CHEMICAL ENGINEERING TRANSACTIONS
VOL. 48, 2016

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Eddy de Rademaeker, Peter Schmelzer

ISBN 978-88-95608-39-6; **ISSN** 2283-9216
DOI: 10.3303/CET1648091

Technical-HSE Management System in the Design Phase of an LNG Plant Project

Masayuki Tanabe, Cesare Turco*

JGC Corporation [2-3-1, Minato Mirai, Nishi-ku, Yokohama 220-6001, Japan
tanabe.masayuki@jgc.com

Recent LNG facilities projects have grown in size and complexity (e.g., larger capacities, remote sites and modularized construction), thus requiring larger investments. This trend has not only increased the investment costs but also added further difficulties to project management during the design phase (e.g., large, joint venture organizations for both, Owner and Contractor, that combine partners with different company cultures, personnel hired specifically for the project, complicated contract formations and splits of work, and extensive and complex government permitting and approval requirements). In addition, the project schedule is also usually very tight in order to start up the facilities sooner.
Recent projects apply a risk-based approach in defining and ensuring a safe design, rather than using the traditional deterministic approach. A risk-based approach and decisions based on a probabilistic cost-benefit analysis are inherently difficult. They require obtaining a firm output from various analyses and studies, which in turn, require firm design data that is only available at the latter stages of the design phase. Delays in HSE input to design may result in major schedule delays in project execution.
Typical problems observed in such complex projects are differences in problem statements and optimal outcomes when there are multiple stakeholders, different philosophies, insufficient coordination and inefficient design change control, all leading to inconsistencies in HSE design.
The HSE Management System (HSE MS) typically focuses on site occupational HSE. However, due to the increased difficulties in engineering execution and project management in recent projects, detailed planning of how to handle Technical HSE aspects in engineering is becoming more and more important, and therefore, the traditional application of the HSE MS for occupational safety and for preparing HSE procedures and organizing and managing HSE studies (e.g., HAZID, HAZOP and SIL) do not suffice. Detailed consideration of how to handle and manage the technical HSE aspects in engineering is critical for its successful implementation.
This paper discusses a framework for the effective management of HSE MS in the design phase, and it provides some key considerations (e.g., project environment evaluation method, HSE organization and the decision-making process).

1. Introduction

The HSE Management System (HSE MS) in projects mainly covers occupational safety, and it is typically in accordance with OHSAS 180001. The HSE MS for plant operation (or process safety management) is, instead, normally in accordance with OSHA PMS. The HSE MS during the project design phase also refers to OSHA guidelines, but it is not fully covered by those guidelines.
While occupational and operational HSE MS are the responsibility of the Project Management, the technical HSE Management is normally considered to be under the Engineering Management. In projects where the HSE in design is based on a deterministic approach (specification requirements based on the minimum requirements of codes and standards), the HSE management is mainly focused on ensuring the implementation of the requirements. However, in projects where a risk-based approach is applied, a specific technical HSE management system and plan are required, as a more complex interface management is required for proper and consistent implementation of the technical HSE requirements (e.g., the same accident scenario for the different design teams, such as the fire scenario for pressure relief design, emergency

Please cite this article as: Tanabe M., Turco C., 2016, Technical-hse management system in the design phase of an lng plant project, Chemical Engineering Transactions, 48, 541-546 DOI:10.3303/CET1648091

depressuring system design, fireproofing application, and layout and separation distances; and the same approach to probabilistic analysis and acceptability criteria).

In fact, many recent projects that use a risk-based approach suffer from HSE issues in engineering execution. For example, a risk assessment was not completed during the FEED phase, and since the design had not been verified, inherently safer design options were not implemented.

Recent LNG facilities projects have grown in size and complexity (e.g., larger capacities, remote sites and modularized construction) and this results in larger investments. This trend has not only increased the investment costs but also added further difficulties to project management during the design phase (e.g., large, joint venture organizations for both, Owner and Contractor, that combine partners with different company cultures, personnel hired specifically for the project, complicated contract formations and splits of work, and extensive and complex government permitting and approval requirements). In addition, the project schedule is usually very tight in an effort to start up the facilities sooner. Due to these difficulties and the criticality of ensuring the proper implementation of the HSE requirements, a Technical HSE MS specifically designed for the engineering phase is required.

