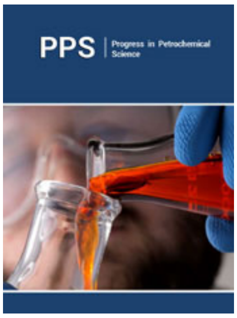
Crimson Publishers
Wings to the Research

Mini Review

# Technological Challenges of Petrochemical Process Safety

ISSN: 2637-8035




**Hu Shaolin* and Xiwu Li**

Guangdong University of Petrochemical Technology, Maoming, Guangdong, China

***Corresponding author:** Hu Shaolin, Guangdong University of Petrochemical Technology, Maoming, Guangdong, China

**Submission:** February 17, 2023
**Published:** March 14, 2023

Volume 5 - Issue 1

**How to cite this article:** Hu Shaolin* and Xiwu Li. Technological Challenges of Petrochemical Process Safety. Progress Petrochem Sci. 5(1). PPS. 000605. 2023.
DOI: 10.31031/PPS.2023.05.000605



## Abstract

Petrochemical process is a high-risk process accompanied by failures, risks, accidents and even disasters. Preventing risks and ensuring safety has always been an eternal topic in the petrochemical industry. Based on the analysis of some typical accident cases at home and abroad, this paper reviews the development history, technical status and shortcomings of petrochemical production process safety technology, and systematically summarizes the technical problems and challenges in four aspects of petrochemical safety technology, which is helpful for us to sort out the existing deficiencies and clarify the future development ideas.

**Keywords:** Petrochemical; Large-scale system; System safety; Safety control

**Abbreviations**: ESD: Emergency Shutdown System; SIS: Safety Instrumented System; F&G: Fire and Gas; BMS: Burner Management System; FSCS: Failure Safety Control System; PLC: Programmable Logic Control; SCADA: Supervisory Control & Data Acquisition

## Introduction

Petrochemical industry is an important industrial field that has lasted for nearly 100 years and is related to the national economy and the people's livelihood. The petrochemical industry originated in the United States in the 1920s and rose in Europe in 1950s. In 1953, Karl Ziegler, a German federal chemist, successfully invented the method of producing polyethylene based catalyst at low pressure. In 1955, a British chemical company, built a large polyester fiber production plant. Since the 1960s, the petrochemical industry has expanded to Asian countries. China's petrochemical industry developed rapidly in the past 30 years. The added value of the petrochemical industry accounts for about 12% of the global petrochemical industry, ranking third only after the United States (about 20%) and the European Union (about 30%). While the petrochemical industry has brought a lot of fuel, power, industrial and agricultural production and urgently needed materials for mankind, accidents and disasters from the petro-chemical production process are also lingering. For example, the highly toxic chemical explosion accident in Italy in 1976 spread over an area of 18 square kilometers; the explosion of liquefied gas containers caused by pipeline leakage in Mexico City in November 1984 left the factory in ruins, killing 650 people and injuring more than 4000; the highly toxic gas leakage accident at the Union Carbide Pesticide Factory in Bhopal, India, which occurred in December 1984, spread over 40 square kilometers and resulted in 3800 deaths and 150000 hospitalizations, becoming a disastrous and tragic accident that shocked the world. Different from other industries, the safety issue faced by petrochemical industry is due to the flammable, explosive, toxic and harmful materials throughout the entire production process. The safety hazard during the full life cycle (production, storage, refinement, transportation and disposal) may incur unimaginably terrible accidents if any carelessness. Therefore, it is very necessary to carry out theoretical exploration and targeted technical research on around petrochemical process safety, discuss how to effectively control and prevent accidents and disasters in petro-chemical process, and how to effectively solve the technical bottleneck of fault safety in petro-chemical process [1,2].

