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Barrier management as proactive approach for technical integrity and risk management

Keywords

barrier, system, risk, barrier management, technical integrity, offshore, safety performance, TIMP

Abstract

Technical Integrity Management system is a program for continuous follow up on selected technical barriers against major accidents and critical elements for production regularity. Technical integrity management is a crucial element in running a business in safe, sustainable, and effective. The technical integrity is based on the available data in the plants/installations, competences and skills within the organisations and emphasizes on gaining a complete overview of technical conditions of safety systems and barriers. The system helps the companies to document and follow-up the technical state of its operations and assets throughout the platform/installation life cycle. The program contributed to increased risk understanding of safety barriers and better compliance with national and industrial requirements. The system helps risk owners, production managers, platform management to take rational and informed decision quickly. It is a main contribution to understanding the condition of platforms and assets and a great input to better understanding the related risks to safe operations and preventing the undesired events including prevention of major accidents. The main aim of this chapter is to highlight the importance of barrier management and technical integrity management programs is prevention major accidents by identifying the weaknesses related to equipment, systems, and barriers through controlling different accident scenarios.

1. Introduction

This chapter will share day-to-day experiences in the field of barrier management and technical integrity management. It is based on 15 years experiences with implementing a holistic approach to managing the technical integrity and enhancing the risk management across plants/installation in the energy industry, mainly from Equinor in several locations and continents including production facilities offshore as well as onshore.

2. Technical integrity management

Technical Integrity Management system is a program for continuous follow up on selected technical barriers against major accidents and critical elements for production regularity. Technical integrity management is a crucial element in running a business in safe and effective operations of facilities. Asset integrity management requires understanding the risk of operations depending on classifying the events based on their probabilities and consequences. Hazard identification and risk assessment are invariably linked to a safe operating envelope (Atherton & Gil, 2008). Understanding of Risks is an essential element for managing the business, increasing the opportunities, and preventing the undesired incidents including major accidents. Based on Reason Swiss cheese model (Reason, 1990) accidents can be seen as the result of interrelations between real time *unsafe acts* by front line operators and latent conditions such as weakened barriers and defences. Barriers might also be identified for accidents that do not

Safety and Reliability of Systems and Processes, Summer Safety and Reliability Seminar 2023.

DOI: 10.26408/srsp-2023-15.

cause major accidents (Gustafson, 2014). It is necessary to emphasize reduction of impact of risks to a minimum possible level and having a risk-based approach to handle the daily operations, projects and further developments.

Managing risk related to technical conditions and barrier performances is imperative for a proactive risk and technical management of assets. The authorities and major energy companies have a strong emphasis on having a clear overview of the technical conditions of systems and operations. These can be done by a proactive active in management of the technical integrity with right competences and necessary resources to ensure the compliance with national- and industrial requirements.

The national health, safety, and environmental regulations in addition to the company's own technical and operational requirements are the main basis for ensuring the safe and effective manner of operations and deliveries. The responsibilities are defined based on predefined roles and responsibilities. To prevent majoring accidents, the companies need to understand the main risks and risks elements effecting the function of the safety systems and barriers in the plant/installations. The companies are using different tools in managing technical integrity by providing operators and managers with a comprehensive overview of the condition of systems and technical barriers. These tools form a solid basis when risks are assessed prior to the initiation of operational activities in the field.

Assuring technical integrity in any process plant design is essential to ensure that there will be no harm done to people or damage to the environment. This applies whether the design is for a new facility or a small modification to an existing facility (Bale & Edwards, 2000). To gain overview over the technical conditions there are needs for certain indicators to understand the functionality of these system and their components. There are needs to define and understand these barriers, through understanding the functionality, reliability, capacity, and maintenance management.

The technical integrity management is part of the total barrier management for the company. The management regulation in Norway requires that the barriers shall be established that at all times can:

- identify conditions that may lead to failures, hazard, and accident situations,
- reduce the possibility of failures, hazard and accident situations occurring and developing,
- limit possible harm and inconveniences.