This paper discusses a framework for the effective management of HSE MS in the design phase, and it provides some key considerations (e.g., project environment evaluation method, HSE organization and the decision-making process).

2. Consideration for process safety management principle

This section briefly presents the HSE design principles, including the required interfaces between the design and the risk analysis and studies.

2.1 Safety design concepts

Risk based approach

A risk-based approach requires detailed design information in order to ensure the accuracy of the risk evaluation results. When the risk evaluation is conducted in the early stages of the design, it can only be based on assumptions due to the lack of maturity of the design. The results, therefore, include a large degree of uncertainty. Thus, towards the end of the detailed engineering phase, as part of the design verification, an update of the risk evaluations and studies is required. The detailed planning and the proper management of this cycle (i.e., input from design, feedback to design, and update) is a key success factor in the engineering execution.

Further, although the initial assumptions for risk analyses and studies normally already include safe margins to allow for increases or changes due to design development (e.g., exact locations and elevations, and parts counts), in many cases, such safety margins are not sufficient, since changes in design and increases in the number of components in the detailed design phase may be significant. Thus, the final values of DAL (Design Accidental Load) sometimes exceed the initial analyses and evaluation.

In addition, when a project is executed by a Joint Venture (JV), each JV partner will conduct their own analyses and studies for the areas within their scope of work (vertical split of work). This project formation increases the interface management and presents problems related to consistency between the assumptions and the results, also because the times at which the analyses and the studies are conducted by the various partners may differ.

Hazard management process

The Hazard Management Process in design is a systematic process addressing how Loss of Containment (LOC) scenarios and HSE risks are identified, their potential effects are assessed, the threats are controlled, the appropriate mitigating barriers are identified, and the consequences are mitigated. This is therefore a process for designing plant safeguarding systems based on accident scenarios.

Although industry standard designs for safeguarding systems are based on fire scenarios, consistency between the safeguarding systems provided by the different design disciplines is rarely achieved. For example, even if the same fire scenario is considered in the design of the PSV and ESD and EDP (safeguarding systems for the prevention and mitigation of the effects) and in the design of the Active and Passive Fire Protection System, Separation Distances, and Spill Control System (Slope and Surface Drainage), no particular multi-discipline consistency check is normally conducted. These safeguarding systems should, therefore, be designed considering not only the process design aspects, but also the facility layout design. Further, supporting systems, critical for the proper functioning of the safeguarding systems, should also be designed based on the same accident scenarios and their escalation (e.g., instrument and power supply cable (fire retardant or fire resistant) distribution should avoid common cause failure).

Recently, great emphasis has been placed on the specific requirements of the Functional Safety Management Plan (FSMP) for SIS design, which is part of overall HMP, and partly overlaps with the design hazard management (DHM).

2.2 Philosophy of process safety engineering

Hierarchy of process safety design options

The hierarchy of the protection layers is key to the reduction of the likelihood and consequent severity of an accident. However, once an accident occurs, the public perception of the accident is defined only by its consequences. Therefore, providing only protection layers that reduce the likelihood of an accident is not sufficient. The hierarchy of the protection layers should be as follows:

1. Reducing the hazard (e.g., process selection, inventory and operating conditions)
2. Greater separation distances
3. Reducing likelihood (prevention layers, such as PSV and SIS)
4. Mitigation measures (e.g., ESD and EDP, and Fire Protection System)
5. Administrative control

Inherently safe design (ISD) options result in greater investment costs, and they are normally considered and implemented in the early design phase, which is largely driven by the feasibility of the project (i.e., investment and running costs). Thus, early identification of ISD options (i.e., philosophy) is critical for the correct implementation of safety in design.

3. Technical-HSE management system in design phase

3.1 Framework of technical HSE MS

The Project HSE MS should specifically cover the technical HSE aspects in order to ensure an inherently safe and consistent application of the HSE requirements in the design. A simplified representation of the Technical HSE MS for a Joint Venture formation is shown in Figure 1 a).

The Project Policy should specifically refer to a detailed HSE design policy (i.e., not to a general, “coverall” policy, but to detailed guidelines for the design teams of each JV Partner) and to a specific Design HSE Plan, presenting the relations between the specific plans and procedures, such as pre-FEED and FEED studies, HAZID and ENVID, QRA, HAZOP, DHMP, FSMP, and to the other safety assessments, specifying the timing and the disciplines responsible and the leaders, for each of the partners. Further, the plan should also give the acceptability criteria for the various scenarios.

