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Facilities Integrity Management System: Practical Case Studies for Enhancing Production Operations in the Energy Sector

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Abstract

In this study, we have presented real case studies demonstrating major asset integrity issues that must be addressed to maintain seamless operation. To address these issues, FIMS was designed to be propelled by a clear and transformative mission: to eliminate high-impact incidents that could compromise safety, health, environmental stability, and financial integrity. Our unwavering commitment to safety and reliability is evident as we work to eradicate equipment and facility failures, significantly improve reliability, and drastically reduce unscheduled volume losses that can disrupt operations and impact profitability. We are dedicated to meticulously optimizing capital and operating expenditures while prioritizing a culture of safety that stands firm in our principle of "Nobody Gets Hurt." Our resolve to prevent substantial incidents in our processes and facilities is a cornerstone of our strategy, establishing us as leaders in maintaining our License to Operate. By strategically managing our base activities, we will seek to maximize value and achieve exceptional economic recovery from each reservoir, ensuring we harness every possible opportunity for growth and efficiency. We recognize the crucial role of our stakeholders in this journey, and their support is integral to our success. In addition to these efforts, we are committed to institutionalizing industry-leading integrity and reliability programs. We will relentlessly pursue excellence in meeting and exceeding our volume and reserve expectations while achieving our ambitious targets related to unit operating costs. With our determination unwavering, we are dedicated to delivering exceptional results that not only meet but exceed the expectations of our stakeholders. This commitment reinforces our reputation for excellence and reliability in the industry, and we are confident in our ability to continue exceeding your expectations.

Keywords
Integrity Goals, Alignment with Business Objectives, Risk Mitigation Barriers, Framework, and Effectiveness

Abbreviations

Words	Definition
RCFA	Root Cause Failure Analysis
PDRR	Prevent, Detect, Respond & Recover
PBP	Production Best Practice
UVL	Unscheduled volume loss
UVDT	Unscheduled volume down time
ALT	Asset Leadership Team

1. Introduction

The Facilities Integrity aims to prevent High-Impact Equipment and Facility Failures proactively. Our foremost business objective is to embed safety into the very core of our operations. We are steadfast in our commitment to ensuring that nobody gets hurt and eradicating significant incidents related to our processes and facilities. By striving for industry-leading performance in our License to Operate, we uphold our responsibilities and demonstrate our unwavering dedication to excellence. We will strategically manage our base activities to maximize value and drive exceptional economic recovery from all reservoirs. By institutionalizing best-practice integrity and reliability programs, we will meet and exceed our volume and reserve expectations while successfully achieving our unit operating cost commitments. To effectively mitigate risks, we will implement robust barriers designed to prevent high-impact equipment and facility failures, significantly enhancing our reliability. Our relentless focus will be on optimizing costs through efficient resource allocation, process streamlining, and technology adoption. This will ensure the most efficient utilization of our resources, driving us toward unparalleled operational success.

1.1 Objectives

FIMS is a crucial initiative that prioritizes safety in our operations. Our primary objective is to inspire and motivate by attaining industry-leading License-to-Operate performance through meticulous management of base activities that significantly enhance the value of our process operations. This approach is vital for cultivating new resources that drive sustainable and profitable growth. Furthermore, we are deeply committed to strengthening our external relationships, fostering a sense of inclusion and positioning ourselves as the partner of choice in our industry.

By investing in the development of our people and maximizing organizational capabilities, we empower our teams to reach their highest potential and achieve remarkable results. Together, we are laying the foundation for a successful and innovative future.

2. Literature Review

Kirill et al.2022 discussed the OPERATOR System: Control, Monitoring, and Diagnostics of Software and Hardware in Instrumentation and Control Systems. Kuo-Chi Chang et al. 2019 discussed the Study of the High-tech Process Mechanical Integrity and Electrical Safety. Firmansyah Aditya et al. 2023 discussed the Architecture of the Manufacturing Operation Management System In a Gas Processing Facility. K. Nishiki et al. 2000 discuss the Integrated management architecture based on CORBA. A.C. Silva et al. 2009 discuss the Quality assurance of complex systems - satellite AIT. Marie Kim et al. 2024 discussed the Enhancing Factory Energy Management Systems through Ontology-Based Metadata Management. Michael A. Nevins et al. 1989 The Building of a Nuclear Power Knowledge-Based Control System

Incorporate a broader range of failure modes. Committed to addressing issues before they lead to mission aborts. Enhance our ability to assess and track reliability growth effectively. Increase the statistical power and confidence in our reliability evaluations during testing. Establish realistic and attainable reliability growth goals. Eliminate subjectivity from the reliability scoring process. Correct a greater number of failures that adversely impact system availability, maintainability, and operating or sustainment costs.