The main difference between the Norwegian PSA regulations and the EU directive is that the directive focuses only on major accidents, whereas PSA's regulations focus both on smaller and major accidents (Gustafson, 2014). The operators in the field of energy production or any of their partners must ensure operations have necessary strategies and processes to cover all phases of safe operation from the design, construction, operation, and to the cessations. These activities include defining the systems, barriers and maintaining them to ensure that the barriers function is safeguarded through the plants lifecycle.

There are many definitions for technical integrity. Asset technical integrity refers to a condition where the technical state of assets incorporates all related operations and business processes as one process. Such integration ensures that there will be no harm done to people, property or the environment and this leads to reduced risk exposure of the firm (Rahim et al., 2010). IOGP relates the asset integrity to the prevention of major incidents, and defines it as an outcome of good design, construction, and operating practices (IOGP, 2008). Technical integrity is concerned with the development of the design intent for plant and equipment to provide safe operation. It includes the processes and competencies required to ensure that the communication and development of that design intent through specification, procurement, detail design, fabrication, erection, and testing match the original intended use (Bale & Edwards, 2000).

Technical integrity is a system or installation platform's ability to function as intended and in accordance with regulations (regulatory requirements) and internal requirements. The technical integrity refers to the state that technical states of the assets are incorporated in all related operations and business as one process, to ensure that there will be no harm done to people, property, or the environment. Other definitions are related to the management systems, strategies, and activities aimed at maintaining plant assets in required safe and productive condition for the desired life of those assets.

While other definitions are referring to an overall state of safety in terms of functionality, operability, and reliability. Ratnayake and Markeset (Ratnayake & Markeset, 2010) state that the main challenges are related to technical integrity management on implementing the organizational strategy, maximizing the availability and efficiency of equipment, controlling the rate of equipment deterioration, ensuring safe and environmentally friendly operations, and minimizing the total cost of the operation.

3. Technical integrity management performance system

The technical integrity emphasizes a complete overview of technical conditions and related information, and the ability of the companies to document the technical state of its assets. It is based on an integrated view of the current state of operations, and the identification of all critical interfaces (OECD, 2008), to ensure that all gaps and unnecessary overlaps in processes are eliminated. Developing a system for preventing major accidents are an essential part of defining the process and measurements that help the companies to have clear overview over the elements threatening the safe operation and gaining the broader knowledge of the barriers needed to prevent undesired events. The main aim of establishing a system for technical integrity is to have more focus and understanding of the equipment's and how they are always performing according to the required performances through the expected lifetime.

The Maintenance Management System, as a whole or as partially should be part of the total asset integrity management systems to achieve the required objectives. Such objectives include the following: eliminating all potential hazards, reducing critical incidents and near miss incidents, maintaining the condition, functionality and operability of the inventory, reducing failure incidence or Mean Time Between Failures (MTBF), reducing downtime after failure or Mean Time To Repair (MTTR), increasing maintenance personnel skills and work experience, and increasing the plant/systems/equipment reliability and availability (Rahim et al, 2010). These require conducting a preventive maintenance based on recommended intervals and instructions both from the manufacturers and the technical experts within the company. The accumulated knowledge will be based on experiences and incidents that have occurred, to analyse them, find out root causes and enabling the organisation to make appropriate decisions in preventing the major accidents.

The technical integrity evaluations are based on the evaluation of specific safety performance standards for safety systems and functions, based on the identified hazards, availability, capacity, response time and survivability.

The evaluations are conducted by skilled engineers from different disciplines, the evaluations and condition assessments are conducted individually or through multidiscipline involvement. The duration of assessments is defined based on work process requirements.

The evaluations are documented through the tool by using the Bow tie to illustrate the condition of each barrier, the Bow tie, illustrating the barriers reducing the probability of any undesired incidents and the other side of the bowtie, illustrating the barriers that contribute to reducing the consequence of outcome of the incidents (Figure 1).