Implementing ISD

The most important aspect in establishing the Technical HSE MS is the clear indication of the HSE execution strategy. In each design and project phase (e.g., Pre-FEED, FEED, EPC), the potential ISD options that can be implemented are different, as late changes in or additions to the design have great cost and schedule impacts. For example, selection of the process licenser can only be done during pre-feed, as it would be difficult and costly to select or change the Licensor during the FEED, and it would not be feasible to change it during the EPC. Adequate separation distances between areas are to be set during early FEED, as they will have great impact if they are changed at the end of the FEED, and it would be physically impossible to modify them during EPC as the foot print of the plant is normally fixed at that time.

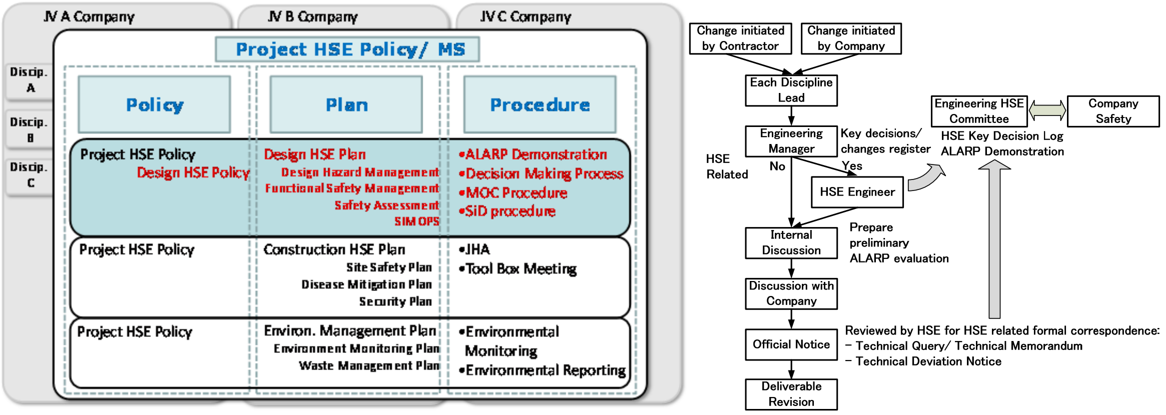
Separation distances can mitigate accident escalation. Therefore, the escalation of large, but less credible accident scenarios should be prevented by setting the safety distances between areas and units; and the escalation of smaller, but credible accident scenarios should be prevented by setting the safety distances between pieces of equipment within the same area.

Decision making process and ALARP demonstration

In many cases, decisions related to major development and changes are carefully scrutinized for their commercial and schedule aspects. However, many such decisions include HSE aspects, which may affect the design hazard scenarios or the design of Safety Critical Elements (SCE). When the decision making process overlooks the safety aspects, it may result in late design changes, which in turn, will require significant expenditures to resolve them.

The suggested decision making process for decisions taken to ensure the proper consideration of HSE aspects is shown in Figure 1 b).

Technical Queries (TQ) are commonly used for handling and recording design issues and the decision process between Plant Owner and Contractor. When a TQ is issued by the Plant Owner or the Contractor disciplines, the TQ should be evaluated first by the discipline engineers who prepared it to identify the HSE issues. The TQ form should include a check box for indicating that HSE aspects are involved, and the TQ log sheet should include the results. Then, based on discipline’s evaluation results, the Engineering Manager (EM) should decide whether the TQ involves HSE issues or not. If the EM considers the TQ to be HSE related, the TQ will be forwarded to the Technical HSE Group and preliminarily discussed with Company’s Technical HSE Group. The TQ will then be revised as necessary and officially issued. Some TQ’s may require an ALARP demonstration to justify the decision to be taken. The following flow chart shows the process for TQ preparation and issue. The same process may be applied also for projects where technical queries are handled by official correspondence (i.e., letters).