3. FIMS - Facilities Integrity Goals and Challenges

To fortify the integrity of our process operations, we must take unequivocal action to avert High Impact Equipment and Facilities failures. Such failures can have dire consequences, affecting not just Safety, Health, Environmental, and Security (SHES) standards but also imposing significant financial burdens, as shown in Figure No. 1.

We are unwavering in our commitment to enhancing equipment reliability to ensure peak performance and will actively work to eliminate unscheduled downtime—this is essential for our ongoing success. Figure No. 1 vividly illustrates the corrosive effects that can undermine our facilities' structural integrity, showcasing our mission's urgency. By prioritizing these critical initiatives, we will safeguard our operations and cultivate a foundation for sustainable growth and resilience in the face of challenges.

Pipeline clamp corrosion **Internal Piping corrosion** **Flare Pipe corrosion**

Figure 1. Evident Corrosion factor at pipeline clamp, Internal piping and Flare piping

3.1 FIMS Risk Mitigation Barriers

To significantly enhance our operational reliability and avert high-impact equipment and facility failures, we are committed to optimizing costs and maximizing resource utilization with exceptional precision in production operations at Qatar Energy.

As depicted in Figure 2, we have implemented four robust control barriers to prevent incidents effectively. The first line of defense is maintenance execution. Should this initial barrier fail, our second layer—operator care—will spring into action to mitigate any potential risks. If the second layer is compromised, we will engage our third line of defense, engineering surveillance, to monitor and address emerging issues. Finally, if the first three barriers fail, our critical fourth layer, equipment inspection, will be activated to safeguard against incidents. The consequences of failing all four layers can be severe, underscoring the imperative nature of our multi-tiered approach to risk prevention.

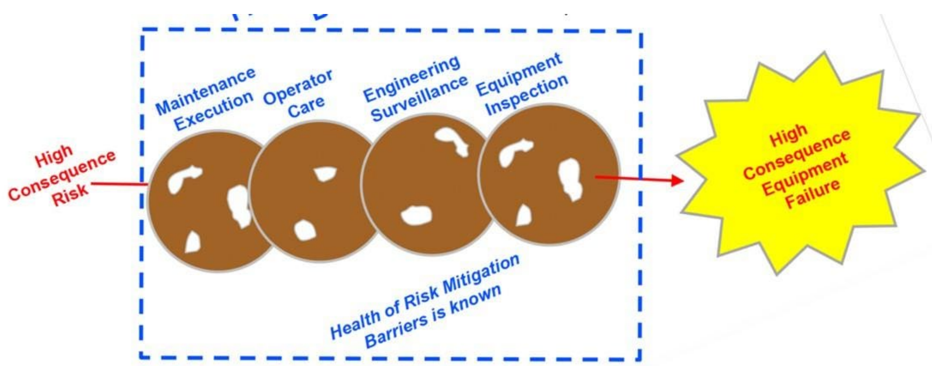


Figure 2. Risk mitigation plan framework

To effectively mitigate risk, it is crucial to prioritize Maintenance Execution, Engineering Surveillance, and Equipment Inspection, all of which are integral components of our risk mitigation strategy. Conversely, Equipment Failures are not included in this plan. Focusing on these key areas will ensure a more reliable and safer operational environment.