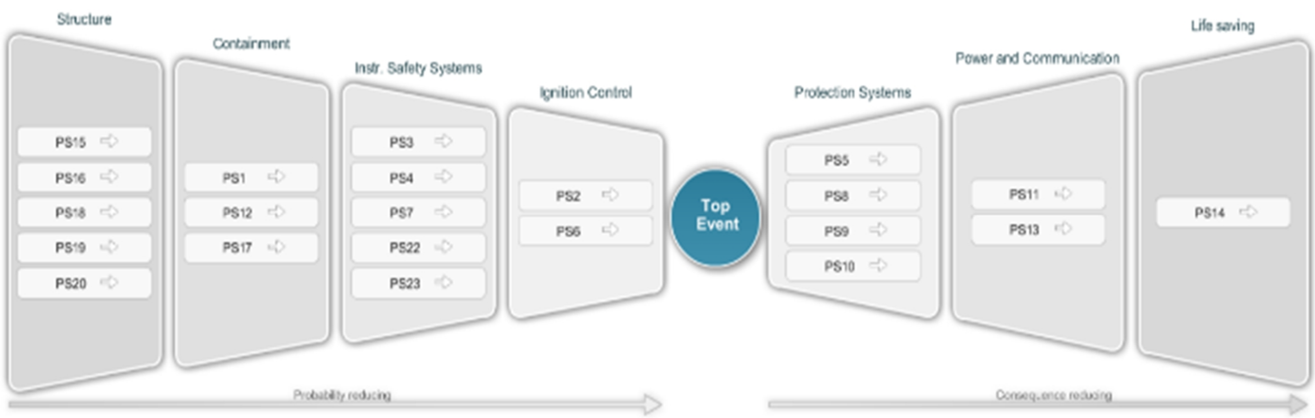

Figure 1. Bow tie model for visualizing the barriers.

4. Main indicators for technical integrity

Indicators for technical integrity management can be categorised as automatically generated information or manually gathered information these includes inspection and verification activities. Verification activities such as document reviews, surveys and audits may be used as separate methods, and they may provide additional (manual) input to performance indicators. (Hauge & Øien, 2016) The indicators and monitoring activities can give useful input to improvement, learning and benchmarking for own asset, and with other assets and companies in the industry. All the indicators can be calibrated based on the characteristics of a plant (Davatgar et al., 2021). These indicators can be categories as reactive indicators or proactive indicators:

- the indicators related to the preventive maintenance management,
- the indicators related to the corrective maintenance management,
- the indicators related to previous incidents,
- the indicators related to the documentations,
- the indicators related to the inspection activities,
- the indicators related to previous verifications and findings.

5. Barriers and barrier management

Barriers can be categorized into three main categories: technical, operational and organizational barriers. The weakness of barriers and their elements can individually or in combination affect the result of the undesired event. Where more than one barrier is necessary, there shall be sufficient independence between barriers. (PSA, last amended 16 December 2021).

The Norwegian management regulation Section 5 on barriers is emphasizing that the barriers shall be established that always can (Figure 2):

- identify conditions that can lead to failures, hazard and accident situations,
- reduce the possibility of failures, hazard and accident situations occurring and developing,
- limit possible harm and inconveniences.

