25th International Symposium

In Association with IChemE

2022 PROCEEDINGS

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

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Fuel Type and Ignition Location Effects for Vented Deflagrations

Peter A. Diakow*, J. Kelly Thomas, Keith Macon, and Emiliano Vivanco
Baker Engineering and Risk Consultants, Inc.
3330 Oakwell Court, Suite 100
San Antonio, TX 78218-3024
(210) 824-5960
*Presenter E-mail: PDiakow@BakerRisk.com

Abstract

BakerRisk has performed a test program to evaluate the effects of fuel type and ignition location on blast loads within and external to an enclosure during a vented deflagration. Four test series were conducted: methane-center ignition, propane-center ignition, methane-rear ignition, and propane-rear ignition. Methane and propane are representative of low and medium reactivity fuels, respectively, in the Baker-Strehlow-Tang (BST) vapor cloud explosion (VCE) blast load prediction methodology. Comparisons are provided between the test data and calculations made using standard methods commonly applied to predict vented deflagration blast loads. The methods assessed in detail were the National Fire Protection Association Standard on Explosion Protection by Deflagration Venting (NFPA 68) and the FLACS computational fluid dynamics (CFD) code. Other venting standards and practices are also reviewed relative to the test data.

The vented deflagration tests were carried out using BakerRisk's Deflagration Load Generator (DLG) test rig. The DLG is 48-feet wide × 24-feet deep × 12-feet tall, yielding a total volume of 13,800 ft^3, and enclosed by three solid steel walls, a roof, and floor. The rig vents through one of its long walls (48-feet wide × 12-feet tall), which was sealed with a 6 mil (0.15 mm) thick plastic vapor barrier to allow for the formation of a slightly hyperstoichiometric fuel air-mixture throughout the rig. The flammable gas cloud was ignited either in the rig center or near the center of the rear wall. Congestion was provided by a regular array of vertical cylinders (2.375-inch and 2-inch outer diameter) that were evenly distributed throughout the rig. The congestion level inside an enclosure can be quantified as the ratio of the obstacle surface area (A_{obs}) to that of the enclosure internal surface area (A_s), i.e., $A_r = A_{obs}/A_s$. The A_r value was approximately 0.70 for these tests.

The average peak pressures and impulses for each test series are provided, along with pressure histories both internal and external to the rig for selected tests. Comparisons of the test data to predictions made using NFPA 68 and the FLACS CFD code are also provided.

Keywords: Vented Deflagration, Testing, CFD, NFPA 68, Blast Effects, Explosions

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Understanding Flammable Mist Explosion Hazards

*Jesse Brumbaugh, Don Connolley, *Jacob Lindler
aeSolutions, Inc.
Houston, TX 77042

*Presenter E-mail or Presenters E-mails: jesse.brumbaugh@aesolutions.com, jacob.lindler@aesolutions.com

Abstract

While there is extensive testing and validation of hazards from flammable vapors, less information is available regarding flammable liquid mists. A method is suggested for reasonably estimating the nature and severity of flammable liquid mist hazards by applying published mist property correlations to model inputs and outputs in dispersion modeling software. Better estimating these hazards is important to properly evaluate what mitigations will be needed.

One common high flash point liquid that can pose a flammable mist hazard is heating oil. Published literature has documented that the flash point of a flammable mist can be much lower than that of the pure material, and the lower flammability limit (LFL) of a flammable mist can be as low as 10% of the material's vapor-phase LFL. The actual LFL of a flammable mist has been experimentally observed to be a function of the droplet size.

Since many oils consist of a blend of hydrocarbons with various carbon chain lengths, only a few compounds may be chosen to represent the material in commercially available consequence modeling software. This paper will propose: 1) further guidance on an approach that will reasonably approximate the mist properties in the model; and 2) a practical example of modeling the consequences of a mist release.

Finally, a case study will be provided where a range of known real world preventative and mitigative measures were tabulated, the existing measures were evaluated against these measures, then upgrades were proposed based on the model observations.

Keywords:
Hazards, Facility Siting Data, Physical Data, Flammability Diagram, Flash fire, Flammable Gas/Vapor Release, Aerosol Explosion, Vapor Cloud Explosion, Aerosol, Flammable Limits

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Insights from 594 Tank Farm Fires from around the World

Henrique M. Paula, * Ph.D., President, Galvani Risk Consulting, LLC,

The Woodlands, Spring, TX 77382-5005

Correspondence: hmpaula@galvanitx.org

Abstract

This article presents several insights from research of fire incident data from tank farms from around the world, which store products ranging from low flashpoint materials to crude and heavier hydrocarbons. The incidents and information in the database came from over 130 mostly publicly available sources, including technical and news reports. Updating of the database takes place when new studies require analysis of previous incidents. The database contained 594 fire incidents at the time of preparation of this article, and this research has already supported the analysis of the reliability of fire water protection system, hazard identification, and risk assessment for several tank farms.

The researched provided valuable insights regarding the frequency of tank farm fires, the frequency of boilovers, the frequency of injuries/fatalities, the expected numbers of injuries/fatalities per incident, the frequency of dike fires, the probability of failure of the fire water system, the time to extinguish (TtEx) the fires, the ignition source, and the types of tank roofs. When the database provided sufficient information, these numbers appear as a function of the material or product. The data also allowed plotting TtEx as a function of (a) time for over a century, (b) tank diameter, and (c) number of tanks on fire.

Keywords: Fire, Explosion, Boilover, Tank, Tank farm, Flammable, Combustible, Quantitative risk assessment, Reliability, Fire water protection system.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

NFPA 497 and EI Part 15 Comparison in the Application of Hazardous Area Classification

A Shukor Bin Mahat, Zainudin B Ismail A, A Mutalib B Ismail, M Fakhrul Farhan B Mohd

Petroliam Nasional Berhad (PETRONAS), Malaysia

Presenters E-mails: shukor_mahat@petronas.com.my, zainuis@petronas.com.my, mutalib_ismail@petronas.com.my, farhan.mohd@petronas.com.my

Abstract

In oil and gas industries, various steps have been considered in each plant life cycle to eliminate the hazardous scenarios arising from the release of flammable substances. Unfortunately, present of flammable or explosive atmosphere are not always avoidable where even a small fugitive release will give rise to hazardous area. This hazardous area can be described as a three-dimensional space in which a flammable or explosive atmosphere may be expected due to present of flammable fluids and/or combustible dust.

Hazardous event such as fire and explosion resulting in multiple fatalities and equipment damage will occur due to completion of fire triangle or dust explosion pentagon in the hazardous area. Elimination of ignition sources in hazardous area is one of effective strategy that can be adopted by engineer to prevent fire and explosion from occurring. This can be achieved by performing hazardous area classification study as reference to proper selection of electrical and instrumentation equipment in those areas.

Today, several publications are available to guide engineer in the development of hazardous area classification. This paper evaluates NFPA 497 and EI Part 15 guidelines advantages, limitation, and additional measures to be considered in the development of hazardous area classification for a better management of ignition sources.

Keywords: Fire and Explosion, Flammable Atmosphere, Fugitive Release, LFL, Ignition Sources, Ex Equipment, Ventilation

INTRODUCTION

Hazardous Area Classification (HAC) is an assessment for division of a plant or installation into hazardous areas and non-hazardous areas and its further sub-division of the hazardous areas into

zones i.e., Zone 0, Zone 1 and Zone 2. This classification is based on the flammability of materials which may be present and the probability of a flammable atmosphere occurring.

In this paper, two internationally accepted standards i.e. NFPA 497 and EI part 15 are reviewed to highlight the advantages as well as hidden disadvantages.

METHODOLOGY

NFPA 497 (2021) and EI Part 15 (2015) documents were reviewed in term of relative equipment magnitude, approach in determining flammable cloud radius, and effect of ventilation in the development of hazardous area classification drawing.

FINDING AND DISCUSSION

Relative Equipment Magnitude

Hazardous area is defined as the extend distances in which flammable materials with lower flammability limit LFL concentration are expected to exist. In NFPA 497, equipment handling flammable material will be categorized based on the equipment size, pressure and flow rate prior to selection of classification diagram in which the extend of hazardous area are determined. In EI part 15 secondary grade of release (i.e., flange, valve, and seal), leak size as determined using Risk-based approach with the respective equipment operating pressure are used in the estimation of release rate where the hazardous area is determined.

Based on consequence modelling technique, release rate calculation will depend on hole size area, differential pressure between atmospheric pressure and operating pressure, and discharge coefficient. For futive pressurized release, the release rate will not reach the maximum operating flow and depleting the overall equipment inventory due to small leak size. Therefore, flowrate and equipment size will not be the determining factor in estimating hazardous area extend.

Flammable Cloud Estimation

In EI part 15, there are three (3) approach that can be selected in the determination of hazardous area which is Direct Example, Point Source, and Risk based approach. Direct example approach is used in limited cases for common facilities such as storage tank and filling facilities. Point Source approach is selected once the release hole size is known and the release rate can be easily determine such as process vent. On the other hands, risk-based approach is selected to determine the hazardous are for secondary grade release where the release rate is unknown. Typically release hole diameter of 2 mm will be selected for secondary grade of release where the maximum hazardous area is calculated at 6 m from leak source. In NFPA 497, Direct example approach is applied where there are several classification diagrams for users to choose based on four (4) criteria's i.e., Relative Equipment Magnitude, density of material, location of leak source, and equipment type. The classification diagram will determine the minimum extend of hazardous area originating from the leak source where the longest distance of hazardous area is determined to be 100 ft (30.48 m) as per Figure 5.10.1 (g), Figure 5.10.1(h) and Figure 5.10.1 (i).

Based on the findings, NFPA 497 will produce a more conservative results where the extend of hazardous area can encroach uncontrolled ignition sources such as occupied buildings, public road, and offsite population. Although it is more conservative approach, it is not practical to classify

hazardous area outside of process area. If this condition occurs, dispersion modelling as per EI 15 is recommended to optimize the hazardous area radius.

Effect of Ventilation

Ventilation is a significant element to be considered when determining hazardous area classification. In region where the wind speed is low due to obstruction, accumulation of flammable gas is expected with significant cloud size. Subject to severity of ventilation surrounding the leak source, the extend of hazardous area radius can increase greatly and the initial Zone can change to higher Zone. In EI part 15, surrounding area of leak source can be categorized into five (5) categories which are open area, congested area, stagnant area, enclosed area with adequate ventilation, and enclosed area with inadequate ventilation. Each type of area will influence how area classification radius is drawn as well as the selected hazardous area zone. In NFPA 497, effect of ventilation is only considered based on outdoor area, indoor area with adequate ventilation and indoor area without adequate ventilation. No consideration is given for congested area and stagnant area.

CONCLUSION

Both standards are internationally accepted standards in Hazardous Area Classification study. However, based on discussion above, NFPA 497 have several hidden disadvantages such as unnecessary requirement to determine equipment flowrate and size, too conservative radius that may go beyond process and plant boundaries as well as lack consideration of ventilation in open area. These limitations are covered in detailed in EI part 15 where consequence modelling is used to determine release rate and extend of hazardous area. On top of that, confined and stagnant region are described in detailed with the impact on HAC zone as well as radius.

REFERENCES

[1] "Model Code of Safe Practice Part 15 Area Classification for Installations Handling Flammable Fluids", Energy Institute, 4th edition, 2015.