3.2 FIMS Framework

The FIMS framework encompasses key elements such as program design, execution, stewardship, and continuous improvement. A total of 17 impactful FIMS programs as shown in Table No.1—including pressure equipment, pipelines, and machinery—have been meticulously defined to drive exceptional results and enhance overall efficiency. Figure No.3 demonstrate how to begin, it's essential to identify critical equipment and establish robust inspection protocols, risk-based testing, and preventative maintenance requirements. Design and implement comprehensive integrity programs and procedures that effectively safeguard our assets. Next, execute the plant integrity program with precision by diligently collecting and analyzing data while ensuring that the integrity program is carried out seamlessly. Finally, conduct thorough program analysis and reporting to drive continuous improvement initiatives. Embrace the opportunity to redesign the program as needed, enhancing our operational effectiveness and reinforcing our commitment to excellence.

Table 1. Impactful FIMS programs

01 Corrosion Control and Chemical Injection	07 Marine Systems	12 Security
02 Pressure Equipment	08 CICA (critical instrumentation, controls and alarms)	13 Fire Fighting Equipment
03 Pipelines	09 Electrical Systems	14 Oil Spill Response Equipment
04 Structural Equipment	10 Cranes and Lifting Gear	15 Safety Equipment
05 Machinery	11 Emergency Communications	16 Mine Mobile
06 Subsea Equipment		17 Minerals Processing Equipment

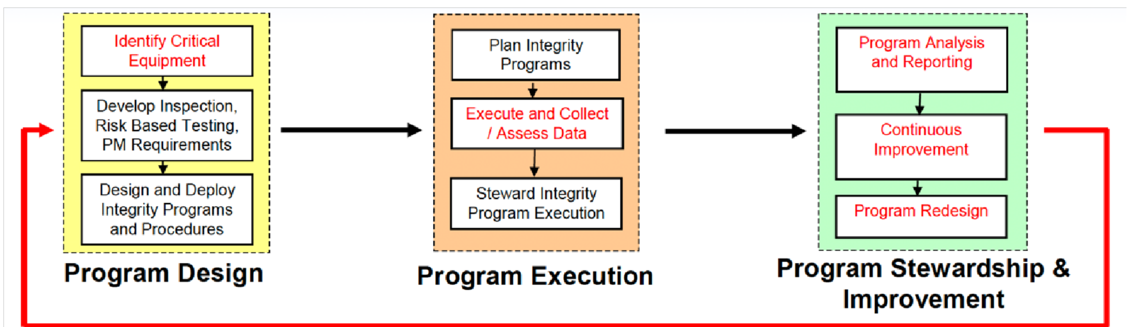
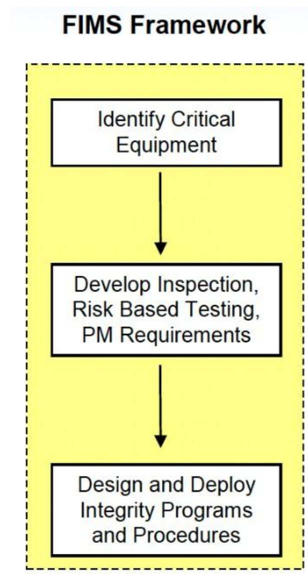
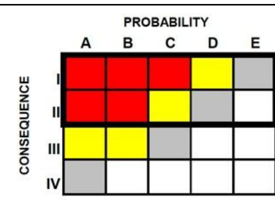


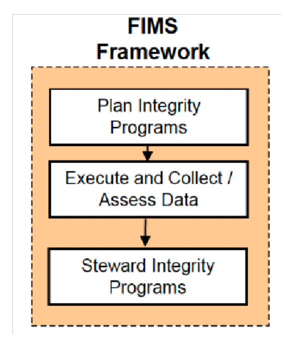
Figure 3. Program design execution framework

The equipment mentioned is categorized as non-critical and is thoroughly encompassed within the FIMS framework, which includes vital sectors such as Pressure Equipment, Electrical Systems, Pipelines, and Machinery, with wells being an exception. It is essential to highlight the variety and complexity of well types involved in our operations. These include oil production wells, which extract crude oil from subterranean reservoirs; gas production wells, dedicated to harnessing natural gas resources; and condensate wells, which capture valuable liquids associated with gas extraction. Additionally, gas reinjection wells play a crucial role in maintaining reservoir pressure, while power water injection wells are utilized to enhance oil recovery. Produced water injection wells, on the other hand, manage the byproducts of extraction, ensuring efficient and sustainable operations. Each type of well contributes uniquely to our operational ecosystem and underscores the importance of understanding their specific functions.