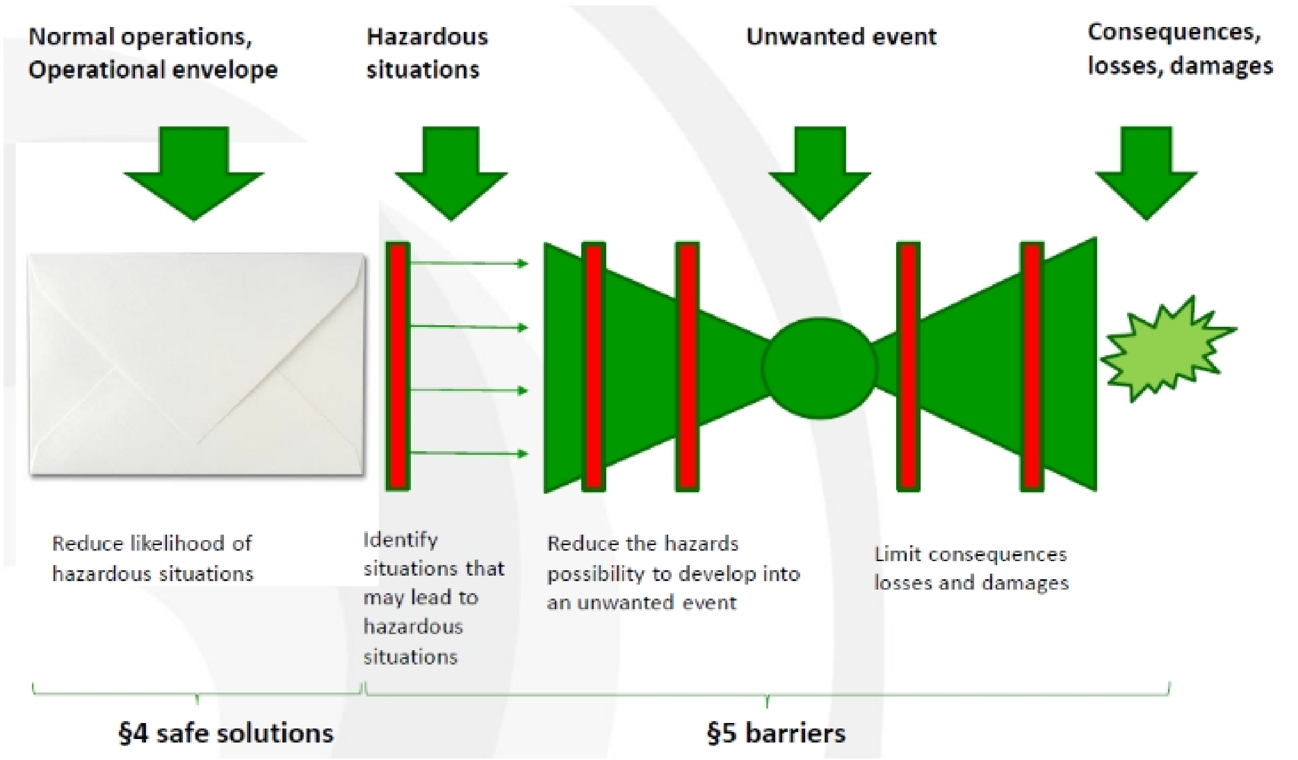

Figure 2. Barrier diagram (Lootz & Ersdal, 2016).

The barrier management can be defined as systematic and continuous activities to ensure the necessary barriers are identified and in place for the prevention of failures, hazards and accident situations (PSA, 2017). The management of safety and technical barriers requires a total risk overview approach, through the effective identification and management of risks by defining:

- the barriers and barrier elements,
- different scenarios and chain of events based on various barrier impairments,
- the performance standards for the barriers and barrier elements,
- the tests and test intervals,
- the barrier validation and evaluation intervals,
- the sequence of indicator evaluations,
- the monitoring the reporting processes and management,
- the learning from the current barrier conditions and managements,
- the process and means of communicating the risk related to the barrier conditions.

Main technical barriers for safety are defined in NORSOK S-001 as following:

- layout,
- containment,
- open drain,
- structural integrity,
- process safety system,
- emergency shutdown,
- emergency depressurization and flare/vent system,
- gas detection,
- fire detection,
- ignition source control,
- human – machine interface for CCR (central control room) systems,
- natural ventilation and heating, ventilation and air conditioning,
- ignition source control,
- fire detection,
- emergency depressurization and flare/vent system,
- active fire protection,
- passive fire protection,
- emergency power and lightning,
- public address, alarm and emergency communication,
- emergency power and lighting,
- Passive fire protection,
- active fire protection,
- escape and evacuation,
- rescue and safety equipment,
- marine systems and position keeping,
- avoidance of vessel collisions,
- well integrity.