[2] "NFPA 497 Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Location for Electrical Installations in Chemical Process Areas", National Fire Protection Association, 2021.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Luck or Resilience? How 1% Will Occur 100% of the Time

David Wilbur, Don Zhang
Managing Member & CEO
Research & Technology Scientist
Vetergy Group LLC

Abstract

Operational Resilience emerges when leaders discover that careful efforts to prevent faults and error at best get us 99% of the way there. Resilient leaders expect the remaining 1% will occur 100% of the time. Plus, the 1% involves uncertain, unpredictable, and dynamic events requiring behaviors informed as much by art and rhetoric as science. This simply means resilient leaders spend equal time guiding their organization to be just as adept at responding to disruption and restoring stable operations. Through this captivating case study of four US Marine F/A-18Ds and eight lives as they approach certain disaster, you will experience why resilient leaders constantly ask…" What are we not seeing?" Fortunately, your own system holds the answer, but perhaps not where you expect to find it. We will see how dramatic differences among leader behaviors produce more resilient, more competitive, higher performing, future industry leaders or not.

I. LEARNING OBJECTIVES

- How human error is a system product useful in improving organizational safety
- Why a reductionist approach to causal analysis is not enough to improve human performance
- How system thinking is required to enhance resilience and human performance

II. PRESENTATION FORMAT

- Single Speaker w/ Technical Paper

III. TRACK

- Innovation, Research and Development
- Safety Leadership

IV. TOPIC

- Operational Resilience
- Human Factor

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Admitting Human Error in the Workplace – Maximizing Safety and Reliable Performance with Human Factors

David Wilbur
Managing Member & CEO
Vetergy Group LLC

Abstract

Human error is inevitable and serves as a symptom of systemic failure. As with all symptoms, it becomes a signal spurring systemic change. The idea is to welcome error as an indication that leadership should investigate the dark, murky, uncomfortable cultural issues that made the error seem like a good idea at the time. Instead of blaming individuals for error, ask why the system responded the way it did. In a real-world example, we will study an organization's emergent behavior through the actions of two operators. As a rule, these operators did not set out to cause failure; rather, they intended to contribute to the larger success of the organization. Nevertheless, as part of a multi-dimensional operating framework, they were shepherded by complex events into making decisions that instead contributed to an incident. This highly interactive, case-study driven workshop will use firsthand experience and show you how to apply new principles of human error to your own operations.

LEARNING OBJECTIVES

- How human error is a system product useful in improving organizational safety
- Why a reductionist approach to causal analysis is not enough to improve human performance
- How system thinking is required to enhance resilience and human performance

PRESENTATION FORMAT

- Single Speaker

TRACK

- Innovation, Research and Development
- Safety Leadership

TOPIC

- Operational Resilience
- Human Factors

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Safety and security in CPS-enabled remote offshore green hydrogen production

Ahmed Elkady, Syeda Halim, Mahmoud El-Halwagi, and Faisal Khan
Mary Kay O'Connor Process Safety Center,
Artie McFerrin Department of Chemical Engineering,
Texas A&M University, College Station, TX 77843-3122, USA.

Abstract

Green hydrogen is seen as a great potential to decarbonize hard-to-electrify industries and support the growth of renewables by solving the problem of seasonal energy storing due to intermittency. However, hydrogen production through water electrolysis is a novel hazardous process with limited testing. Additionally, several hazards come from extreme operating conditions in offshore locations. Consequently, it's safer to do such operation remotely and with as low as reasonably practical people on board which requires monitoring and control. A great solution to that is to utilize the capabilities of the most recent technologies that accompanied the 4th industrial revolution such as digital twins (DTs), Internet of things (IoT), and cyber-physical systems (CPSs). Such relatively new concepts raise new safety and security challenges.

The current work is on the aspect of analyzing cyber security and safety challenges that arise from remote offshore green hydrogen production. It analyzes the literature to investigate opportunities and challenges presented by the application of CPSs in hydrogen production facilities. The analysis attempt to answer following questions: (i) What are the technological enablers for offshore water electrolysis process safety? (ii) What are the characteristics of industry 4.0 technologies that are likely to cause safety and security issues? (iii) What are the safety and security issues introduced by industry 4.0? How can these issues be addressed? (iv) What are other technical challenges related to safety and security?

It is observed that technological enablers include:

- Digital twins (DTs): model multiple designs and scenarios, including variables such as weather, to optimize the process, maximize return on investment and minimize risk.
- Internet of things (IoT) and cyber-physical systems (CPSs): monitor process using key performance indicators (KPI) such as energy consumption and production rates which facilitates rabid anomaly detection. It can also help in safety compliance management and prevent violation acts and offer real time alert management systems. Finally, with remote control capabilities, IoT can help in controlling safety levels during normal and emergency conditions

CPSs have characteristics that introduces safety and security challenges. This includes complexity, heterogeneity, interdependency between cyber and physical processes. Other characteristics include fragmentation, autonomous reconfiguration decisions, and other constrains like physical

and resource. CPS autonomous reconfiguration decisions and compensatory actions may cause fault masking effects. There are also security-related issues including integrity and availability challenges in the presence of cyber-physical threats with unknown external disturbances. More challenges include resilience assessment, and human factors. This paper provides a comprehensive risk assessment and management that should proactively identify these potential technical problems so that appropriate actions can be taken to reduce or eliminate the probability and/or impact of these problems.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

How have artificial intelligence and expert systems contributed to human reliability and factor analysis in chemical process systems?

Esmaeil Zarei [a], Faisal Khan [a,b*], Rouzbeh Abbassi [c], Yahui Zhang [a]

[a] Centre for Risk, Integrity and Safety Engineering (C-RISE), Faculty of Engineering and Applied Science Memorial University of Newfoundland, St. John's, NL, A1B 3X5, Canada

[b] Mary Kay O'Connor Process Safety Center (MKOPSC), Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, TX, 77843-3122, USA

[c] School of Engineering, Faculty of Science and Engineering, Macquarie University, Sydney, NSW, Australia

Corresponding author; fikhan@mun.ca

Abstract

Human reliability and factor analysis (HR&FA) have been thoroughly explored from various aspects (e.g., engineering, psychology, physiology, ergonomics) in critical systems. Accordingly, numerous conventional techniques have been developed and applied in each domain to improve system safety from the human perspective. However, emerging socio-technical systems, industry 4.0, and artificial intelligence reveal these methods' incapability and necessity toward state-of-the-art intelligent approaches. Hence, this work is designed to demonstrate how artificial intelligence and expert systems have contributed to HR&FA, focusing on machine learning (e.g., Neural and Bayesian Networks) and knowledge and data-driven modeling approaches in chemical process systems. We considered six elements of HR&FA to illustrate these contributions: (I) human failure probability estimation/prediction, (II) modeling performance variability factors' influences, (III) local and conditional dependency modeling, (IV) capturing human factors into risk analysis, (V) uncertainly characterizing in HR&FA and finally (VI) human behavior modeling. Furthermore, this work highlighted some important misapplications that should be addressed using these advanced approaches. This research yields detailed insights into HR&FA and process safety.

Keywords: Human error assessment; Human reliability analysis; Human performance; Human factor

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Failure of Automated Valves in SIL3 SIS service

Josh Lowery*

Eastman Chemical Company

Longview, TX

*Presenter E-mail: jlowery@eastman.com

Abstract

The failure of six newly installed metal seated ball valves in 160psig steam service. Valves were installed in a SIL3 SIS system, fully tested multiple times before and after installation. The valves were tested, "stroked" after 3 months of service and none of the six valves moved below the 30% open position.

Valves were disassembled and forensic investigation performed with the participation of the end user, the integrator and manufacturer of the valve. Mysterious white powder was discovered in the valve, and determined by the valve manufacturer to be the cause of the increased torque required to stroke the valve. This presentation will provide the source and composition of the white powder, manufacturer specified valve torques, the torques as found during the failure mode and the torques after the valves were cleaned of the white powder and re-assembled. Also addressing Partial stroke testing, ANSI leakage class, contaminants, valve assembly methods and testing, temperature ratings of components, actuator sizing.

Keywords: PST, Partial stroke testing, ANSI leakage class, valve torque, contaminants, assembly lubricants, temperature ratings of individual components, actuator sizing

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Seven Common Flaws in Root Cause Analysis

Monica Philippart, PhD
Ergonomic Human Factors Solutions, LLC
Austin, TX 78733, USA
monica.ergohf@gmail.com

Abstract

Root Cause Analysis (RCA) is a systematic and structured evaluation methodology that helps identify causes of undesired outcomes. In 2016, the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) published a fact sheet encouraging "employers (owners and operators) to conduct a root cause analysis following an incident or near miss at a facility." This is currently the investigation methodology of choice for most organizations in high-hazard industries.

The reason RCA is so widely used is because it can deliver invaluable results. As that same OSHA/EPA factsheet stated, "By conducting a root cause analysis and addressing root causes, an employer may be able to substantially or completely prevent the same or a similar incident from recurring."

Because RCA is so commonly used, and most organizations have been using it for many years now, the quality of the analyses done with the use of this tool is taken for granted. Yet, we continue to see the same, or similar, problems popping up. RCA is key to solving organizational and operational problems. But only its rigorous use provides the desired results, improving interrelated areas such as Incident Management, Process Safety, Continuous Improvement and Risk Management. One serious consequence of not conducting a proper analysis is that the organization spends time and money implementing ineffective initiatives. Another serious consequence is that the organization moves forward with the false reassurance that problems are being addressed.

This paper, based on more than two decades of experience conducting, facilitating and evaluating root cause analyses, reveals seven flaws commonly observed in RCAs, and explains the significance of each flaw as well as how to prevent it.

Keywords: Root Cause Analysis, Human Factors, Human Performance, Safety and Environmental Management Systems, Continuous Improvement, Incident Investigation, Process Safety.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

How to Integrate Human Factors in Root Cause Analysis

Monica Philippart, PhD
Ergonomic Human Factors Solutions, LLC
Austin, TX 78733, USA
monica.ergohf@gmail.com

Abstract

Oil and Gas companies have been required to address human error in their Safety and Environmental Management Systems since 2010. This was a result of the Final Rule for 30 CFR Part 250 Subpart S - Safety and Environmental Management Systems (SEMS). One of the main objectives was "to focus attention on the influences that human error and poor organization have on incidents." "Investigation of incidents" was, thus, one of the SEMS elements that required consideration of human factors after the regulatory changes. This drove companies not already doing so to begin to evaluate human error as part of their investigations. However, there was, and still is, insufficient guidance on either appropriate implementation steps or qualifications of those conducting the human error analyses.

Root Cause Analysis (RCA) is a systematic and structured evaluation methodology that helps identify causes of undesired outcomes. Encouraged by the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) in a fact sheet published in 2016, RCA is currently the investigation methodology of choice for most organizations in high-hazard industries.

RCA can deliver invaluable results; but in order to uncover the root causes of human error, the factors that affected human performance relevant to the incident under investigation must be identified, evaluated, and properly integrated into the RCA. This presentation discusses what factors to evaluate, when, and how, in order to properly integrate human factors into RCA and uncover the root causes also of human error.

Keywords: Root Cause Analysis, Human Error, Human Factors, Human Performance, Safety and Environmental Management Systems, Incident Investigation.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Trend Analysis of Loss of Primary Containment (LOPC) to Improve Safety Performance

Abstract:

To continuously improve upon process safety performance, it is essential for companies in the chemical and petroleum industries to implement effective leading and lagging process safety metrics. Trend analysis of these metrics, if done correctly, can be used to improve the existing safety performance of the company.

There is a saying "what gets measured, gets managed". This is effectively what trend analysis is. There are two types of trend data: lagging and leading. Lagging data comes from adverse events that have happened and for which we are trying to prevent reoccurrence. Leading data comes from proactively looking at behaviors before they result in an adverse event.