a) Technical HSE management system b) Suggested decision making process

Figure 1: Proposed Framework of technical HSE management system

3.2 Technical HSE team organization

Due to the larger size of recent projects, more Technical HSE personnel are required. Therefore, for such projects, it is recommended to provide a dedicated Technical HSE Manager and a Technical Safety Lead Engineer (refer to Figure 2). This formation also provides for independence of the Technical HSE team from the design team (i.e., a Technical HSE Manager for design, and a Technical Safety Lead for technical safety). Due to the variety of HSE aspects (e.g., process safeguarding design, structural design loads, 3D model reviews) and application of new technologies (e.g., functional safety management, CFD and FEM assessments using 3D data, and reliability and probability analysis), ensuring the competency of HSE Team members is highly important. The Technical HSE Manager requires not only knowledge and skills in assessment techniques, but also knowledge in engineering and design, in order to manage the interfaces between the Technical HSE team and the engineering disciplines. The Technical HSE Manager should also be responsible for managing the third-party specialist consultants doing the analyses. It is very important to communicate to the consultants an overview and strategy for the Technical HSE Design in the project.

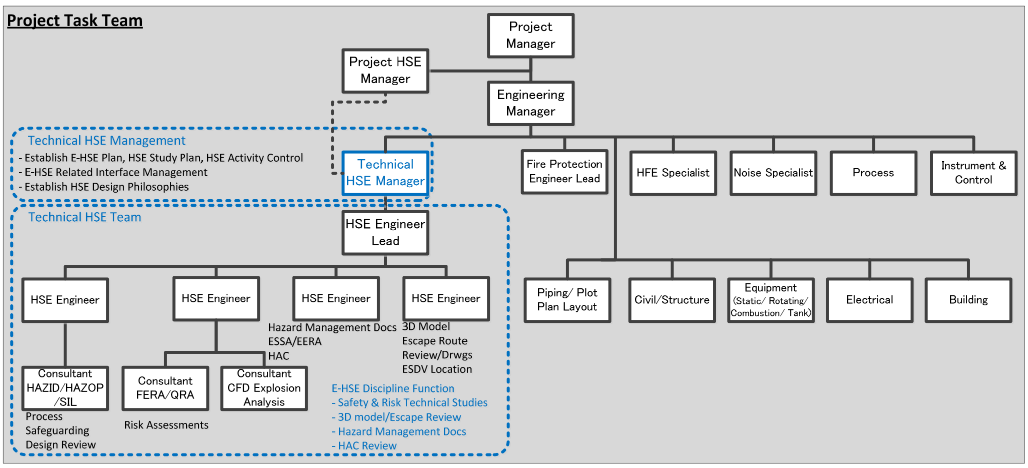


Figure 2: Example of technical HSE team organization

<u>Independency of technical HSE engineers</u>

Although the Technical HSE Manager reports to the Engineering Manager and coordination between the Technical HSE Group and the other design groups is essential, it is important to ensure the independence of the Technical HSE Group from the design groups. This is to prevent design decisions involving HSE aspects from being driven only by cost and schedule considerations. However, in some projects, the design groups relied too heavily on HSE aspects for decisions involving normal engineering and design practices.

4. Experience with a large LNG module project

A risk-based approach was implemented for the project execution, in particular the design, and it required strict management and control due to the extensive regulatory and technical HSE requirements, a three-partner Joint Venture with four main design centers and several production engineering centers, and modularized construction with three main fabrication yards. The Project key issues identified were as follows:

- Commonality in design through the various project design centers and design phases.
- Verification of, and check for compliance with applicable laws and regulations, national and local authorities' permits, and codes and standards
- Verification of COMPANY HSE requirements
- Identification and implementation of the recommendations of the FEED Environmental Impact Assessment and QRA, and issue of data and information for their update
- Identification and planning of the HSE risk assessments, reviews and studies to be conducted (e.g., HAZID, HRA, ENVID, HAZOP, SIL, Explosion and Fire Hazard Studies, QRA, E-HAZOP, C-HAZOP, ALARP studies, and Bow Ties).
- Potential high plant noise levels
- Ground flare capacity, radiation and noise
- Layouts of plant and equipment to mitigate HSES risks and to ensure operability, maintainability and constructability
- Technical HSES risks, such as loss of containment and consequent fires and explosions, identification and reduction to ALARP.
- Management and control of design interfaces, in particular in HSES issues and plant wise systems, with licensors, between the Joint Venture Partners' design groups, and consultants.