6. Overall plant technical integrity

Plant assessment level is based on a comprehensive evaluation of the most serious known deficiencies or findings that affect the level of risk in terms of major accidents and downtime. These including each individual impairments or multiple impairments in the same module or area.
The information flow discipline, system or barrier level are important contributors. It is necessary that the total evaluation is based on correct data with a high quality, the way data are compiled could tell a lot about the validity and ranking of numbers (Hollnagel et al., 2006) this may influence the decisions on the defined priorities for the next period or long rang priorities.
The overall plant technical integrity assessments are conducted with active participation of all main stakeholders including both technical and operations personnel to ensure a common understanding of the current statues for safety condition of barriers in the plant, the risks emerged from these conditions and highlighting the barrier impairments, the consequences and corrective action. The summary report is produced with the name of all participants and published in the tool following this meeting. The risks are communicated to major stakeholders and priorities and mitigating measures are decided or implemented to compensate for any degradation in technical conditions.

7. Main accident scenarios

The main aim of technical integrity management programs is prevention major accidents by identifying the weaknesses related to equipment, systems, and barriers through controlling different accident scenarios. It is essential that this identification process is exhaustive for all potential accidents with major consequences (Hollnagel et al., 2006). In industry like energy industry including oil and gas, thee list of potential accidents might be very long, the most known scenarios includes:

- ignited gas leaks; includes gas and condensate leaks in seabed and on topsides (release rate: volume/time),
- fire and explosions,
- ship collision with platforms,
- loss of stability, structure collapse and capsizing,
- dropped loads and objectives,
- terror/piracy on-board,
- cyber attacks.

8. Reporting and monitoring activities

Based on inputs from all indictors the barrier assessments will be performed, status of the barriers shall be documented in the tool for follow-up and visualization of technical integrity on regular basis and when significant changes occurring. The evaluation includes are any known conditions that have not been captured through the indicator evaluations. The overall evaluation of the barrier integrity will be assessed in terms of function requirements, reliability, maintenance requirements and condition control, management, and survivability requirements.

Barrier status evaluation and barrier weaknesses will be highlighted based on deficiencies and impairments. The barriers will be graded according to a predefined criticality/risk level grades. Based on these criticalities the necessary preventive and corrective measures are identified and visualized. For higher criticalities a compensatory and/or corrective measures shall be described and followed-up by the technical and operations management teams. The decisions based on technical conditions are influenced by several factors i.e. by technical expertise and professional judgments. Competence in decision making is significantly influenced by the technical expertise, level of experiences, familiarity with situation and practice in responding to problem situations (Flin et al., 2008). The companies have defined set of key performance indicators as both proactive and reactive indicators. These indicators can be also used for monitoring technical integrity status and benchmarks with similar assets and projects.

9. Equinor approach and system for technical integrity management

Equinor as one of the major energy companies has established an own system for managing the technical integrity across all platforms and installations, namely the program called TIMP (technical integrity management program). The program is based on defining and follow up based indicators to evaluate the technical condition safety in addition to indicators to evaluate the operational condition safety. These indicators can be a sort of benchmarking indicator to assess the required performances.

The elements of the program are based on known national requirements, international and industry standards, as well as the company's own technical requirements and corresponding requirements reflected in the work processes.

The program is based on continuous monitoring and evaluation of the status of equipment, systems, and barriers based on predefined indicators and maintenance programs. The evaluation program includes the verification of the current condition of barriers, related consequences and future developments, and risks related to all levels in the plant/installations. The evaluation includes the required actions to improve the condition of systems and barriers. These corrective actions can be in both short- and long-term categories. The short-term category of actions are often in operative type while the long term actions may require modifications.

In Equinor the TIMP emphasizes the following items.