## Dilemma of Petrochemical Safety

In order to effectively control the safety risk of petrochemical process, production enterprises have begun to develop safety control technologies since the 1950s,. In the 1990s, many different types of fail-safety control systems were applied to the petrochemical safety technology field, such as the process safety-oriented Emergency Shutdown System (ESD) [3], the Safety Instrumented System (SIS), the Fire and Gas (F&G) protective system, the Instrument Protective System (IPS), the Burner Management System (BMS) and the Failure Safety Control System (FSCS) [4], etc., among which the FSCS was singled out. Subsequently from 1996 to 2000, the API (American Petroleum Institute) and the counterpart organizations in European countries issued a series of petrochemical process-related safety standards successively, such as the American national standard ANSI/ISA S84.01, German standard DIN 19250 on the safety of measurement and control devices, German safety standard NFPA 8502 and NFPA 85C on the involved electronic equipment (e.g., heating furnaces) and for preventing the explosion of heating furnaces and multi-burner boilers, international standard IEC 61511 on the safety of plant devices, standard FM 7605 on the safety of the Programmable Logic Control (PLC)-based combustion heating furnaces, and the international safety standard IEC61508 which is reputable all over the world [5]. These international standards run through the new idea of systematic safety management in the whole life cycle of equipment, and specifically reflect the international level of contemporary advanced science and technology, especially safety management and technology [6,7]. However, the widespread application of international safety standards and fail-safety control software systems in safety management has not reduced the catastrophic accidents in the petrochemical industry. The cruel reality tells us that there is a long way to go for system safety and accident prevention.

## Several Technological Challenges

Over the past few decades, governments and enterprises of various countries have formed a series of regulations, procedures and disciplines for the failure safety management of petrochemical processes. Unfortunately, the number of accidents in the petrochemical industry has not decreased year by year. In recent years, the prevention and control of technical accidents should become the focus of safety accident prevention.

a. Challenge 1 is the weak ability to perceive the site conditions and risks: In the emergency of disaster and death threat, accurate perception of the information related to the status of the petrochemical process (temperature and pressure changes, working status of heating furnace and compressor, etc.) is helpful to ensure correct emergency decision-making, avoid blind action and seize the last chance to escape. However, a large number of international petrochemical accidents have exposed the lack of disaster situation awareness and failure safety monitoring capability of large factory-level systems. How to improve the ability of employees on the production line of petrochemical plants to perceive the safety situation of plants and processes is a crucial technical issue for safety and accident prevention.

b. Challenge 2 is the lack of ability to identify false alarms and missed alarms: The status monitoring and disaster alarm of petrochemical process mainly depend on the data of instrumentation. Abnormal instrument data does not necessarily mean that there is an error in production equipment or production process. Abnormal instrument data without equipment fault may induce false alarm; Equipment failure may also be missed due to instrument failure. Both the former and the latter are dangerous. How to distinguish between instrument failure and equipment/process failure is the other technical problem to be solved urgently.

c. Challenge 3 is the lack of awareness of hidden dangers of equipment and pipelines: The structure of petrochemical equipment is very complex, and there are many hidden pipelines. Many equipment and pipelines do not have the conditions for direct monitoring. Once the equipment or pipeline suffers fatigue damage or hidden cracks due to corrosion or aging, the consequences are extremely serious. How to indirectly monitor hidden dangers in equipment and pipelines is another difficult problem in petrochemical safety technology.

d. Challenge 4 is the weak ability of interlocking response deduction and disaster risk prediction: Petrochemical production involves a long process flow. On the one hand, local faults, failures and accidents can easily trigger subsequent process catastrophes; on the other hand, abnormal state changes to a certain extent can also induce disasters.

e. Challenge 5 is due to workers' mis operation or carelessness or workers' lack of attention to the situation: In fact, when workers work in the same position for many years, they may gradually form a self-righteous carelessness or gradually lose their original vigilance. In addition, workers in one position are not familiar with the working conditions of other positions.

f. Challenge 6 is the inconsistency between theory and technology or the incompleteness of theory: For example, as we all know, PID control is the most common control strategy used in the petrochemical processes. The existing theoretical research on PID control parameters tuning hardly takes into account the dangers that may be caused by obvious overshoot during dynamic response. In fact, taking the ethylene cracking process as an example, the petrochemical process involves cracking reaction under high temperature and high pressure complex environment, and it is very dangerous if the control process has obvious overshoot.