This presentation will describe how all Loss of Primary Containment (LOPCs) reported for a site was used to develop a plan to further improve the safety performance of the site as part of the continuous improvement initiative. Topics to be covered include:

1. Reason for this continuous improvement initiative
2. Scope of the work
3. Approach used to define system root cause
4. Trend analysis results
5. Approach taken to define system element improvement ideas.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Implementing and Maintaining an Evergreen Risk Screening Program in an Exploration and Production Company

Yuan Lu

Occidental Petroleum Corporation

Abstract

Occidental Petroleum Corporation (OXY), a Fortune 500 Exploration and Production (E&P) company with global operations, has developed a program to identify facilities that have potential impact to public and environment receptors, referred to as "risk screening". This then allows OXY to assess and effectively manage the risks associated with these facilities through their internal "Specialized Field Risk Management" (SFRM) program. However, conducting risk screening and keeping it current in an operating environment is very challenging because of the large number of ongoing development projects, the frequent change of operating conditions, and public encroachment on these facilities. This paper presents a systematic approach developed by OXY to implement and keep this risk screening program evergreen under these changing conditions. In this approach, existing project management systems such as Management of Change and Well Tracking System were leveraged to develop and convey the risk screening workflow. In areas of concern such as public encroachment, where monitoring processes were not in place, a risk screening workflow was created to address the gap. This risk screening workflow was also integrated into asset acquisition due diligence activities to support these important business decisions. These workflows were consolidated into a single robust risk screening program managed by a centralized functional group. This program has been proven effective in identifying and avoiding potentially high offsite risks in the planning stage of a project, as well as to help manage these risks through the asset's life cycle.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Application of machine learning in predicting the potential consequences of railway incidents transporting hazardous materials

Hadiseh Ebrahimi [*1], Fereshteh Sattari [*], Lianne Lefsrud [*], Renato Macciotta [†]

[*]Department of Chemical and Materials Engineering, School of Engineering Safety and Risk Management, University of Alberta, Edmonton, Alberta T6G 1H9, Canada

[†]Department of Civil and Environmental Engineering, School of Engineering Safety and Risk Management, University of Alberta. Edmonton, Alberta T6G 1H9, Canada

Abstract

A large volume of hazardous materials (hazmat) shipments is transported by railway in Canada. Railway transportation of hazmat is dangerous, and severe consequences, even with low probability, may happen to people in railway incidents. Risk assessment is necessary to control and reduce the consequences of railway incidents. Besides the traditional methods of risk assessment, machine learning provides new ways to manage new situations and to find new knowledge. The main purpose of this study is to propose a reliable machine learning model to predict the potential consequences of railway incidents transporting hazmat. Regression algorithms, including neural networks, linear regression, decision trees, and support vector machine (SVM) are employed to predict the potential consequences of railway incidents transporting hazmat. Railway occurrences database system (RODS) is used to find the input and output variables. Input variables are including, the primary causes of railway incidents, the weather conditions, the conditions of the track, etc., and the output variables are including, the number of injuries, fatality, evacuation, and the total damage cost in the railway incidents. Principal Component Analysis (PCA) method is used to identify the variables that have the most significant effects on potential consequences of railway incidents. Then, the performances of the different machine learning algorithms are compared to find the most reliable method. The result of this study shows that the consequences of railway incidents transporting hazmat are not random, and there are underlying patterns and trends between data that need to be extracted. The findings of this study can help decision-makers towards safe operations of hazmat railway transportation.

[1] Corresponding author email address: hadiseh@ualberta.ca

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Natech risk management in the framework of climate change

Alessio Misuri, Federica Ricci, Valerio Cozzani*

LISES – Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali, Alma Mater Studiorum – Università di Bologna, via Terracini n.28, 40131 Bologna, Italy. *e-mail: valerio.cozzani@unibo.it

Abstract

The Arkema accident, occurred in 2017 during hurricane Harvey, highlighted the potential impact of severe natural events on the safety of workers and population, assets integrity and business continuity of the chemical and process industry. Complex cascading events might arise from the interaction between natural hazards and technological installations handling hazardous substances, leading to the so called Natech scenarios. The increasing frequency of climate-dependent intense natural events, exceeding the expected time of return, resulted in a number of such events all over the world. A further intensification and reduction of return time of climate-dependent natural events, as intense rainfalls, hurricanes and tornadoes, is expected in the future as a possible effect of climate change and global warming.

In this framework, the need for a specific, comprehensive risk management approach to Natech events is evident. Actually, recent severe Natech events evidenced that, besides the direct structural damage of equipment items, the accident progression was initiated by the lack of operability of auxiliary systems and utilities available in the plant, and that the unavailability of safety systems in place was a key factor in accident development. These features of Natech scenarios are not captured by the current risk assessment procedures, which mainly focus on the release of hazardous substances caused by the structural damage of equipment.

In the present contribution, a comprehensive approach to the assessment and management of Natech risk is proposed, based on an innovative holistic framework addressing the identification and characterization of both "direct" Natech scenarios due to equipment damage, and of "indirect" Natech scenarios generated by the failure of auxiliary systems and utilities. The specific role of the modification of safety system performance during Natech events in the escalation of accident consequences is also addressed. Categories of hazardous substances having critical properties which may lead to major accidents in case of utility system failure were identified, in order to support the identification of "indirect" Natech scenarios. The implementation of specific safety systems and specific safety barriers addressing resilience to natural events and adaptation to climate change is also addressed.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Analyzing Time to Failure for Critical Safety Barriers in Offshore Well Operations

Abstract

Examining time to failure, particularly for those events where the well control equipment component life was unexpectedly short, can indicate that design, manufacturing, or procedural changes may be required to prevent similar events. A statistical analysis of time to failure, calculated as the period from the reported installation date to the failure date, was performed for a sample of blowout preventer (BOP) stack and BOP control system components, as well as for selected components on other well control equipment subunits. These failures were then further explored to determine factors that may have influenced the time to failure, such as where the component resides (i.e., the equipment subunit), its operating environment, and its usage, among other variables. This analysis is based on information collected through SafeOCS, a confidential reporting program for the collection and analysis of data to advance safety in offshore energy operations.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Describing Offshore Safety Culture with a Multi-Component Toolkit Approach

Ezra Wari[1], James Curry[2], Weihang Zhu[3,4], Brian Craig[2], Muhammad Muzamil Hussain[4], Arturo Haces-Garcia[5], Oghosa P Idahosa[2], Emad Zeni[2], Gubbala Seshasaikrishna[2]

□

[1]Department of Industrial Engineering, University of Houston, Houston, TX

[2]Department of Industrial Engineering, Lamar University, Beaumont, TX

[3]Department of Engineering Technology, University of Houston, Houston, TX

[4]Department of Mechanical Engineering, University of Houston, Houston, TX

[5]Department of Electrical & Computer Engineering, University of Houston, Houston, TX

Abstract

This paper presents the safety culture assessment toolkit developed for the offshore oil and gas industry. The key components of this toolkit are safety culture surveys, worker interviews, site safety audits, a review of corporate safety management systems, potential leading indicators (accident precursors), and site safety observations. This multi-component toolkit is expected to provide a more comprehensive assessment of offshore safety culture. With careful wording of survey questions, safety culture surveys can provide insight into employee attitudes towards safety. The paper discusses how safety culture surveys can be incorporated with site audits, interviews, incident reviews, and leading indicators to give a more complete picture of offshore organizational safety culture. A safety maturity model is proposed to incorporate the results from these safety culture measurements. Like most safety maturity models, the model goes from safety in reaction to events to continual improvement. Individual data elements are fed into the safety maturity model with organized rules so that the process for evaluating data is well established prior to data collection. The proposed safety culture toolkit is expected to describe the offshore safety culture with inclusive coverage.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Is There A "Hidden" SIS in Your Legacy Control System

Presenter: MC Chow, Emerson Automation Solutions

Abstract

When looking at modernizing a programmable process control/automation system e.g. those based on Distributed Control Systems (DCS), Programmable Logic Controllers (PLC) or even Direct Digital Control (DDC), particularly one that has been in service for some time (say 20+ years), have you considered compliance to current process safety standards like IEC/ISA 61511 2018?

"Protective functions" such process interlocks, emergency and process shutdowns that are implemented in the legacy system need to be accounted for and safety assessed in the new design. These functions may well reveal a "hidden" Safety Instrumented System (SIS) that was part of the legacy system, and now needs to be part of the new system.

In many cases, "replacement in kind" automation modernization projects do not consider these "latent" safety functions; they have been, at best, overlooked and at worst, ignored. If these safety functions are not properly implemented in the modernized system, the facility may not have the proper protection from process hazards that a modern Integrated Control and Safety System (ICSS) can provide.

A best practice in automation modernization is to ensure process HAZOPS and Layers Of Protection Analysis (LOPA) are updated as part of the project and the results used to determine if a SIS is required as part of the replacement system's architecture.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

WORKSHOP "LOPA Gone Wild!?"

Abstract:

This will be a WORKSHOP to discuss the current state of LOPA being done for new projects and within existing facilities with symposium attendees. Over the past few years, LOPA is requiring more risk gaps to be filled by safety instrumented systems. What use to be 1-3 gaps have become 2-5 gaps and IEC 61511 only allows 4 gaps to be covered with instrumented solutions. There two sides to this issue and we would like to have input and discussion from both:

1) LOPA practitioners
2) SIS design practitioners

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Process Safety Cards – Visualizing Knowledge & Operationalizing Wisdom

David Hatch
Process Hazard Analyst, Process Safety Integrity, david.hatch@psintegrity.com,

+44 7496 690919

Abstract

Process accidents continue to occur despite established procedures, better technology & bigger data.

To improve the awareness of less technical personnel (both frontline & back office) to potential Loss of Integrity, Control or Containment scenarios and increase their vigilance to such events & their potential causes so they can be promptly addressed; memorable images are shown on familiar poker sized playing cards representing typical hazardous events.

'Players' are encouraged & helped to learn & apply the principles using this simple mnemonic:

- **REMEMBER** Events
- **RECOGNISE** Threats
- **RESPECT** Barriers
- **REPORT** Concerns

Thereafter, there is an obligation on the duty-holder to:

- **RECOVER** Protection

A pack of Process Safety cards has 52 scenarios which are divided into the following 'suits':

DEGRADATION (♠)

- Internal Corrosion
- Chemical Attack

- Thermal Shock
- Manufacturing Defect
- Creep
- Erosion Or Thinning
- Ageing
- Installation Error
- Poor Design Or Modification
- External Corrosion
- Wear & Tear
- Vibration Or Fatigue
- Maintenance Deficiency

DISCHARGE (♥)

- Inadequate Isolation
- Biological Release
- Clearing Blockages
- Containment Not Closed
- Improper Handling
- Disconnection
- Access Opened
- Frothing Or Foaming
- Misdirection
- Accidental Discharge
- Reverse Or Backflow
- Uncontrolled Relief
- Poor Housekeeping

DAMAGE (♣)