Program Design

Identification of Critical Equipment • High consequence: 1 or 2 on Risk Matrix o Critical A: SHES (e.g., firewater pump) o Critical B: Financial (e.g., compressor) **Develop / Implement Risk-Based Equipment Strategies** • 98% equipment strategies in place across Qatar Petroleum	
Success Attributes: • Equipment criticalities and strategies are kept current as Asset risk changes over time	

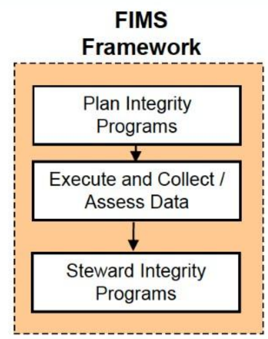
Program Execution

Program Execution Tasks for critical equipment are effectively planned and executed • PM, inspection, and surveillance task results are analyzed • 97% task compliance across **Qatar Petroleum** Tasks completion is tracked and stewarded	

Program Stewardship and Improvement

Success Attributes:
Effectiveness of programs is known and communicated to key ALT members

- Learnings from PM, inspection, and surveillance activities are applied to all similar equipment
- Equipment failures or degradation are investigated for root causes and learnings are applied to all similar equipment
- Cost efficiency of executed tasks is evaluated and improved



3.3 Are we effective

A meticulous analysis of execution results is essential, providing invaluable insights that can inform crucial adjustments to the program scope for improved effectiveness. Conducting a comprehensive criticality assessment is a cornerstone of the program design process, enabling us to identify key priorities and risks. Once the design phase is complete, altering the program scope is no longer feasible; thus, it becomes paramount to manage and oversee the execution of the program with diligence and strategic foresight, ensuring that every aspect aligns with our objectives for optimal success as shown in Figure 4.. • Identify key programs that drive performance

- Review performance at asset level
- Assess whether the desired level of risk mitigation is achieved
- Drive improvements

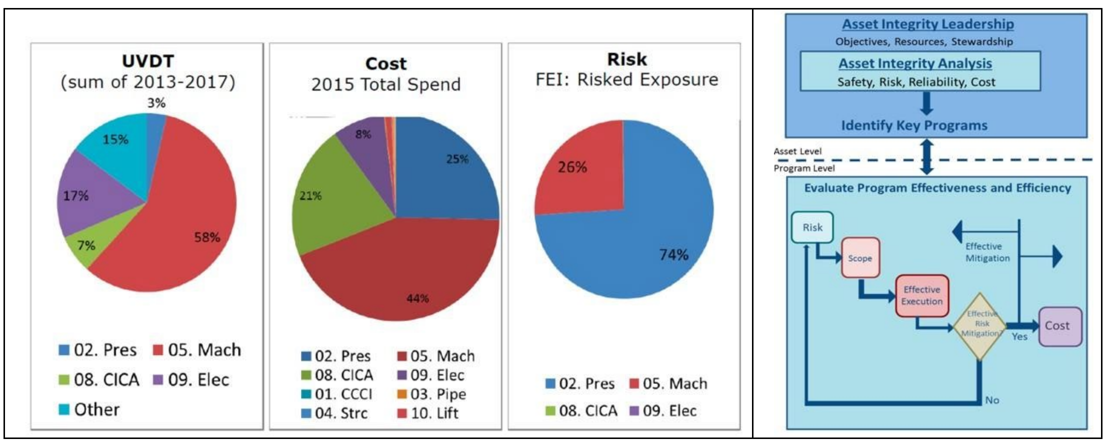
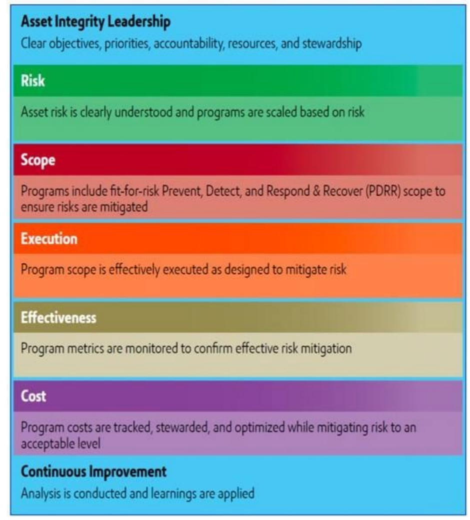


