / FEED Stage Gate Review

Stage gate review is a requirement that is required at key milestones/phases during the life cycle of capital projects to ensure that the process safety requirements are properly completed and achieved its objectives.

The stage-gate review is conducted by an independent and experienced multi-discipline team familiar with the relevant facility/process and technology. This team assesses whether the project management team has fulfilled its process safety objectives (requirements and deliverables) for the current project phase. At the conclusion of the review, the review team shall make recommendations for any improvements needed, and indicate to the Gate Keeper, based on process safety, whether the project is ready to proceed to the next stage.

The key objectives of in Basic Engineering/FEED stage-gate review are generally to ensure the design meets applicable process safety regulations, standards, and relevant corporate expectations.

With the progression of the project, the evaluation of major hazards involves more detailed, quantitative HIRA studies than was possible in the previous stage. This in turn allows residual risk to be optimized by applying ISD principles and managed through a diverse range of passive and active safety design measures. Accordingly, the gate review is to evaluate/ensure whether the major hazards are in line with the established risk management strategy, and continuously reduce risk to an acceptable level.

7. Process Safety Studies in Detailed Engineering Phase

With the progression of the project, more information becomes available. Accordingly, it is appropriate to update, as necessary, some of the studies that have been developed in the previous phase. Moreover, develop any other studies which are proportional to the requirement of the detailed engineering phase. In this regard, for any updated study, the inputs and expected output deliverables will be the same as mentioned in the corresponding study in the previous phase. On the other hand, for the newly developed study, the indicative list of input data and expected output deliverables will be mentioned.

7.1. HAZOP (Detailed Engineering)

A detailed engineering HAZOP report should be submitted considering modifications during previous phases, package data and information availability, and any updates to the P&IDs.

7.2. Safety Integrity Level Classification/Assessment Study (SIL Study)

If a particular hazard cannot be eliminated or sufficiently mitigated through ISD principles or other barriers, such as alarms, pressure relief, control loops, etc., it may be necessary to design a safety instrumented system (SIS) to reduce the risk. For example, risk reduction measures like spacing and segregation should be exhausted before determining any requirement for SIS. The layer of Protection Analysis (LOPA) is normally used to identify if additional protection layers are necessary to mitigate the risk where applicable, and if they are to be provided using safety instrumented functions (SIFs).

For a SIF to mitigate a major accident hazard, it must typically respond on demand and therefore should have high reliability. LOPA is most commonly used (although other methods include risk graph or QRA) to determine how reliable each SIF needs to be, i.e., its safety integrity level (SIL). The required SIL rating should then be used to design each SIF, in line with functional safety standards, such as IEC 61511.

In case the project will perform only basic engineering HAZOP, then SIL classification can be performed during basic engineering.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- P&IDs
- Cause and Effects Chart

- HAZOP Report
- QRA Reports
- Plot plans
- Approved SIL Assessment Methodology

Output data

- SIL assessment study report

7.3. Final/Updated Facility Siting Study

Site layout and spacing of process units, other equipment, and buildings should have been finalized in the FEED project phase. If not, any layout issues need to be urgently resolved before the detailed design can proceed as layout and spacing may impact the specification of design safety measures. Accordingly, optimizing plant layout and facility siting options might be feasible at this stage considering the same principles described in **section-6.8.**

7.4. Final/ Updated Vent to Safe Location (Dispersion Modelling)

During the Detailed Engineering phase, many of the requirements commenced in FEED require refining and updating to achieve completion before procurement and/or construction. This might require updating the figures for venting to a safe location, and this shall be achieved by applying the same principles discussed previously in **section-6.10.**

7.5. Final/Updated Hazardous Area Classification

According to the level of project information, HAC reports, datasheets and drawings are deliverables to be completed and refined during the detailed engineering phase in which, for example, all the planimetry of the plant areas are detailed and defined. Moreover, a complete design for packages is achieved. Accordingly, the HAC study shall be updated considering the same principles applied in **section-6.12**.

7.6. Final/Updated Evacuation, Escape & Rescue Analysis (EERA)

During detailed engineering, all EERA deliverables/families of documentation issued since FEED are properly updated and finalized. The design of the escape, evacuation, and rescue system shall follow the same principles discussed in **section 6.14**.

7.7. Final/Updated Quantitative Risk Assessment (QRA)

To continue the risk reduction efforts, the QRA study conducted in FEED needs to be updated as greater design detail becomes available especially vendor-designed equipment. Updating QRA shall consider the concepts discussed in **section-6.15.**

7.8. Final/Updated Fire & Explosion Risk Analysis (FERA)

During Detailed engineering, when the optimization has been completed, risk studies comprehend all that risk evaluation activities (including FERA) that have the intent of confirming the risk level for the asset, environment, personnel, and reputation. Updating the FERA study shall be achieved considering the same principles mentioned in **section-6.16.**

7.9. Safety Integrity Level Verification (SIL Verification)

The main objectives of the SIL Verification study are:

- To verify that the Safety Instrumented Function (SIF) can meet the architectural constraints as specified in IEC 61511.
- To verify that the Probability of Failure on Demand (PFD) for each classified SIF meets the SIL requirements as defined in IEC 61511.
- To establish optimum proof test intervals for each SIF.
- For each SIF not meeting its requirements, the most reasonably practicable options are recommended to meet the SIL assigned for that SIF, if necessary.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- SIL Assessment Report
- Failure Data from Vendors / Established / recognized sources
- P&IDs
- Vendor Safety Manual
- Cause and Effect
- Process Operating and Control Philosophy
- Make/Model and Data Sheet of SIF Components

Output data

- SIL verification report

7.10. Final/Updated Fire & Gas 3D Mapping Study

During Detailed Engineering, when the optimization has been completed, all the planimetry of the plant areas is detailed and defined, and vendor-designed equipment is available, it is required to update the F&G 3D mapping study considering the same principles discussed in **section-6.20.**

7.11. Final/updated Active Firefighting Calculation Study

To continue the risk reduction efforts, various technical safety studies that have been conducted in FEED need to be updated as design detail becomes available. Accordingly, active firefighting calculation shall be updated considering the same principles discussed in **section-6.21.**

7.12. Detailed Engineering Stage Gate Review

Stage gate review is a requirement that is required at key milestones/phases during the life cycle of capital projects to ensure that the process safety requirements are properly completed and achieved its objectives.

The stage-gate review is conducted by an independent and experienced multi-discipline team familiar with the relevant facility/process and technology. This team assesses whether the project management team has fulfilled its process safety objectives (requirements and deliverables) for the current project phase. At the conclusion of the review, the review team shall make recommendations for any improvements needed, and indicate to the Gate Keeper, based on process safety, whether the project is ready to proceed to the next stage.

The key objectives of the Detailed Engineering Stage Gate Review are to evaluate and assure that all the objectives of process safety during this project phase have been achieved. These objectives shall include but are not limited to the following:

- Refine and complete the design hazard management process (including functional safety, SCE, and performance standards).
- Final/update HIRA and other process safety specialist studies and address all study findings to ensure that process safety aspects are adequately addressed in the detailed design.
- Ensure that the process of management of change (MOC) has been fully implemented to evaluate late design changes.

8. Process Safety Studies in Construction, Commissioning, & Start-up Phases

8.1. SCE Identification & Performance Standards in Operation

The identification process and the performance standard of safety-critical elements do not stop with the conclusion of the Basic Engineering/FEED phase, but it is updated, refined, and improved (e.g., carrying out the assurance activities, such as maintenance, inspection, and testing), confirmed and integrated during the Construction, Commissioning and Start-up phase to establish the operational SCE's Performance Standards. During the Construction, Commissioning and Start-up phase, key personnel of the future operations team are being hired and the Engineering team has space of time, the operational Performance Standards to be developed address the following:

- Revising the list of SCEs when modifications in the project are done.
- Ensuring that assurance activities are listed in performance standards in accordance with operations and maintenance manuals from original equipment manufacturers (OEM) and assigned to competent people.
- Ensuring that verification activities are listed in performance standards and assigned to competent people.
- Adding the tag number items among the SCEs identified (If possible) shall be reviewed and confirmed during the operation phase.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- List of SCEs developed previously
- SIL verification report if available
- Original equipment manufacturer (OEM) operations & maintenance manual
- Maintenance program
- Risk-based inspection (RBI) report (if available)

Output data

- SCE's operations performance standards

8.2. Simultaneous Operations (SIMOPS)

A preliminary simultaneous operations (SIMOPS) study should be performed during construction/commissioning/start-up to evaluate potential conflicts if two or more activities are likely to occur in proximity to one another at the same time. Typical activities that could occur simultaneously include construction, drilling, commissioning, maintenance, and production. It is particularly relevant to brownfield developments. The purpose of the study is to ensure that potential conflicts, hazards, and risks are identified and assessed to enable plans to be adjusted to eliminate SIMOPS or apply appropriate safety measures. A SIMOPS study typically uses a HAZID, What If, and/or checklist approach.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- List of main/critical activities
- Metrological data
- project schedule/plans
- production plans

Output data

- Simultaneous Operations report & Matrix

8.3. Operations Safety Case

Design safety case that has been prepared in Basic Engineering /FEED should be updated and finalized during the detailed design stage of the project by compiling inputs from the contractor(s), engineering disciplines, and other sources of process safety information, such as HIRA studies.

The design safety case document should be used as the starting point for the development of an Operations Safety Case. The completed design safety case should be shared with the future operations team to provide information on the major accident hazards (MAH), and how they are managed through ISD, including design safety measures and associated performance standards in the final design. A dossier of all safety study work undertaken should be compiled and transferred to operations. Any design limitations for safe operation should also be brought to the operations team's notice.