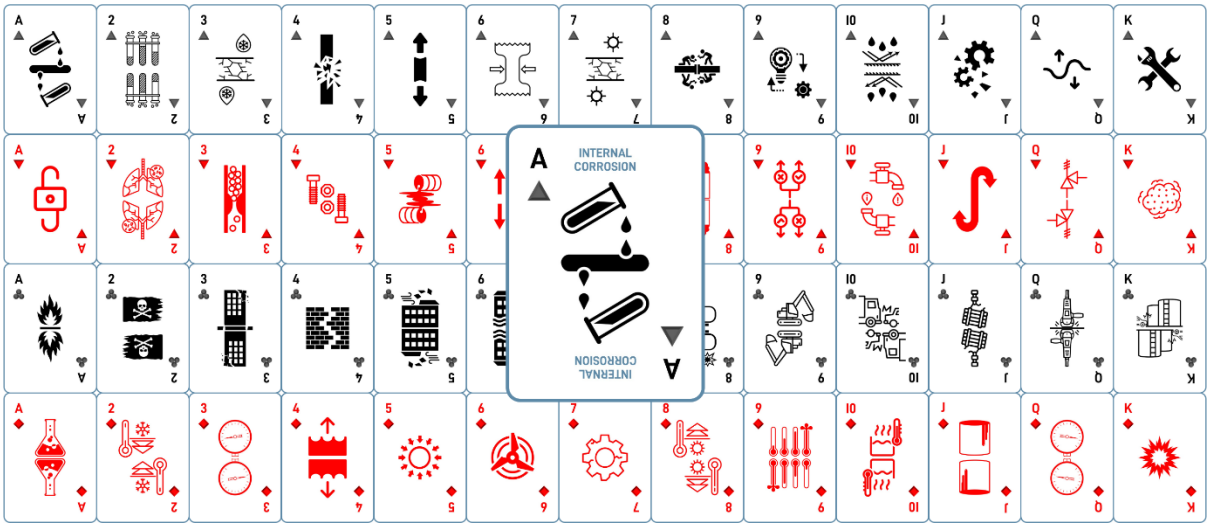
- Adjacent Fire Or Heat
- Attack Or Sabotage
- Subsidence
- Structural Collapse
- Wind Damage
- Flood Impact
- Lightning Strike
- Adjacent Explosion
- Excavation
- Transport Incident
- Dropped Object
- Containment Breached
- Vehicle Impact

DEVIATION (♦)

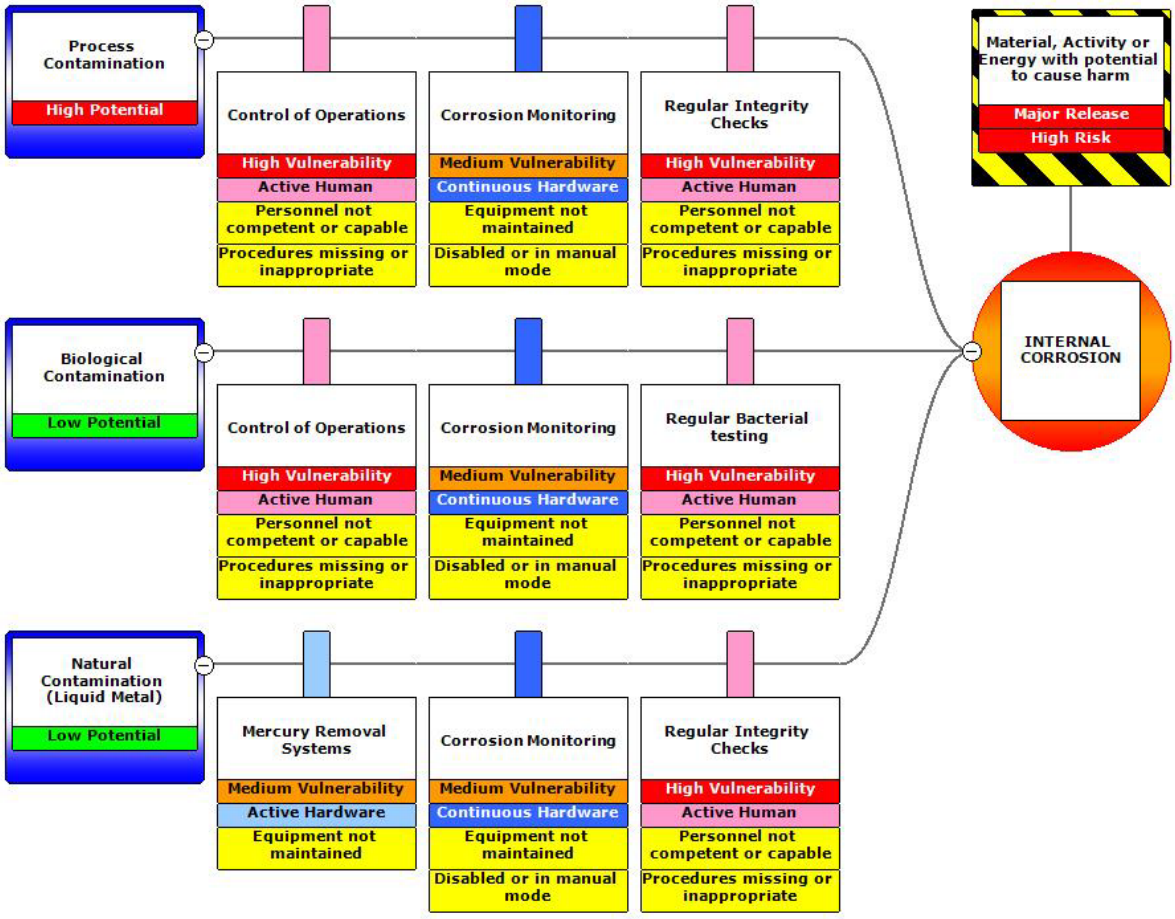
- Runaway Reaction
- Cold Embrittlement
- Low Pressure (Vacuum)
- Liquid Movement

- Thermal Contraction
- Overspeed
- Induced Stress
- Overheating
- Thermal
- Expansion
- Phase Change
- Overfilling
- High Pressure
- Internal Explosion

These provide simple visual prompts to remind or inform “players” of the potential for major hazardous events. An example deck & sample card are shown below:



Scenario summaries are also presented as separate pages with one event on each sheet. They include typical (suggested) Causes for the loss and visual representations of the scenarios in bowtie format.



In the above example, Barrier Degradation Factors are shown in yellow to highlight the potential challenges to the protection measures those personnel must be vigilant of to ensure that barriers are not allowed to deteriorate. Only the left hand (threat) side of the bowtie is shown because the potential consequences (type & scale of effects) on the right-hand side will be site/process specific.

It is vital that, if the objective is to increase awareness & vigilance, appropriate resources are available to respond to questions or comments from card “players” i.e. they must be encouraged to report concerns e.g. barrier deficiencies or absence, otherwise there is limited opportunity for improvement.

In extreme cases, operations may need to be suspended, or in less urgent situations; planned corrective & preventive action may be required to recover protection or risk reduction measures to their intended presence and performance.

Cards can be used in Operational environments, for example Toolbox Talks or attached to Permit to Work. They can also be used for Hazard Spotting & Surveys during walk rounds.

Management can also benefit from the cards, for example Safety Moments to start meetings or to facilitate Hazard Studies & Team Building.

Process Safety Cards provide a familiar, accessible & memorable platform which can be deployed digitally as well as physically for online/remote collaborate

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Turning Training into Conversations – Enhancements are Engaging

Abstract

Turning Training into Conversations – Enhancements are Engaging. The ability to think about, plan for, and envision our future selves is an important cognitive achievement. Studies have shown two powerful analysis: first, they are able to provide a basis for creating more formalized interventions. Second, they can help uncover the causal triggers underlying conceptual development. Moving from the formal to the conversation, translating key process safety information.

People love talking about stories and the characters inside them that they feel like they know. Create the story telling opportunities about process safety examples and turn real life experiences into the training conversations individuals are excited to talk about the learnings.

Becoming effective at handling high-stakes conversations, or crucial conversations, can make work in general a lot easier and safe to share. We will start with approaching the topic as a conversation, starting with yourself and the standards to develop the story telling. You will see when there are safety concerns or risks arise with a silence response. We are seeking interactions at this point. Your company will want to ensure the business culture allows for sharing safely. The focus is on the storytelling and speaking honestly, to allow others to explore paths. We end with inviting other to the conversation, documenting the information and creating engaging opportunities.

We will review the 7 steps in turning key information into engaging conversations.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Enhancing the Process Safety Capability Acquisition

Mohamad Fazaly Mohamad Ali, Ng Lim Zheng, Ashwene Gengadharan

Petroliam Nasional Berhad (PETRONAS), Malaysia

Presenters E-mails: fazaly_ali@petronas.com ng_limzheng@petronas.com
ashwene.g@petronas.com

ABSTRACT

With the increasingly younger demographics in the oil, gas and chemical industry due to the attrition of baby boomers and commissioning of bigger and more complex facilities, companies are facing challenges of ensuring that the talent they have at their disposal have the necessary capabilities to ensure that their facilities are able to meet the financial objectives in a manner that does not expose these facilities to increased risks of HSE issues which can lead to undesirable outcomes for the businesses. Companies have established competency-based programs which provides focused exposure to the identified groups of personnel to ensure that there are sufficient capable employees in the area of Process Safety to minimize Process Safety risks from design to commissioning and especially during the operations stage.

PETRONAS has embarked on a technical capability building program for its personnel for 20 years with a specific Process Safety program introduced more than 10 years ago which has been successful in grooming not just specialists and technical authorities, but also technical managers that will lead the company into the next stage of its ongoing evolution. However, the company has recognized that there are critical areas of improvement for the Process Safety practitioners, and these are mainly related to risk recognition and the ability to communicate the potential threats to management for timely and effective decisions. This paper is intended to share the approach taken by PETRONAS to address the issues of tacit Process Safety knowledge acquisition to further enhance and accelerate the capabilities of young engineers in the plant as the primary Process Safety risk management resources.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Competency Learning for Future Process Safety Leaders

Kristin Robbins, Senior Director, PSL Business Unit, and Lisa Ruth, CPSM, Vice President, ioMosaic Corporation

Abstract

The role and benefits of online learning for academia (personal) and organizations (corporate) have increased in popularity and have demonstrated higher levels of learner effectiveness and efficiency, surpassing and antiquating in-person training programs. In this paper, a case study will examine how an online learning management system (LMS) with education structured as building blocks increases overall competency specific to a particular skill set. The success of this LMS is not limited to competency development and incremental learning. A key role begins with the LMS "content creators". Together these concepts bring new meaning to lessons learned and cultivate a proactive, future learning environment that will advance the next generation of process safety leaders.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Reframing PSM in the Context of Operational Risk Management and ESG Sustainability

Michael Marshall, PE
Oil & Gas Industry Consultant
Michael Marshall LLC

Abstract

The regulatory climate changed considerably following the highly publicized incidents at BP Texas City in 2005, Tesoro Anacortes in 2010, Chevron Richmond in 2012, and ExxonMobil Torrance in 2015. Each happened not due to a failure of equipment, instrumentation, facility siting, operator, procedure, communication, supervision, or training, but rather a failure of all those things together, i.e., a management system failure. In addition to tens of millions of dollars in enforcement actions, legal consequences are now getting personal as was the case for plant management in the aftermath of the 2011 Chevron Pembroke incident. Systemic failures were cited in a May 2019 sentencing hearing at Swansea Crown Court with the plant declared "fundamentally unsafe" due to a series of errors and failings that contributed to a multi-fatality incident.

Companies are now increasingly being asked by investors and external stakeholders to engage in a broader Environmental, Social, Governance (ESG) landscape relative to environmental, health, and safety (EHS) performance, and risk reduction in the context of asset integrity and process safety human factors (the "organizational incident") is at the core of that expectation. To that end, companies are currently seeking to ensure holistic, enterprise-wide visibility and accountability for dynamic ESG programmatic efforts, materiality assessments, and sustainability solutions.

To date, no data management system or tool exists which effectively converges the highly interlinked EHS, compliance, and enterprise risk platforms with an asset integrity (and performance) predictive analytic framework. To get there, industry must reframe PSM and EHS management systems in the context of "operational risk management (ORM)," i.e., a broader risk reduction management system which more effectively integrates equipment with worker and production process data to better identify, analyze, and control risks at the physical asset level.

As for today's EHS software platforms, they aggregate only a limited amount of data from process safety and environmental workflows - incident reporting, near miss data, safety processes, environmental spills and releases - as necessary to satisfy regulatory compliance reporting requirements. Their inability to effectively integrate asset integrity and equipment-specific RAGAGEP, e.g., risk-based inspection (API 581 RBI), integrity operating windows (API 584 IOWs), fitness for service (API 579 FFS), corrosion control data (API 571 damage mechanism review [DMR]), equipment specific inspection data, etc., is an impediment to satisfying the full

complement of ORM and ESG sustainability expectations. There is clearly a need to move towards a consolidated enterprise information management platform architecture which consists of risk reduction solutions and decision support functionality by "giving voice to equipment."