A specific Technical HSE Plan was prepared by the Technical HSE Manager in order to plan, monitor, and control the large number of HSE studies conducted by the several JV partners and consultants. A Risk Assessment Execution Plan was developed, and a Functional Safety Management Plan (FSMP), covering the implementation of the functional safety management for process safeguarding design (especially for SIS), was also developed separately under the Design Hazard Management Process. The structure of the HSE MS documentation was as shown in Tables 1 through 3.

Table 1: HSE management system

Overall Plan	Specific Area Plan	Procedure
HSE MS		
Eng. HSE Management Plan	Risk Assessment Execution Plan Functional Safety Management Plan HFE Implementation Plan Noise Management Plan SIMOPS Plan	HAZID Study Procedure ENVID Study Procedure HRA Study Procedure HAZOP Study Procedure SIL Study Procedure QRA Procedure HSE Action Tracking Procedure Management of Change Procedure ALARP Demonstration Procedure Safety in Design Procedure
Fabrication Yard HSE Plan	-	(apply each Fabrication Yard HSE procedures)
Construction HSE Plan	Emergency Response Plan	Orientation, Education and Training Procedure
	Fire Protection and Prevention Plan	HSES Risk and Hazard Management Procedure
	Occupational Health Plan	Incident and Hazard Reporting Procedure
	Security Management Plan	Fitness for Work Procedure, and the like
Environment Management Plan	Air Emission Management Plan Liquid Discharge Management Plan Waste Management Plan Underwater Noise Management Plan Erosion and Sediment Control Plan	Spill Response Procedure Waste Management Procedure Cultural Heritage Management Procedure Vegetation Clearing Procedure Fauna Handling Procedure, and the like

Table 2: Action plan (extract)

No.	Item Description	By Whom	Location	By When	Deliverables
1	Prepare Process Design Data	Process Lead	YOC		Process Design Basis
2	Follow up of FEED HAZOP	Eng. Manager	YOC		Revised P&IDs Operation Manuals
3	P&ID Internal Review	Eng. Manager	YOC		P&IDs
4	P&ID COMPANY's Review	COMPANY	YOC		Marked P&IDs
5	Verify, update and finalize Process Safeguarding Systems	Process Lead	YOC		Process Safeguarding Diagram
6	Identify and specify hydrocarbon inventory	Process Lead	YOC		Hydrocarbon Inventory

Table 3: Responsibility matrix (extract)

Document Type	Preparer	Checker	Approver
Overall HSES Execution	HSE Manager	Deputy Project Director	Project Director
Engineering HSES Plan	Tech. HSE Manager	HSE Manager	HSE Manager
Engineering HSES Philosophy	HSE Engineer	Tech. HSE Manager	Tech. HSE Manager
Engineering HSES Procedure	HSE Engineer	Tech. HSE Manager	Tech. HSE Manager
Engineering HSES Reports	HSE Engineer	Tech. HSE Manager	Tech. HSE Manager

By assigning the technical HSE function directly under the Engineering Manager, the design information flow related to HSE was tightly controlled and directed to the Technical HSE Manager. Further, regular Technical HSE meetings were called by the HSE Leader with all design disciplines in order to ensure a common understanding of the HSE requirements and enhance the coordination and working relationships between the engineering disciplines in the various design centers. A Technical HSE Induction Training package was also provided to all members in the project.
As a result of having a dedicated Technical HSE MS, the recommendations of the hazard assessments and risk studies were properly implemented throughout the project, from the conceptual design to the detailed design, in a timely manner, without any significant, late design changes.

5. Conclusion

In this paper, a framework for establishing a Technical HSE MS is discussed. Setting the proper Technical HSE MS (based on the complexity of the scope of work, project organization and contract formation) as a part of the Engineering Execution Plan is the key element for the effective implementation of HSE requirements in design. Key aspects to be considered for an effective Technical HSE MS are as follows:

<u>Organization aspects</u>

Independence of HSE group from discipline groups
Multi-discipline regular HSE review and status meetings
Competency and training

<u>Technical aspects</u>

Technical Queries and ALARP systems
Establishment of acceptability criteria
Implementation of ISD
Specific technical HSE plans covering such aspects as risk assessment execution plan and Functional Safety Management Plan

Reference

Tanabe, M., Miyake, A., 2012, Approach enhancing inherent safety application in onshore LNG plant design, Journal of Loss Prevention in the Process Industries, 25, 809-819.1.2011