MARY KAY O'CONNOR PROCESS SAFETY CENTER
TEXAS A&M ENGINEERING EXPERIMENT STATION

18th Annual International Symposium
October 27-29, 2015 • College Station, Texas

Evaluating GREEN as a New Risk Reduction and Mitigation Strategy in the Petroleum Industry

*Mohammad A. AlKazimi, Ph.D.
Kuwait Oil Company
Maaxx5@mst.edu

Hanan Altabbakh, Ph.D.
Ministry of Education
Kuwait

Katie Grantham, Ph.D.
Missouri University of Science and Technology
Rolla, Missouri

Susan Murray, Ph.D.
Missouri University of Science and Technology
Rolla, MO

*corresponding author

Abstract

The Petroleum industry uses different risk mitigation strategies to mitigate potential failures within its facilities. Yet, these strategies could not prevent major accidents, on different scales, from occurring as they negatively impact the industry. The purpose of this paper is to evaluate Generated Risk Event Effect Neutralization (GREEN) as a new tool to select adequate risk mitigation strategy to prevent potential failures in petroleum industry. More than fifty major accidents in the industry underwent GREEN evaluation and compared with existing risk mitigation strategies used in to mitigate potential failures.

Introduction

The increasing global demand for petroleum is the driving mechanism for the petroleum companies to continuously upgrade their facilities and implement the latest technological advancements in equipment, computerized software, and synchronized human-system interaction (Health and Safety Executives, 2013).

Despite different hazard analysis and risk mitigatio techniques, accidents in the petroleum industry resulted in both catastrophic environmental and financial consequences (Rodrigues & Simmons, 2012). For example, In 2010, the explosion of The Deepwater Horizon rig in the Gulf of Mexico resulted in eleven casualties, more than $40 billion in compensations and lawsuits, and created the worst environmental catastrophe in U.S. history by gushing more than 4.9 million barrels of crude oil in the Gulf of Mexico (Kerr, Kintisch, & Stokstad, 2010). In 1984, more than 40 tons of Methyl Isocyanate gas leaked from the Bhopal pesticide plant in India and immediately killed more than 3,800 people, and thousand more at later years, in addition to $470 million in compensations (Broughton, 2005) More than 167 crew members, onboard of Piper Alpha's production platform in the North Sea, were killed due to an explosion. The damage impacted the oil production in the North Sea region and resulted in more than $3.4 billion in losses (Cullen, 1993). In 2012, a gas leak in the Paraguana Refinery Complex in Venezuela created a massive explosion which destroyed the facilities and killed more than 41 workers in one of the major refineries in Venezuela (Petroleumworld.com, 2014). These accidents, and many more, are some of the few examples that negatively impacted the Petroleum industry (Anderson & LaBelle, 1994; Davies, 2010).

The purpose of this paper is to evaluate Generated Risk Event Effect Neutralization (GREEN) as a new tool to assist, both engineers and decision makers, in selecting adequate risk mitigation strategy. GREEN will assist in exploring different mitigation strategies and their capabilities in preventing potential failures in the petroleum industry. In order to validate the results of GREEN, thirty out of fifty major accidents were selected and underwent GREEN evaluation. The main cause of the failures was electro-mechanical, material failure, and design flaws. The causes of the accidents were validated by an official accident report. Thus, GREEN evaluation was compared with existing risk mitigation strategies used to contain potential failures and their consequences. In addition, Petroleum industry's professionals were consulted to validate both GREEN and industry's risk mitigation strategies and best precise as basis of rationalization.

Background

Different risk mitigation methods have been used in the industry to contain the consequences of potential failures. Asset integrity management (AIM), an inclusive maintenance and inspection program designed to ensure facility's reliability, is one of common strategies applied in the industry (Rezae & Abbas, 2013). Risk based inspection is one of AIM programs where it recognizes, evaluates and charts potential risks that can impact the equipment's mechanical integrity. The program is essential to monitor the equipment's degradation due to operating and environmental conditions as it forecasts and recommends corrective measures (Marley, Jahre-Nilsen, & BjØrnØ, 2001).