An operation safety case can then be prepared by adding details of how residual risks are managed by:

- Facility’s management system (e.g., operating procedures, employee training, maintenance practices, management of change, etc.).
- Specific administrative/procedural measures that operations intend to implement (including resolution of some recommendations in the final HIRA study/s).
- Emergency response strategy and provisions.
- Operation safety case could be developed during the late stage of the detailed engineering phase; however, it is recommended to develop an operational safety case during the Construction, Commissioning, and Start-up phase due to the following reasons.
- Key personnel of the future operations team are being hired to review & update the design MAH bowties to reflect operation phase requirements.
- Operations and maintenance manuals from all equipment original equipment manufacturers (OEM) are available.
- EPC engineering team has enough time to coordinate and participate in developing the operation safety case.

In terms of inputs/outputs of such a study, the following is an indicative list of the required input data and the expected output deliverables.

Input data

- The latest versions of relevant Company standards, if any
- Process description with accompanying process block diagrams for all equipment
- Scaled plot plan(s) for the facilities showing the location of the plant equipment and location and dimensions of the site
- Equipment lists and layouts drawings
- PFDs
- P&IDs
- The company preferred international codes & standards
- Company HSE/PSM management systems
- Company Emergency response plan
- Emergency Shutdown & Blowdown Philosophy
- Cause & Effect matrix
- Formal safety assessment available studies (HAZOP, LOPA, SIL verification, etc.)
- Original equipment manufacturer (OEM) operations & maintenance manual
- Maintenance program
- RBI report (if available)

Output data

- Operation safety case includes the following parts:
  1. Introduction
  2. Facilities and Operations Description
  3. HSE/PSM management systems
  4. Formal safety assessment including QRA and Bowtie for Major Accident Hazards
  5. Emergency Response
  6. Conclusions and ALARP Demonstration

For more details, you can refer to Major Accident Hazard Management (MAHM) Guideline, document number EGPC-PSM-GL-006.

8.4. Construction/Commissioning /Start-Up Stage Gate Review

Stage gate review is a requirement that is required at key milestones/phases during the life cycle of capital projects to ensure that the process safety requirements are properly completed and achieved their objectives.

The stage-gate review is conducted by an independent and experienced multi-discipline team familiar with the relevant facility/process and technology. This team assesses whether the project management team has fulfilled its process safety objectives (requirements and deliverables) for the current project phase. After the review, the review team shall make recommendations for any improvements needed, and indicate to the Gate Keeper, based on process safety, whether the project is ready to proceed to the next stage.

The key objectives of the Construction/Commissioning and start-up Stage Gate Review are to evaluate and assure that all the objectives of process safety during this project phase have been achieved. These objectives shall include but are not limited to the following:

- Manage the process safety risks identified during previous phases that are relevant to fabrication, construction, and installation, including actions from the constructability study.
- Execute asset integrity management (AIM) practices and procedures including Quality Assurance/Quality Control (QA/QC) to deliver integrity and maintain design intent, especially for SCE and other protection systems.
- Implement a change management process, and thoroughly evaluate any late design changes.
- Identify and manage key process safety information.
- Ensure that operational readiness reviews (PSSR) have been conducted and their recommendations satisfactorily resolved before start-up commences.
- Maintenance of asset integrity during commissioning and start-up.

9. References

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

[2] PMI, 2013, Guide to the Project Management Body of Knowledge, PMBOK Guide Fifth Edition.

[3] ISO, 2016. Petroleum and natural gas industries - Offshore production installations - Major Accident hazard management during the design of new installations (ISO 17776).

[4] ISO, 2012, Guidance on Project Management (ISO 21500).

[5] IChemE, 2015. Frank Crawley Brian Tyler, HAZOP: Guide to Best Practice third edition.

[6] API, 2001, Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities (RP 14J).

[7] IEC, 2016. Functional safety –Safety instrumented systems for the process industry sector (IEC 61511, second edition).

[8] API, 2013 Fireproofing Practices in Petroleum and Petrochemical Processing Plants, (RP 2218, third Edition).

Annex A - List of Environmental Laws and Implementing Regulations for Environmental Protection

Environmental law:

- Law 4 for the Year 1994 for the Protection of the Environment was Amended by Law 9 for the Year 2009.
- Ministerial decree PM 1095 for 2011, PM 105 for 2015, PM 964 for 2015, PM 544 for 2016, PM 618 for 2017, PM 1963 for 2017 to amend PM 338 for 1995.

Waste management law:

- Law 202 for the Year 2020 for waste management and the ministerial decree 722 for 2022.
- Ministry of petroleum decree 673 for the year 1999 regarding hazardous substances Licensing.
- Ministry of petroleum decree 1352 for the year 2007 regarding hazardous waste handling and transportation Licensing.

Effluent Discharge law:

- Law 48 for the Year 1982 regarding the Protection of the Nile and Waterways from Pollution.
- Law 93 for the year 1962 regarding effluent discharge.
- Law 27 for the year 1978 regarding potable water resources.

Other laws and requirements:

- Civil defence approval on firefighting and detection systems.
- Labour Law 12 for the year 2003.
- International Conventions as per the Conventions List published on the EEAA website.

The user of this document shall update the above-mentioned list before use to seek any new or changed law or regulation that may be enacted after the issuance of this document.