"Data Rich & Insights Poor" is a characteristic observation in too many organizations not fully or properly deploying digital analytics and transformation tools. The ineffectiveness of incident reduction processes, tools and software applications in use today can be characterized as follows:

- A lot of data is being generated, but is not categorized, risk ranked, and prioritized by economic impact for data-driven systemic root cause analytics, thereby enabling whole classes of defects to be resolved across a plant as well as enterprise-wide
- Lots of emphasis on compliance, but too little focus on process safety risk reduction
- Inability to normalize data and KPI development relative to performance and process parameters
- Not built on an asset/equipment framework which integrates inspection and condition monitoring data as well as API 581 RBI, API 584 IOW, and API 571 DMR programs, thereby lacking business perspective regarding the impact of asset integrity on process safety and risk/incident reduction
- Other than API 754 Process Safety Event (PSE) Tier 1 and 2 KPI comparisons, there is little evidence of competitive KPI/indices benchmarking of the much more numerous near miss and unsafe conditions data of "free lessons" Tier 3 and 4 PSEs
- Failure to use process safety RAGAGEP like the AIChE CCPS Risk Based Process Safety PDCA management systems approach for systemic risk/failure mode analytics and enterprise-wide KPI benchmarking
- Insufficient evaluation of process safety as a function of mechanical availability and associated economic impact (lost production cost is a huge driver for process safety risk reduction)
- Lacking risk reduction solutions and failure modes decision support functionality based on industry best practice standards (including API 754)
- Not utilizing a predictive approach involving algorithmic correlation relative to causation
- Incapacity to link condition monitoring and failure analysis from data historians (e.g., OSIsoft PI) for predictive analytics, advanced pattern recognition, machine learning, artificial intelligence and time-series event frame annotations
- Lacking functionality and a highly configurable user interface for custom KPI trending, reporting, alerts/notifications, action planning and follow-up

Process plants are built around a myriad of machine and equipment assets like pumps, compressors, heat exchangers, piping, vessels, control valves and instrumentation, with the integrity of those assets being key to properly managing plant reliability and process safety risk. Given the demands of PSM program elements like mechanical integrity, hazard assessment, procedures, change management, incident investigation, and information management, it can be difficult for plant personnel to keep up. Today's digital transformation movement coupled with analytic tools holds the promise to help.

The convergence of information technology (IT) and operations technology (OT) data has been greatly facilitated by the proliferation of low-cost sensors and internet-protocol-enabled devices. Connecting people, processes, and equipment is the next wave of the industrial revolution which has been called the Industrial IoT (IIoT), or Industry 4.0. It is here, and it will be the early adopters who gain the competitive advantage in this new frontier.

Again, no data management system or tool exists on the market today which effectively converges the highly interlinked EHS, compliance, and enterprise risk platforms with an asset integrity (and performance) predictive analytic framework. Market surveys have confirmed that there is clearly a need for a software solution which couples the management systems of asset integrity and process safety (AIM + PSM = AIPSM) into an ORM/ESG compliant analytic framework which can be queried to inform real-time, risk-based analyses and decision-making relative to safety, environmental as well as profitability impacts. At a minimum, such an "AIPSM" framework for driving risk reduction program effectiveness, maturity, and continuous improvement should encompass the following:

- Analytics and KPI benchmarking specific to asset integrity, performance, and process safety
- System for categorizing, prioritizing, and risk ranking by economic impact/lost profit opportunity
- Enabling problem solving teams to resolve high value deep-dive systemic problems
- Failure modes decision support functionality
- IIoT data-driven predictive modeling capability
- KPI reporting, alerts/notifications, and action planning
- Fully integrated API 754 including culture, human factors, and the "organizational incident" involving complex equipment and systems
- High degree of configurability for customizable KPIs, reports, data trending and alerts

So, with predictive analytics at the core of an asset integrity and process safety management AIPSM framework, this paper discusses methods, metrics, performance analyses, KPIs and benchmarking techniques for driving ORM and ESG sustainability as they relate to the ultimate concern of any PSM program, i.e., loss of primary containment and associated impacts to production, profitability, and process safety.

Keywords: asset integrity, process safety, software, incident management, metrics, KPI benchmarking

Michael Marshall, PE: Mike has 40 years' experience working in the downstream, midstream and petrochemical industries. While working first with Chevron (10 years) and then Marathon Petroleum Company (23 years – retired and now consulting), he progressed through various in-plant and corporate engineering, operations, maintenance, and equipment inspection/reliability supervisory and managerial positions.

It was Mike's many years of hands-on experience in areas of equipment reliability and mechanical integrity while serving in frontline engineering, operations and maintenance roles which instilled in him the importance of properly designed process risk minimization and management systems, performance metrics and KPIs. He has unique insight and expertise in areas of risk-based equipment and mechanical design relative to loss of primary containment damage mechanisms, safety systems and overpressure protection.

Mike has developed a time-tested process optimization methodology which utilizes root cause failure analysis (RCFA), reveals process safety opportunities and quantifies the economic impacts ($'s lost profit opportunity LPO) of equipment anomalies, LOPC incidents and upset/malfunction operating conditions. This systemic RCFA approach is key to analyzing and trending cost minimization, driving asset/process optimization and maximizing process safety performance in

the refining industry.

Mike is frequently invited to speak at industry conferences and continues to advance and present white paper ideas relative to process safety management, mechanical integrity and equipment reliability. Mike has attained industry recognition with white paper presentations at the American Institute of Chemical Engineers conferences and the Mary Kay O'Conner process safety symposium, and committee participation for the American Petroleum Institute.

Mike graduated from Purdue University in 1981 and is a licensed Professional Engineer.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

How to Structure and Lead an Enterprise Process Safety Lifecycle Management Software Selection Process

Abstract

Over the past decade, the process safety discipline has encountered one of its most formidable changes - digital transformation. As the changeover began, technologies moved from paper-based, spreadsheet and desktop software platforms to holistic cloud technologies; digital transformation moved from early adopters to became part of the mainstream solution. Organizations looking to embrace this shift encountered many issues, both culturally and logistically. However, the greatest challenge was the most basic of all; very few process and functional safety experts had participated in an enterprise-wide, digital software selection process. Executing this unfamiliar course of action by a company's IT staff, upper management, or business operations team, could prove to be a serious risk to one's career or the organization, if the procedure were to fail. Our presentation features lessons learned from a leader of Shell's software selection team in the company's search for a functional safety digital platform. It showcases the framework, techniques, and roadmap Shell utilized to successfully conduct an enterprise software selection process effectively and efficiently.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

HAZOP Leader Certification Program

Amirzudin Mizuar, M Faizal B Mat Husin, M Hasnul Adib B M Noh, M Fakhrul Farhan B Mohd

Presenters email: amirzu@petronas.com.my hasnuladib.noh@petronas.com.my faizal_mathusin@petronas.com.my farhan.mohd@petronas.com.my

Petroliam Nasional Berhad (PETRONAS), Malaysia

ABSTRACT

Chemical industries are commonly linked with major accident hazard that can cause multiple fatalities, extremes environmental damage as well as major asset damage. In managing these hazards, a proper and structured hazard evaluation tools are deemed necessary to be adopted as early as during facility design phase up until the end life cycle of the facility. Hazards and Operability studies (HAZOP) which are originally developed by ICI in early 60s due to the need for a better hazard evaluation and design review tool has become the preferred and widely used hazard evaluation tool in the world today. Leveraging on multidisciplinary organization with deep knowledge in their respective field, each facility process line will be evaluated using HAZOP methodology to identify the hazards, extend of consequences, and the adequacy of safeguards as barrier.

Although the established HAZOP methodology with a set of guidewords to cover all angles is near perfection, incident in chemical industries still occurring where in some cases are not fully evaluated during HAZOP brainstorming session. The most common causes are the ability of HAZOP leader to trigger critical discussion point and the non-standardization of HAZOP assessment throughout the organization. This paper focus is to share the approach taken by PETRONAS to address the issues associated with HAZOP as well as the journey taken by PETRONAS organization to establish PETRONAS HAZOP Leader Certification (HLCP) program.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Demonstration of an Integrated Risk Information Solution (IRIS) using Computational Knowledge Graphs

Abstract

Chevron is a global company, and we want to break silos, manage complexity, simplify decision making and promote innovation to win in any environment. Model Based Systems Engineering (MBSE) puts a systems model at the center of everything we do leveraging a common language known as Computational Knowledge Graphs.

As Chevron advances towards increasingly more complex operations and facilities, risk is also becoming increasingly complex. To manage these complexities, the Chevron Risk Fusion Team is creating system models and applying machine learning in computational knowledge graphs which can express all the relations between system elements (planning, requirement analysis, design, implementation, deployment, maintenance, etc.). Current theories employed in systems engineering have constraints that limit a system model's capability to be applied in real world applications. To provide a foundation for managing real world situations, we have developed a tool to improve PHA LOPA consistency and the comparison between similar facilities. We can create computational knowledge graphs to represent a collection of interlinked requirements and data to link everything to the big picture.

This could improve decision quality, enhance precision and consistency, reduce risk, improve performance optimization, and facilitate a shared understanding of risk across the enterprise.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Consequence centered PHA/LOPA analysis Vs Scenario by scenario approach

Abstract

Consequence centered PHA/LOPA is a trend that has been gaining strength with the emergence of fully integrated Functional Safety management software packages and the popularization of the Bow Tie barrier analysis technique. This approach deviates from the most traditional line by line cause-consequence pair analysis that sometimes results in virtually the same scenario being analyzed several times with resulting distinct solutions for the same problem.

This presentation will discuss the advantages and disadvantages of one approach vs. the other based on the author's Functional Safety consulting experience and an overview of existing industry guidelines. Particularly, there will be consideration of aspects like: consequence definition (too much granularity Vs. too much "lumping"), initiating events frequency summation considerations and its implications on RRF and IPL demand mode determination, identification of intermediate events and intermediate IPLs.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Boost the Value of Your HAZOPs With a Relief Systems Expert

Author: Nancy Faulk
Co-Author: Praveen Dhote

Industry track (see email): 25th Process Safety International Symposium - PHA, PSM, layer of protection, incident data, incident investigation, case studies

Abstract

Overpressure analysis approach and hazard and operability study (HAZOP) guideline techniques have many similarities. These process safety elements are based on different standards and use a different set of "rules," for example, the latter takes credit of instrumentation as safeguard, whereas overpressure analysis based on API Standard 521 typically does not. In this combined approach, hazards are identified in a systematic manner for each equipment, along with preventative and mitigative safeguards, including BPCS, emergency shutdown valves, and relief devices. Relief devices are the last line of defense; hence, it is important to give them expert attention during the HAZOP study.

A recent case study has shown that identifying major causes and consequences with the help of a relief systems subject matter expert (SME) *before* the workshop will reduce the workshop duration and cost involved significantly, and more importantly, will add a level of confidence that the analysis of the HAZOP team a*ccurately* reflects the relief device capabilities as a safeguard, compared to simply checking the relief device report. Afterwards, the workshop team can concentrate more on operational and maintenance issues which are often sidelined, due to inadequate time in workshop. Details of these recent HAZOP experiences will be discussed in the presentation.

Key words (select 3): HAZOP, Pressure Relief, Safeguards

Target level of presentation (Introductory, intermediate or advanced): Intermediate

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Quantitative Bowtie Analysis

Abstract

Research into Unified Hazard Assessment combining HAZOP, LOPA, and bowtie analysis yielded techniques that elegantly address the limitations of LOPA while providing a significantly improved graphical communications method.