The existence of high percentage of Hydrogen Sulfide (H2S) in crude oil labels it as sour crude oil and causes infrastructure integrity damage to pressure vessels and pipelines. (Wilhelm & Kane, 1986). Producing sour crude oil can result in different types of mechanical failures in pressure vessels, heat-exchangers, and pipelines. Hydrogen Induced Cracking (HIC), Stress Corrosion Cracking (SCC), Hydrogen-Induced Stress Corrosion Cracking (HSCC) or Sulfide Stress cracking (SSC), and Stress-Oriented Hydrogen-Induced Cracking (SOHIC) are some of the mechanical failures resulting in producing sour crude oil (Bosch, Herrmann, & Jansen,

2006). Yet, as a mitigation strategy to contain the damage, material selection, fit-for-purpose, risk-based inspection, and stress /corrosion resistance epoxy coating are utilized rigorously to assure production and prevent unscheduled shutdowns (Al-Shamari, Al-Sulaiman, Al-Mithin, Jarragh, & Prakash, 2013).

Moreover, the industry employed the usage of instrumentations and sensors to convert physical variable input in to signal variable output In order to maintain operations within restrictive design specification (Fortuna, 2007, Lundteigen & Rausand, 2007). The harsh working environet of these instrumentation and sensors and the nagatively impact the integrity as well as the accuracy of transferred signal. In order to accuratly measure any fluctuation in the operating parameter, "more than one instrument is utilzed to measure the same process parameters to provide redundancy and added protection" once the primary instrument fails (Lipták, 2002).

These thorough methods, to name several, evaluate potential risks and try to sustain them within tolerable limits (Flin, et. al, 1996; Vinnem et. al, 2010; Yasseri & Mahani, 2013). Yet, with stringent techniques and risk mitigation tools utilized in the petroleum industry, major accidents occur with catastrophic consequences affecting the environment, society and petroleum industry's stakeholders. Consequently, the need evaluate the optimal risk mitigation strategy is necessary to aid, both engineers and decision makers, to choose the optimal risk mitigation strategy. Hence, Generated Risk Event Effect Neutralization (GREEN) is an innovative will assist in exploring different mitigation strategies and their capabilities in preventing potential failures in the petroleum industry.

The Generated Risk Event Effect Neutralization method (GREEN)

The Generated Risk Event Effect Neutralization method (GREEN) is a risk mitigation strategy-selecting tool. The method, following Risk in Early Design (RED), developed by Dr. Grantham and her team identifies and selects the dominating and optimal risk mitigation strategy. Hence, GREEN matrices define possible mitigation strategies where these matrices include "information on potential failure modes and their parameters, parameters that have been changed by mitigation strategies, and the likelihood and consequence changes for a given mitigation strategy" (Krus , Grantham, 2011). Figure 1 illustrate the overall GREEN process of selecting the optimal and dominating risk mitigation strategy to potential failures.