- Multiple data sources are integrated in the indicator overview including incident, equipment, system, barriers, and maintenance programs, etc. to provide a comprehensive view of the data sources. The data are gathered from all relevant sources and plotted together to enable the organisation to utilize the information and establish knowledge the technical condition of equipment and systems.
- Analysis of based data handling to extract relevant information from the maintenance, inspection and verification programs. These structured information present across different tables and contents to match with the indicator definitions.
- The data from previous incidents are classified and will be evaluated according to severity, equipment types and disciplines involved in the events. These including the actions taken to mitigate the consequence of the incident beside eliminating the occurring factors at the same plant or other plants.

TIMP makes use of relevant data (or indicators) for technical barriers, including notifications from the maintenance system, backlog of PM and CM, test reports, inspection reports, incident reports, TTS (technical condition safety) verification findings, and dispensations (Hauge & Øien, 2016). The data or indicators are collected and presented in the TIMP portal and manually assessed by technical experts such as system responsible personnel (Hauge & Øien, 2016). Excellent technical integrity management requires a well-trained workforce and experts, and they are often the central means of achieving high performance in the organization (Ratnayake & Markeset, 2010). Organizations must put in place robust systems for assessing the competence of both their own engineers and of any third-party organizations that they employ (Bale & Edwards, 2000). The success element of the program will be based on the broad training of all engineers participating in evaluation of equipment, system and barriers. In addition to that, the training was offered to major operative leaders and managers across the organisation. The key elements in the training are establishing a standard approach for evaluation and grading the criticalities as well as defining the risks related to the current conditions, impairments, and related risks and corrective or improvement actions. Additional trainings are the management training on the risk awareness and risk communications across entire company.

As the quality management focuses on compliance with procedures, rules and regulations of people and organisation in their activities (Hollnagel et al., 2006). The companies conducting continuous verification of the status of barriers across the assets based on various methodologies. The findings from the audits and verifications are handled and followed-up systematically through other established work processes and tools.

The system does visualise the technical integrity of the platform/installation, it does not explicitly assess the risk level on the asset. The system is a major input for risk management and decisions making processes related to the safety, operations, and production activities.

The system and assessments are transparent, well documented and made visible based on defined access roles.

10. Main benefits from technical integrity program

The direct linking of barriers to specific parts of the management system is unique in risk assessment and system modelling. We believe it provides a fundamental increase in the clarity of the risk control picture (Hollnagel et al., 2006). The program contributed to increased risk understanding of safety barriers and better compliance with national and industrial requirements. The system helps risk owners, production managers, platform management to take rational and informed decision quickly.

Identify and understand the weak signals at different levels including the safety barriers for improved interventions which help the organization to prevent future incident and reduce the consequences if they occur.

The technical integrity management systems and tools provides incentives for continuous improvement, also facilitates experience and knowledge transfer across technical disciplines, facilities, business areas, and the company.

11. Conclusion

The work process for managing the technical integrity should be established and to be part of the companies' management systems. The work process should contain clear definition of roles, responsibilities at each level of the organisation in addition to a method for risk assessment and risk accept criteria levels. Other important element is a capacity building, competence, and training of personnel to gain the full potential of their skills in evaluation of technical conditions.

Facilities for oil and gas production are very different in terms of age, design, technology, complexity, and dependencies. Therefore, there might be a need to different approaches for managing the technical integrity and maintenance. However, continuous maintaining, follow-up and control of technical integrity is equally important for all types of plants and assets.

The input data sources for the technical integrity management should be based on bottom-up approach, by assessing the condition of the plant from the lowest level as components and equipment, thereafter the information will be shared to upper levels to systems, barriers, and the entire platform.

The technical integrity management is dependent on the systematic flow of information from various sources including the maintenance management programs and activities. The technical integrity management is dependent of high skilled people to conduct evaluations and highlight the weaknesses in systems and barriers. It is a main contribution to understanding the condition of platforms and assets and a great input to better understanding the related risks to safe operations and preventing the undesired events including prevention of major accidents.

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