LOPA suffers limitations that are rooted in "one-cause, one-consequence" paradigm. This limitation can result in design errors where engineered safeguards that protect against a consequence with multiple causes can be under-designed by looking at one cause and a time. While some extensions of LOPA that address the issue of multiple causes are commonly used, mitigative safeguards are rarely appropriately addressed and designed.

Safeguards that reduce the magnitude of consequences (i.e., mitigate) instead of preventing loss of containment cannot be addressed at all without ignoring the residual consequence that exists even if the safeguard activates successfully.

Finally, the textual nature of the process also makes results hard to communicate to operations and management.

This paper will provide background on how Unified Hazard Assessment yielded the techniques of Quantitative Bowtie analysis. The paper will also describe in detail how to implement quantitative bowtie analysis along with the mathematical concepts used for quantification of risk for multiple causes and multiple consequences inside a single scenario. The concepts will be presented using example studies that include mitigative safeguards and multiple cause scenarios.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Automated classification of failure data for safety equipment for follow-up in the operations phase

Shenae Lee, Maria Vatshaug Ottermo, Solfrid Håbrekke, Stein Hauge
SESS, SINTEF Digital, Trondheim, Norway.
E-mail : shenae.lee@sintef.no

Abstract

On petroleum facilities, safety equipment is installed to achieve risk reduction. It is important to apply realistic failure data in the design calculations, since too optimistic failure rates may suggest a higher risk reduction than what is obtainable in operation. During the operations phase, the follow-up of the reliability of such equipment is important to ensure that the desired risk reduction is obtained. To ensure that realistic failure data are applied, they should be continuously updated based on the experienced failures, and dangerous undetected (DU) are of particular importance This information is obtained from failure notifications that need to be classified according to the severity of the failure.. However, the collection and classification of failure notifications are rather time consuming. One reason for this is that there is no common format for the notifications, and it is often required to interpret the text data (e.g. description of a failure) in the notification. In this context, Ottermo et al. (2021) presented a taxonomy needed to annotate failure notifications using existing technical language processing (TLP). To build up on this previous work, this paper suggests an approach for automatic text annotations for a larger data set, on the basis of TLP principles. In the proposed approach, the classification of failure modes and detection methods enables the filtering of DU failures in the notifications. This includes definition of entity types (categories) of failure modes and the detection methods that are relevant for the given dataset. The proposed approach is demonstrated by a case where we review the dataset of failure notifications for specific equipment in a petroleum installation and suggest an algorithm that can search key words for identifying DU failures. This approach represents an automized and iterative process of classifying failure data, which can potentially support decisions related to maintenance of safety equipment.

Keywords: Maintenance, Reliability, Failure classification, Reliability data, Operational experience, Technical language processing (TLP), text annotation

Reference

Ottermo, M. V., Håbrekke, S., Hauge, S. ., & Bodsberg, L. (2021). Technical Language Processing for Efficient Classification of Failure Events for Safety Critical Equipment. PHM Society European Conference, 6(1), 9. https://doi.org/10.36001/phme.2021.v6i1.2792

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Integrating process dynamics in data-driven models of chemical processing systems

Md Alauddin[a], Faisal Khan[b], Syed Imtiaz[c], Salim Ahmed[c], Paul Amyotte[a,*]

1. [a] 2. **Department of Process Engineering & Applied Science, Dalhousie University, Halifax, NS, Canada**
3. [b] 4. Mary Kay O'Connor Process Safety Center, Texas A&M University, College Station, TX, USA
5. [c] Centre for Risk, Integrity and Safety Engineering (C-RISE) ,Faculty of Engineering and Applied Science
Memorial University of Newfoundland, St. John's, NL, Canada
6.
* paul.amyotte@dal.ca

Abstract

Data-driven models require high fidelity data of sufficient quantity and granularity. This is challenging in complex chemical processing systems due to frequent sensor breakdown, process shutdown, malfunctioning of equipment, random fluctuations, miscalibration, inconsistent sampling frequencies, and data entry errors. Thus, many models scoring well on the training data fails on the real-time data of industrial systems. This work presents a process dynamics-guided neural network (PDNN) model to improve the generalization. We have added an additional layer in the neural network architecture to incorporate process dynamics such as material and energy balance equations, universal laws, standard correlations, and field knowledge. We evaluated the proposed models on regression and classification tasks related to processing systems representing steady-state and transient behavior. The results were compared against a standard neural network. The proposed model yielded improved generalization ability on the test data. It also produced improved results on models determined by reduced sample-sized data. The proposed process dynamics-guided neural network can be employed as a robust model for handling generalization issues of data-driven methods in processing systems.

Keywords: fault detection, fault diagnosis, process monitoring, fault detection rate, PDNN.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Update on SafeOCS: Building a Comprehensive Source of Safety Data for the Offshore Energy Industries

Abstract

The SafeOCS Industry Safety Data (ISD) Program is a voluntary confidential reporting program that collects and analyzes data to advance safety in energy operations on the Outer Continental Shelf (OCS). Under an agreement with the U.S. Bureau of Safety and Environmental Enforcement (BSEE), the U.S. Bureau of Transportations Statistics (BTS) developed, implemented, and manages the program.

A key objective is to promote ongoing industry engagement in design and application of SafeOCS ISD to ensure that the safety event data captured is value-added. ISD provides a streamlined industrywide data collection effort with the goal of developing tools to assist company leadership in making better risk-informed decisions. The value of promoting aggregated industry safety data, especially events without consequences (e.g., near misses), is to flag trends that may not otherwise be identified in the absence of such a sharing effort.

This presentation will discuss the process used to successfully transform safety data from separate companies to a single database thereby addressing the technical challenges associated with collecting, transforming, and aggregating data from different company-specific databases. Details will be provided regarding the data processing protocols established. A demonstration of ISD interactive data visualization tools will also be provided.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Insights into decision-making for offshore green hydrogen project developments

Sumit Kumar[a]*, Til Baalisampang[a], Ehsan Arzaghi[a], Vikram Garaniya[a], Rouzbeh Abbassi[b]

[a]Australian Maritime College, University of Tasmania, Launceston, TAS 7250, Australia
[b]School of Engineering, Faculty of Science and Engineering, Macquarie University, Sydney, NSW, Australia
*Corresponding author: sumit.kumar@utas.edu.au

Abstract

Green hydrogen is a key element that will play a critical role in the global pursuit of a resilient and sustainable future. However, like other energy sources, hydrogen comes with challenges, including high costs and safety concerns across its entire value chain. To overcome these, low-cost productions are required along with a promised market, as the economy for green hydrogen also depends on demand. Offshore renewables have an enormous potential to facilitate green hydrogen production at large scale. Their plummeting cost, technological advances, and the rising cost of carbon pave a pathway where green hydrogen can be cost-competitive against fossil-fuel-based hydrogen. Offshore industries, including oil and gas, aquaculture, and shipping, will continue to look for cleaner energy solutions to decarbonize their systems/operations and can serve as a substantial market. Offshore industrial nexus, moreover, can assist the production, storage, and transmission of green hydrogen through infrastructure sharing and logistical support. The development of offshore green hydrogen production facilities is in its infancy and requires a deeper insight into the key elements that govern decision-making during their lifecycle. This includes the parameters that reflect the performance of hydrogen technology with technical, socio-political, financial, and environmental considerations. The present study provides a critical understanding of the influential factors that regulate development of an offshore green hydrogen system discovered through a comprehensive review Insights are also provided into the requirements for modelling and analysis of these factors considering synergy of hydrogen production with the offshore industries, coastal hydrogen hub and onshore demand. The results of this critical review will assist the researchers and developers in establishing and executing an effective framework for offshore site selection in the largely uncertain and hazardous ocean environment. Overall, the study will facilitate the stakeholders and researchers in developing decision-making tools required to ensure sustainable and safe offshore green hydrogen facilities.

Keywords: Green hydrogen, Offshore industries, Site selection, Safety, Sustainability

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Capex-Free Production Facilities Optimization Opportunities by Exploiting Installed Automation Infrastructure and Unused Functionalities

Jose David De Sousa Drumond

OMV Exploration & Production GmbH

Control & Instrumentation Advisor / Technical Authority Upstream

Abstract

Automation plays a key role in Operational Excellence, by enabling Safe and Secure process optimization of production facilities. Additionally, increasing the utilization level of the installed and existent capabilities helps in reducing the Total Cost of Ownership by preserving the asset owners' current and future investments in automation infrastructure. This paper presents opportunities identified that exploits commonly unused functionality built-in deep within Control Systems found in Upstream Oil & Gas.

The current global challenges, and the need for transformation driving our industry, requires the development of new and novel Value-Adding services that help us stay competitive as end-users and operators, by enhancing production and materializing cost-reduction opportunities. In this context the focus of this work was the optimization of existing process control behavior without the need of additional investments (CAPEX), and without increase of current OPEX (no licenses or additional maintenance costs). This process involved a detailed scrutiny of the deployed Automation´s and Process Control´s building blocks.

These activities proactively promoted, as an additional consequence, the development of site competence and expertise at each facility, as raising the utilization level of existent Automation, while increasing its actual performance required a deep exploration and understanding of functional and building blocks available within the systems hardware and software, and the identification of bad actors that negatively affect the performance of production equipment and process trains. To accomplish it, the author proposed a systematical evaluation of: 1) Control objectives for individual loops, against overall plant optimization objectives; 2) Current performance of Basic Process Control Functions; 3) Synthesis of optimum control parameters based on required control objectives; 4) Identification of unused advanced solutions already built into the Process Control Libraries of the installed Control Systems. The approach, while avoiding CAPEX expenditure, also allowed to bring benefits to facilities that may not be suitable for dedicated Advanced/Predictive solutions, and in other cases improved the chances of future

successful application of Advanced/Predictive deployments, by eliminating bad actors and taking care of potential non-modeled disturbances.

The presentation explores and details specific examples of some of the exceptional process control optimization opportunities that have been identified over the years, and that in almost all cases required no additional CAPEX. The paper also highlights how this type of exercise contributes in a positive way to increase the level of competence and expertise of the field team that gets involved in this type of activities.

Keywords: Process Control, Optimization, Automation Levels, Cost Effectiveness, Operational Excellence, Competence Development, Control Loops, Costs of Ownership

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Managing Migrations: Identifying Criticalities in Transitioning a Maintenance Management System

Cheyna Kaspar
Eastman Chemical Company
Presenter's E-mail: ckaspar@eastman.com

A healthy company must periodically evolve its Maintenance Management Systems (MMS) to achieve continued compliance with today's myriad of regulatory requirements and audits. When looking to change the present process, whether from paper to digital or through a digital software migration, the transition team must first achieve a thorough understanding of current maintenance processes and how they are executed. Intervals, tolerances, procedures, drawings, manuals, responsible personnel, outcomes, historical data, trending data, and measures are all critical factors that need to be considered.

A successful MMS migration identifies the needs and wants of all levels of users, from maintenance personnel to engineering and from operators to management. Then, and only then, can a plan be made to preserve what works, change what doesn't, and remove only what is obsolete. Failure by the transition team to fully vet these three factors will: cause necessary data or functions to be lost; allow inefficient processes to be carried over or created; jeopardize uptime and capital while fixing oversights after implementation. These omissions can also lead to further reliability issues, fines during audits, and increase the risk of safety incidents.

This paper will focus on the fundamental questions that Operations, Engineering, Reliability, and Maintenance should consider for Instrumented Protective System (IPS) documentation as part of a Computerized Maintenance Management System (CMMS) transition. Information Technology and Security requirements also have a significant impact on a CMMS transition, but are a separate topic outside this paper.