Figure 4. Program design execution framework

3.4 FIMS Effectiveness Tool

The FIMS framework is a transformative approach that incorporates vital elements such as program design, implementation, stewardship, and continuous improvement. It features 17 robust FIMS programs, detailed in Table No. 1, that focus on critical areas like pressure equipment, pipelines, and machinery. Each of these programs is meticulously crafted to achieve outstanding results and significantly enhance overall operational efficiency.

Reference Guide: • Contains success attributes and health questions to help identify areas for improvement **Purpose:** • Help mature facilities integrity programs to be fit-for-risk, aligned with Asset objectives, and effectively and efficiently executed **Desired Outcomes:** • Scope is fit-for-risk and aligned with Asset objectives PDRR mindset is applied • Programs are effectively and efficiently executed • ALT ownership and collaboration is demonstrated	

The FIMS scope is strategically designed to be "Fit-for-Risk" and aligns seamlessly with the asset's objectives. An impressive 90% of the equipment within the Asset FIMS program is classified as criticality A, underscoring the program's focus on high-impact assets. Additionally, the asset objectives have been tailored specifically to enhance the effectiveness of the FIMS program. However, it is crucial to note that no integrity data analysis has yet been performed. This presents a valuable opportunity for further improvement and optimization.

4. Discussion

The defined operations management programs have consistently stayed current after installing production operations facilities. However, it is essential to acknowledge that the asset scope continues to present a risk. In response, management has not only complied with guidelines but also fostered a proactive compliance mindset, demonstrating their commitment to risk management. By executing the program as a generalized application, we aim to maximize effectiveness. These initiatives are strategically driven, even in the face of limited data. Emphasizing this focused approach will strengthen our operations and mitigate risks effectively**.**

The ALT (Asset Leadership Team) program is dedicated to crafting a dynamic framework that not only aligns strategically with our asset objectives but also effectively addresses the risks we encounter. Our foremost priority is to ensure compliance and effectiveness, protecting the well-being of all individuals involved. To maximize our impact, it is crucial to distinguish clearly between generalizations and the specific focus of our initiatives. We are firmly committed to developing a robust operational framework that empowers the ALT with true ownership and accountability.

Your role in deriving valuable insights from our inspection results is essential for driving continuous improvement and achieving excellence. Together, we can elevate our asset management capabilities and attain exceptional outcomes. Let's take this journey forward and make a lasting impact!

5. Conclusion

Effective corrosion management is crucial for ensuring the longevity and reliability of pipeline systems. Corrosion under pipeline clamps poses a significant risk, as localized crevice corrosion can develop beneath the clamps, leading to structural weaknesses and potential failures. Internal corrosion in piping is another persistent challenge, often accelerated by the transport of corrosive fluids, microbial activity, and inadequate protective coatings, ultimately compromising the integrity of the pipeline. Additionally, flare pipe corrosion, worsened by high-temperature exposure and aggressive gases, can result in material degradation, increasing the likelihood of leaks and operational hazards.

To address these corrosion concerns, a comprehensive approach is necessary. This includes regular inspections, advanced monitoring techniques, and the implementation of effective mitigation strategies such as protective coatings, cathodic protection, and corrosion inhibitors. By prioritizing proactive maintenance and integrity management, industries can significantly extend the service life of critical infrastructure while minimizing safety risks and operational disruptions.

Seawater is highly corrosive due to its high concentration of chlorides, sulfides, and other salts, which pose significant risks to pipeline systems. In gas transportation, it is essential to ensure that pipelines are completely dry, with moisture content limited to below 180 lb. Using a TEG (tri-ethylene glycol) or a molecular sieve unit is effective in mitigating the corrosive effects of moisture and ensuring the integrity of the system.

When dealing with LNG (liquefied natural gas) or LPG (liquefied petroleum gas), proper drying is essential. Employing MEG (mono-ethylene glycol) is crucial for removing as much moisture as possible, as high moisture levels can drastically increase corrosive risks, especially from hydrogen sulfide (H2S). Prioritizing these measures is vital for maintaining the safety and longevity of pipeline operations.