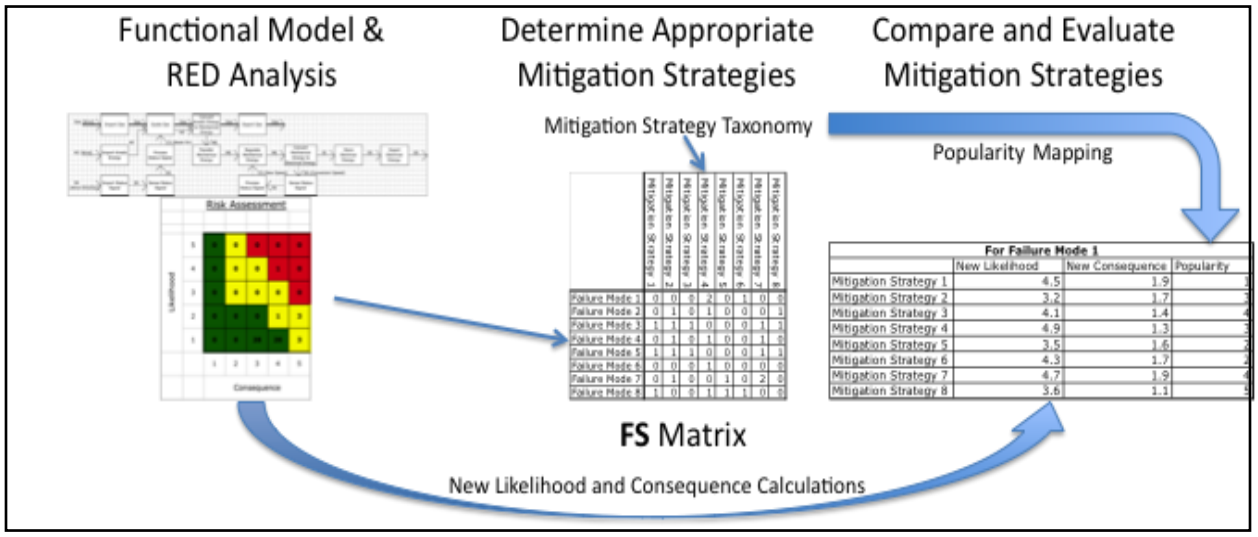

Figure 1. The GREEN Process (Krus and Grantham, 2011)

Applying GREEN in the Petroleum Industry

The petroleum industry utilizes different risk assessment tools to reduce the likelihood of accidents occurrence to a tolerated risk level. However, and with the usage of these tools, accidents of different scale occur. The current rigorous techniques and risk mitigation strategies applied in the petroleum industry fall short in preventing major accidents. Therefore, and in order to validate Generated Risk Event Effect Neutralization (GREEN) as a new tool to select adequate risk mitigation strategy to prevent potential failures in petroleum industry, more than fifty major accidents in the industry underwent GREEN evaluation and compared with prevailing risk mitigation strategies used in to mitigate potential failures.

Conclusion

As the petroleum industry utilizes various strategy selection tools to mitigate potential failures, mishaps on different measures occur resulting in an impact to the industry. Generated Risk Event Effect Neutralization (GREEN) analysis applied to evaluate the suggested risk mitigation strategies. The analysis was successful to recognize the possible strategies to adequately control failures. GREEN is beneficial in generating a list of potential failure modes and their corresponding control strategies. The tool can aid newly recruited engineers and non-technical decision makers to accurately, moderate the likelihood and consequence of failure modes; particularly in the conceptual design stages.

References

Health and Safety Executives. (2013). *Health and Safety Executives*. Retrieved November 18, 2012, from http://www.hse.gov.uk

R. Flin; K. Mearns; M. Fleming & R.Gordon (1996). *Risk perception and safety in the offshore oil and gas industry.* Sheffield: HSE Books.

J. E.Vinnem; , J. A. Hestad; J.T. Kvaløy; L.E. Skogdalen (2010). Analysis of root causes of major hazard precursors (hydrocarbon leaks) in the Norwegian offshore petroleum industry. *Reliability Engineering & System Safety*, 1142-1153.

S. Yasseri; R. Mahani (2013). *Quantitative Risk Assessment for Oil and Gas Facilities.* Manchester, UK: Smart Petroleum Ltd. Retrieved July 19, 2013

K.G. Lough; R. Stone; I.Y.Tumer (2009). The risk in early design method. *Journal of Engineering Design*, 155-173.

D. Krus; K. Grantham,; S. Murray (2012). Generated risk event effect neutralization: identifying and evaluating risk mitigation strategies during conceptual design. *The 22nd Annual INCOSE International Symposium (IS 2012).* Roma, Italy: International Council on Systems Engineering.

KNPC. (2014, 04 1). *Kuwait National Petroleum Company KNPC*. Retrieved from http://www.knpc.com.kw/en/AboutKNPC/Pages/default.aspx

J. Thomson (2013). *Refineries and Associated Plant: Three Accident Case Studies* . New York, New York: Safety In Engineering Ltd.