Key Words: Instrumentation, Interlocks & Safety, Maintenance, Procedures, Process, Records, Transitions

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Procedure automation is changing the game

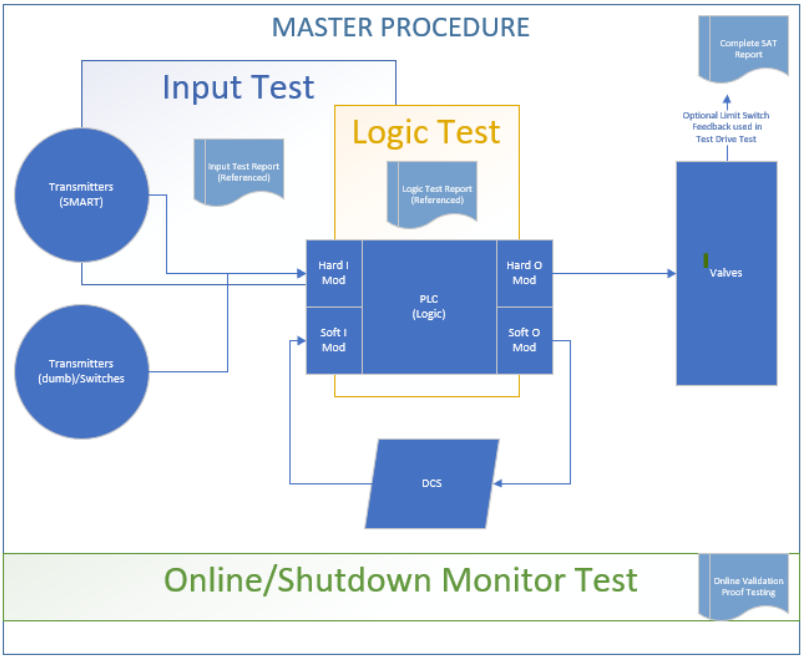
Brian Bailey, ProLytX

Abstract

Regulations dictate that Safety Instrumented System (SIS) testing be done but do not stipulate how the testing is to be conducted. This results in a variation of the testing quality, coverage, repeatability, and auditability across different facilities. Operators are looking for ways to optimize their testing procedures to save time, manage staffing demands, and trim costs while remaining compliant and with safe operating perimeters. Some go about this by focusing on speeding up the testing process, but even quality testing done quickly can be challenging to document, resulting in auditing issues.

We propose adopting a segmented testing approach and combining it with automated validation software. This approach dramatically reduces plant downtime, improves facilities' overall testing quality, and reduces costs without sacrificing safety.

IEC61511 allows for segmented testing (testing in parts), meaning that SIS logic can be validated outside a Turnaround or maintenance window. We will present how this segmented testing approach combined with automated loop tests and field inspection provides full test coverage and documentation.



The presentation will demonstrate our experience with this procedure and show data from multiple sites that document plant savings and testing discoveries. It will show that we can reduce the critical path by up to 5 days with immediate ROI on procedure development. As well as will cover sample test failures, logistics, compare and provide the pros and cons of manual and automated methodology, and suggest modifications to site testing and Management of Change (MOC) requirements.

We can do more extensive testing and testing in abnormal conditions, which increases quality and coverage without the need for additional manhours. Automation and segmented testing procedures outcomes are fewer human errors, reduced execution time, and enhanced safety.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Cybersecurity Best Practices for Remote Monitoring and Operation

Brad Bonnette
Wood Applied Intelligence
17325 Park Row, Houston, Texas 77084
Brad.Bonnette@woodplc.com

Abstract

The impacts of the Covid-19 pandemic have increased the demand for remote monitoring, operation and reduction of site staffing for process facilities. Control systems and communication technologies have enabled remote connectivity to facilities for remote monitoring or operations, which are being further expanded as operators consider expanding remote monitoring centers into remote operation centers, or implementation of diversified operating centers that can remotely monitor or operate process facilities and equipment.

This is not a new concept, as SCADA monitoring and control centers have been implemented and active for years. However, with the further proliferation of global network connectivity, cloud infrastructure, Industry 4.0 concepts and technology, the exposure to intrusion, interception or infection has increased greatly since the days of private-channel backhaul networks. Additionally, the tools and skill level of adversaries looking to compromise industrial networks have increased at accelerating rates as well.

Addressing security for industrial networks, and especially wide-area network, internet or "cloud" connected networks is not a single step application of technology or administrative measures, or just "securely extending" required network connections and applications to a remote operation applications. As the targeted degree of reduced facility staffing and remote operations increases, the need for secured autonomous systems and applications at the facility increases, to provide required resilience, fault tolerance, error and compromise-resistant operation of process facilities.

This presentation will explore principles in backhaul architectures, Cybersecurity practices to be considered in the design, development and implementation of remote operations, autonomous systems and associated applications for reduction of facility staffing.

Keywords: Cybersecurity, Remote Operations, SCADA, Autonomous Systems

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Transitioning from One Explosive Fuel to the Next – Safety Considerations in the Emerging Small-Scale Hydrogen Economy

Taylor Sulmonetti, Christopher Buehler, Sean Dee, Achim Wechsung, and Enakshi Wikramanayake

Abstract

Over the past several decades, there has been a focus on the development of the hydrogen economy, driven by the desire to decarbonize the energy system through utilization of alternative energies and fuels. With both the current and future interest in utilizing hydrogen, it is crucial to evaluate and mitigate the fire and explosion risks posed by hydrogen during storage, transfer, and usage especially with increased attention to small-scale, emerging hydrogen markets such as on-site generation, residential appliances, and transportation application. While many other fuels such as natural gas, propane, and gasoline also present flammability and explosive hazards, hydrogen has several unique characteristics. These include, but are not necessarily limited to, a relatively low ignition energy, low density, and wide flammability limits. These properties present unique challenges for risk management compared to other flammable liquids and gases that will need to be addressed as the hydrogen economy further expands into smaller-scale commercial and residential applications.

In this paper, we will explore the properties of hydrogen and how they impact the fire and explosion hazard when being utilized in small-scale, modular, or mobile applications. Then, best practices, risk management, and current regulations will be discussed for storage and transferring hydrogen, with a focus on highlighting that impact on equipment design and safety management. Finally, a case study will be presented that reviews an incident involving a hydrogen leak and ensuing jet fire that ignited during the removal of a portable tube trailer, the main transportation method for supplying emerging or remote hydrogen customers. The events that led to the unintended release and ignition of pressurized hydrogen, and the lessons learned from the incident and how it may translate to applications in commercial and residential settings will be discussed. The case study will highlight several aspects related to the safe storage and transfer of hydrogen in commercial and residential applications.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

On the possibility and effects of BLEVEs of storage vessels containing liquified hydrogen

K. van Wingerden[a], M. Kluge[b], A.K. Habib[b], F. Ustolin[c]

[a] Gexcon AS, Fantoftvegen 38, 5072 Bergen, Norway

[b] Bundesanstalt für Materialforschung und –Prüfung, Unter den Eichen 87, 12205 Berlin, Germany

[c] Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology NTNU, 7491 Trondheim, Norway

kees.van.wingerden@vysusgroup.com

Abstract

Experiments have been performed to determine the consequences of a storage vessel containing liquified hydrogen (LH2) is engulfed by a fire. The tests were performed at the Test Site Technical Safety of the Bundesanstalt für Materialforschung und –prüfung (BAM) in Germany within a research cooperation between BAM and Gexcon as part of the SH2IFT program. Three tests were performed using double-walled vacuum insulated vessels of 1 m^3 volume varying the orientation of the vessel and the effect of the insulation material used (perlite or multi-layer insulation (MLI)). The degree of filling of the vessel was approximately 35 % in each of the tests performed. The fire load was provided by a propane fed burner positioned under the storage vessel and designed to give a homogeneous fire load. In one of the tests a rupture of the storage vessel occurred causing a blast, a fireball and fragments. Apart from measuring these consequences, the conditions in the vessel (e.g. temperatures and pressure) during the heating process were monitored in all three tests. The work described was undertaken as part of the project Safe Hydrogen fuel handling and Use for Efficient Implementation (SH2IFT).

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Development of techno-economic analysis tool for hydrogen refuelling stations in Malaysia

Norafneeza Norazahar[1*], Rafiziana Md. Kasmani[1], Arshad Ahmad[1], Chan Toong[1]

[1]Centre of Hydrogen Energy, Institute of Future Energy, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

*Corresponding author: norafneeza@utm.my

Abstract:

This paper presents a step-by-step development of techno-economic analysis tool for hydrogen refueling stations in Malaysia. The objective is to facilitate the process of techno-economics analysis on different types of hydrogen storage and supply for hydrogen refueling stations. Hydrogen as a compressed gas and a liquid are considered in the development of techno-economic analysis tool. Thus, the equipment of hydrogen refueling station are storage tanks, compressor, pre-cooling unit, electrical, piping control safety, and dispenser. The hydrogen capacity is estimated between 20 kg/day (minimum) and 185 kg/day (maximum). As a first phase of tool development, the study begins with the process of hydrogen filling started at the hydrogen storage. The compressed gas or liquid hydrogen is normally stored at the tank in a rack of cylinders or on an above ground fuel storage tank. Hydrogen in a storage tank could be filled up to approximately 60 vehicles depending on the size of storage tank at both filling stations and vehicles. The challenges of filling hydrogen process is the requirement of higher pressure than the storage tank, which is to get the similar amount of hydrogen energy in a hydrogen driven vehicle as with the gasoline, diesels and petrol vehicles. Hence, the hydrogen refuelling stations should be equipped with compression before the hydrogen fuel dispenser. It is expected that tool of techno-economic analysis provides the cost and rate of investment, cost of maintenance, and payback period.

Keywords: Hydrogen safety, techno-economic analysis, hydrogen refuelling station, renewable energy, rate of investment.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Extension of the EFFETCS dispersion model for buoyant plume rise including lift-off

Andreas Mack, Sonia Ruiz-Pérez, Hans Boot
Gexcon Netherlands, Utrecht, The Netherlands

Abstract

Alternative energy carriers such as hydrogen and ammonia play an important role for the energy transition to reduce global CO_2 emissions substantially. These substances will be produced and used in much larger amounts in the near future to replace hydrocarbons compared to today. Therefore, consequences and risks of bulk storage, handling and transport of these materials must be addressed accurately. Pressurized or liquefied gases released by accident can undergo a transition from heavy gas to rising plume behaviour during dispersion depending on the storage, release and atmospheric conditions and surface effects such as heat transfer. The plume lift-off, plume rise and the entrainment of ambient air play a significant role in the effect distances and the volume of a flammable or toxic cloud.

The EFFECTS code contains different dispersion models for neutral and heavy gas dispersion, which are based on a 1-D discretisation. Since the code was developed in the past with the focus on heavy or neutral gas conditions the simulation of buoyant plumes so far was limited. The aim of the present research was to improve the accuracy of the dispersion model for strongly buoyant plumes and predict the transition from the momentum dominated to the buoyant regime correctly.

The paper describes the theoretical background of the extensions implemented in the dispersion model in EFFECTS. These extensions are aimed at improving the modelling approach for lighter than air plumes. In addition, different improvements addressing the source terms and the numerical stability have been implemented. In particularly for low density gas jet releases like hydrogen, an improved source term model has been implemented which includes buoyancy effects. The validation of the models incorporating these improvements has been performed and is based on preliminary results compared against experimental data including instantaneous and continuous releases, elevated jets and low momentum releases from the ground for different materials including helium, hydrogen and ammonia.