For dry gas applications, particularly in natural gas pipelines, allowable moisture content is typically expressed as a dew point, with a common limit around -4°F (-20°C) to prevent hydrate formation and ensure safe, efficient operation.

In the case of dry LNG, the allowable moisture content is extremely low, generally less than 0.1 ppmv (parts per million by volume), corresponding to a dew point temperature of about -90°C (-150°F). This stringent requirement helps prevent ice and hydrate formation during storage and transportation.

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Biographies

Tariq MASOOD an Asst. Professor at Frostburg State University, Frostburg, Maryland. A versatile, collaborative, accomplished, and knowledgeable professional with a successful track record as a Professional engineer/Academician (Advance Process Integration and Renewable Energy Resources Integrated with Artificial Intelligence) He has also contributed as a Visiting & Adjunct Professor, and Invited speaker, at OIT, UTT, Texas A&M Qatar, UTA, TTU, UND, and UDC, in the United States of America. He joined the Qatar Petroleum since 1997 where he served as a Technical Coordinator Operations/Advisor Qatar Petroleum He is/has been on several Asset Integrity department technical and management committees' member. He is also member of BPTC (Best Practices Technical Committee) under the patronage of H.E: Dr. Mohd Saleh Al-Sada Minister of Energy and Industry Qatar. He has published more than 68 technical research papers in IEEE Conference, Journal, Honeywell Users group and other International Conferences and three comprehensive books on Micro control at Macro level on SMART GRID based FACTS Technology ISBN-978-3-659-40995-0 ISBN: 978-3-659-40995-0 ISBN:978-3-659-40995-0. He received several awards in recognition of his outstanding performance and dedication to improve Qatar Petroleum production operations and control, two Mubarak awards received from H.E Minster of Energy and Industry and three Al-Hasba

Awards received from Director Operations Qatar Petroleum. He was the secretary for the GCC oil producing companies (QP-Qatar, PDO-Oman ARAMCO-Saudi Arabia, KOC-Kuwait, TATWEER-Bahrain, and ADNOC-United Arab Emirates) Production and Maintenance Technical Committee in 2008 and 2011. Research interest: SMART GRID control and optimization of process operations of FACTS controllers, financial markets, renewable resources and control system restructuring, computational intelligence, centralized & decentralized control, large scale optimization and modelling, decision analysis: He is also serving as an Associate Editor IEEE Access (Impact Factor 3.44)

Dr. Jamil Abdo is an esteemed faculty member known for his significant contributions to the fields of mechanical design, systems design and reliability. With a profound commitment to sustainable technologies, Dr. Abdo has dedicated his career to advancing research and fostering innovation in these critical areas. Dr. Abdo holds a Ph.D. in Mechanical Engineering from Southern Illinois University. Currently, Dr. Abdo is a professor and currently the chair of the Department of Engineering at Frostburg State University. Dr. Abdo brings over 20 years of rich academic and industry experience that include more than 15 major funded research projects to his role. Dr. Abdo also serves as director for the Center of Product Design and Advanced Manufacturing at Frostburg State University, where he plays a pivotal role in the development of cutting-edge advanced design and manufacturing techniques and technologies. Dr. is a leading expert in the seamless integration of renewable energy sources. Dr. Abdo excels in engineering systems design. His expertise spans the design and optimization of complex systems, with a focus on minimizing environmental impact and maximizing efficiency.

Dr. Kaimiao Liu is an Assistant Professor at Frostburg State University, specializing in materials science, one of her focus area is natural gas pipeline materials, the environmental effects on pipelines, and welding techniques. Prior to joining FSU, she worked as a postdoctoral researcher and materials scientist at the National Energy Technology Laboratory, where she contributed to multiple projects, including retrofitting natural gas pipelines for hydrogen transport. Dr. Liu has extensive expertise in understanding pipeline material degradation under various environmental conditions and developing strategies to protect materials from deterioration. Her research also encompasses alloy design for a wide range of applications, emphasizing sustainability and minimizing environmental impact. Through her work, she aims to advance materials technology to enhance the durability and efficiency of critical infrastructure.