## Some Thoughts for Solving Challenges

The petrochemical process is critical to safety and the petrochemical enterprise must consider the comprehensive benefits. From the perspective of cost-effectiveness, in order to solve the above six challenges, we must have a comprehensive thinking: First of all, we need to carefully analyze that some challenges (e.g. Challenge 1-4) are due to the lack or imperfection of technology, some challenges (e.g. Challenge 5, etc.) require the efforts of technology and management at the same time, and some challenges (e.g. Challenge 6,etc.) can be solved with the help of principles and basic research. Secondly, a new system safety perspective is needed for the petrochemical process. At present, the functions and design architecture of some typical safety assurance technology products [8] (such as the Safety Instrument System SIS and the Supervisory Control & Data Acquisition SCADA) need to be improved: it is necessary to establish the safety theory and technology of the whole production cycle and the whole life cycle of equipment based on industrial big data; it is necessary to break through the technical problems of false alarm and missed alarm caused by monitoring logic based on fixed threshold; more importantly, it is necessary to form a worker-centered, equipment-centered and process-centered full-scene safety awareness capability. Thirdly, technological progress and management requirements and regulations must be promoted simultaneously. Technological progresses are helpful to prevent and reduce accident risks. However, it is dangerous if workers thoughtlessly idolize and excessively rely on technical tools, and even try to avoid or escape the restrictions on safety regulations. In other words, we need to integrate the human-equipment-process-environment system into the safety system architecture of petrochemical process and build it as a whole. Fourthly, we must adhere to the viewpoint of "Safety First" and put safety requirements at the first place of the process of petrochemical production and ensure that the application of theory in petrochemical plant must be subject to safety.

## Conclusion

In recent years, the post-event analysis of many catastrophic accidents in the petrochemical industry has been attributed to improper management or human error. However, the absence of safety technology, especially fail-safety control technology, can always be found through fundamental analysis. This paper summarizes four technical challenges. At the early stage, our team made a series of beneficial explorations and built up the architecture of system safety technology system. It can be expected that with the development of process monitoring, change detection, fault diagnosis, trend prediction, risk warning and intelligent maintenance technology, petrochemical safety problems will be effectively improved.

## Acknowledgement

This work is supported by the National Nature Science Foundation of China (No.61973094,61933013) and the Nature Science Foundation of Guangdong (No.2023A1515012341).

## References

1. Ding L, Jiang W, Zhou C (2022) IoT sensor-based BIM system for smart safety barriers of hazardous energy in petrochemical construction. Frontiers of Engineering Management 9(1): 1-15.
2. Adamyan VL, Sergeeva GA, Seferyan LA, Gorlova NY (2021) Development of technological measures to ensure the safety of production facilities in petrochemical industry. IOP Conference Series: Materials Science and Engineering 1083(1).
3. Zhu P, Liyanage JP, Kumar R, Panesar SS (2021) Decision quality related to emergency shutdown system in the oil and gas industry: Influences from data and information. Inter J of Decision Sciences, Risk and Management 10(2): 131-159.
4. Wang T, Tang J, Xia H, Pan X (2021) A Review on simulation platforms for complex industrial process. 8th Inter Conf on Info, Cybernetics, and Comput Social Systems.
5. Hokstad P, Corneliussen k (2004) Loss of safety assessment and the IEC 61508 standard. Reliability Engineering & System Safety 83(1): 111-120.
6. Häring I (2021) The standard IEC 61508 and its safety life cycle, in technical safety, reliability and resilience: Methods and processes. Springer, Singapore, pp. 193-207.
7. Brown RK, Hastie M, Khan FI, Amyotte PR (2021) Inherently safer design protocol for process hazard analysis. Process Safety and Environmental Protection 149: 199-211.
8. Rajesh S, Mahadev V (2021) 4-Reliability and maintainability of safety instrumented system. Advances in Reliability Science, in Safety and Reliability Modeling and its Applications, Elsevier, Netherlands, pp. 43-90.