Keywords: buoyant plume, dispersion modelling, hydrogen, helium, ammonia, LNG, consequence analysis

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Combination of LSTM-RNN and CFD simulation to predict location of flammable gas releases in chemical process plants

André Zamith Selvaggio, Felipe Matheus Mota Sousa, Flávio Vasconcelos da Silva, Sávio S.V. Vianna*
UNICAMP - University of Campinas
Cidade Universitária "Zeferino Vaz"
Av. Albert Einstein, 500 - CEP 13083-852 Campinas - SP - Brazil
Tel: +55 19 3521-3947 Fax: +55 19 3521-3910
Presenter E-mail*: svianna@unicamp.br; savio.vianna@cantab.net

Abstract

To prevent gas explosions due to accidental releases and ensure safety in chemical process plants, it is crucial to evaluate in real-time the location of accidental releases. As soon as the gas leak is detected, a trained artificial neural network (ANN) can infer the leakage source accordingly to the wind velocity, wind direction, and gas concentration data. The training and testing of the ANN are based on computational fluid dynamics (CFD). I.e, for a given process plant geometry, given locations of gas monitoring points and given velocity and direction of the wind. The current research employs an ANN trained by CFD data to probabilistically infer the leak locations and potentially mitigate accidental gas releases. The Recurrent Neural Network with Long Short-Term Memory (LSTM-RNN) has been trained by supervised learning with data from CFD dispersion simulations using FLACS (FLame ACceleration Simulator) for 128 scenarios. Four leak positions, eight wind directions, and four wind velocities have been considered in the simulations. As a result, the LSTM-RNN model using 75 neurons leads to 99,4% prediction accuracy.

Keywords: leak location, computational fluid dynamics, artificial neural network, process safety

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

The Impact of Isolation Valve Failure in Exceedance Curves from Probabilistic Explosion Analysis

Pamella Palmeira de Araújo, Sávio S.V. Vianna

UNICAMP - University of Campinas
Cidade Universitária "Zeferino Vaz"
Av. Albert Einstein, 500 - CEP 13083-852 Campinas - SP - Brazil
Tel: +55 19 3521-3947 Fax: +55 19 3521-3910
Presenter E-mail*: svianna@unicamp.br; savio.vianna@cantab.net

Abstract

The modelling of gas dispersion and explosion is of paramount importance in probabilistic explosion analysis. The application of dedicated mathematical models based on computational fluid dynamics paves the ground for the development of exceedance curves. The former, given a risk criterion, can be used to calculate the design accidental loads. The inventory of the segment considered in the analysis is calculated based on the isolable sections that might be defined as sections in between isolation valves. Quite often, the failure of isolation valves is not considered. Such assumptions might pose additional issues to integrity management and sensitivity analysis. In the current work, we propose a dynamic ignition model based on the failure of the isolation valve. Later on, the ignition model is used in the framework of the probabilistic explosion analysis. We conduct a series of CFD simulations to evaluate the extension of flammable clouds considering the isolation valve failure. The vulnerable areas are used to calculate the probability of a passing cloud. The probability of the passing cloud is used to calculate the ignition probability considering the following; the leak duration, the effectiveness of the probability of failure, the failure of the valve, and the volume of the cloud. Following this line of reasoning, we modified the TNO dynamic ignition model and we code it in the framework of the Monte Carlo simulation of the mathematical expressions for gas dispersion and explosion. We show how the exceedance curve is affected by the transient ignition probability as well as the design accidental load. The developed approach emerges as a promising tool for decision-making and integrity management.

Keywords: Monte Carlo, Probabilistic analysis, Simulation, Design accidental load

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Applying Risk-Based Process Safety and ISA/IEC 61511 to Utilities Units

Abstract

Many facilities apply prescriptive codes and standards to strive for safe equipment operation. Such narrow assessments can create inconsistency in the risk approach within a facility. For example, the facility may apply NFPA 85 for boiler and combustion systems while applying a risk-based analysis to equipment in other operating units. These specialized standards can also fail to address the consequences of specific scenarios on other parts of the facility.

This presentation will demonstrate the benefits of applying the principles of the Lifecycle System Safety Analysis defined in ISA/IEC 61511 *Functional Safety -- Safety Instrumented Systems for the Process Industry Sector* and Risk-Based Process Safety throughout the facility. It will also show how codes and standards, such as NFPA for fired equipment, contribute to the analysis to drive a comprehensive risk-based approach to equipment safety.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Alert of the second decision-maker: probabilistic risk analysis of the conflict in the human-AI system

He Wen[1], Faisal Khan[1,2,] *, Md. Tanjin Amin[1]

[1]Centre for Risk, Integrity and Safety Engineering (C-RISE),

Faculty of Engineering & Applied Science, Memorial University,

St. John's, NL A1B 3X5, Canada

[2]Mary Kay O'Connor Process Safety Center,

Artie McFerrin Department of Chemical Engineering,

Texas A&M University, College Station, TX, USA

Abstract

Human-AI systems have been exhibited enormous application prospects in various industries, embedding with digital technologies. However, such shared control systems have two intelligent decision-makers. In the meantime, the contradictory goals and states may result in the conflict between humans and AI in operation. Moreover, the definition, cause, and path of such a conflict have not been well explored and presented. This study conducted a systematic review to explore the research progress on the conflict, constructed the mathematical expression of a conflict in the process industry, and established the evolutional framework from a conflict to an accident. A case study of the water tank level control system was applied to verify the conflict from process data. The results show that conflicts are highly associated with faults; the systematic failures of AI are more frequently leading to a conflict rather than mechanical failures; the protective systems are more likely to conflict with operators. In conclusion, human-centered design in human-AI systems is vital to avoid such conflicts, and the focus should be to pay more attention to human reliability rather than AI reliability.

Keywords: Conflict, fault diagnosis, probabilistic risk analysis, human-AI system

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Overcome the Challenges of Implementing SIF for Reactive Processes

Dr. Angela E. Summers, President†
Eloise Roche, Senior SCAI Consultant
SIS-TECH Solutions, LP
12621 Featherwood Drive, Suite 120, Houston, TX 77034
†asummers@sis-tech.com

Abstract:

Safety instrumented systems (SIS), which implement higher integrity instrumented safeguards, are generally used against process safety hazards with the potential to severely injure, or even kill, personnel or members of the public. Due to the energy inherent to industrial chemical reactive equipment, reactive processes are a common application for safety instrumented systems. However, these applications are more complicated to implement than the typical safety instrumented system, so more process engineering involvement is needed to get the design right.

Reactive application SIS typically focus on the prevention of runaway reactions by ensuring that the temperature or pressure never reach an unsafe state. However, reactive processes respond to loss of control in a way that can complicate the specification of trip point, response time, and sensor subsystem architecture for the SIS. Likewise, while some simple applications can address the reactive hazard by closing emergency block valves, others may require blowdowns, kill agents, and other complex response actions. This paper will discuss some of the unique challenges posed by reactive applications and will provide examples to illustrate how to overcome these challenges.

Keywords: reactive materials, safety instrumented systems (SIS), protection layer effectiveness

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Developing an ecotoxicological model to assess risk posed by microplastics to the Arctic communities

Mohammad Sadiq Saeed[1], Faisal Fahd[1], Faisal Khan[1,2,] *, Rehan Sadiq[3], Bing Chen[4]

[1] Centre for Risk, Integrity and Safety Engineering (C-RISE)
Faculty of Engineering & Applied Science
Memorial University, St John's, NL, Canada A1B 3X5

[2] Mary Kay O'Connor Process Safety Center
Artie McFerrin Department of Chemical Engineering
Texas A&M University, College Station, College Station TX 77843-3122, USA

[3] School of Engineering, Okanagan Campus
Faculty of Applied Science
University of British Columbia, Okanagan, BC, Canada V1V 1V7

[4] Northern Region Persistent Organic Pollution Control Laboratory (NRPOP Lab)
Faculty of Engineering & Applied Science
Memorial University, St John's, NL, Canada A1B 3X5

Abstract

Microplastics are gaining prominence in the environment rapidly. The accumulation of plastics in the Arctic region has disturbed the whole ecosystem. It has posed a serious health risk to the nearby Arctic communities. The organisms at the lower trophic level of the food chain are exposed to microplastics through ingestion. This ingested microplastics then move up the food chain, eventually reaching humans. The food habits and lifestyle of these communities is such that they rely directly on the nature for food and water. These communities consume less processed food or filtered water. In the process, the microplastics get bioaccumulated and biomagnified. This paper quantitatively investigates the impacts on the human heath with apex predator, tertiary, secondary and primary consumer responses to microplastics on a sample Arctic community. It proposes a Bayesian network-based model to determine the causal relationship between the microplastic accumulation and human health. The model predicts the non-carcinogenic risk on an indigenous community in the Arctic region due to the influx of plastics in the region. The proposed analysis will enhance our understanding on microplastic risk particularly towards indigenous settlements and help the policy makers formulate beneficial policies.

Keywords: Plastic and microplastic pollution, human health risk analysis, Bayesian network, Arctic region.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Industrial Cybersecurity and IMO

Matt Malone
Yokogawa Corporation of America
Sugar Land, TX 77478, USA
*Presenter E-mail: matthew.malone@yokogawa.com

Abstract

Floating production storage and offloading (FPSO) vessels and other vessels utilizing shipboard control systems for navigation and downstream process control have industrial cybersecurity recommendations from the International Maritime Organization (IMO). In 2017 the IMO released cybersecurity risk management guidelines with a suggested implementation deadline of 2021. While the IMO cybersecurity guidelines apply to all shipboard computer systems, the purpose of this abstract is to show recommended practices for maritime downstream processing industrial control systems in order to comply with the IMO guidelines. These IMO guidelines reference NIST guidelines of cybersecurity for Identify, Protect, Detect, Respond, and Recover. A thorough Technical Cybersecurity Risk Assessment using passive data capture technology on a maritime vessel industrial control network will be able to provide network visibility, asset inventory, a qualitative risk analysis, updated network architecture, and recommended upgrades. This method can be used as a way for downstream maritime vessels like FPSO's to qualify for compliance with IMO cybersecurity guidelines.

Keywords: Industrial Cybersecurity, FPSO, Maritime, Regulatory Compliance

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

WORKSHOP
IEC 61511 – ARE YOU MISSING SOMETHING?

Abstract

This workshop reviews the information and records that are collected throughout the IEC 61511 lifecycle to support the design, installation, operation and maintenance of safety instrumented systems. It would be easier to manage all the data and documentation if everything started and ended in one set of on-site hands, but the reality is that different departments within a user organization are responsible for different aspects of the lifecycle. Bringing the pieces together in a timely manner requires a clear set of responsibilities and expectations, as well as a good coordinator.

Workshop participants will be challenged to review different slices of the lifecycle and discuss how their organization is collecting, analyzing, and closing identified gaps in the information and records to move toward better compliance.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A Tutorial on Multivariable, Model Predictive Control (MPC)

James Beall
Emerson Automation Solutions
PO Box 2893
Bryan, TX 77805
James.Beall@Emerson.com

Paul Pathasema
Ascend Performance Materials
PO Box 711
Alvin, TX 77512
jppath@ascendmaterials.com

Abstract

Multivariable, model predictive control (MPC) is one of the most common applications in Advanced Process Control. This **workshop** will explain the concepts of MPC through an approachable example, and in a non-vendor specific manner. The concepts of MPC application, implementation and operation will be explained. The concept of process models will be explained. Situations where MPC might have an advantage over advanced regulatory control such as feed forward and override controllers will be explored. Finally, MPC examples in the process industries will be presented to demonstrate its use.

Keywords:
Control, Process, Advanced Process Control, APC, MPC, Multivariable, Model Predictive

Short summary for agenda, submitted 03/11/22.

This workshop will explain the concepts of Model Predictive Control (MPC) in an easy to understand, non-vendor-specific manner. The concepts of MPC application, implementation and operation will be explained.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Risk Based Approach for Fire Safety Design in Oil & Gas Facility

Abstract

Oil & Gas industry often deals with extreme operating parameter of hazardous flammable and toxic material. It is almost certain that in the event of loss of containment from these facilities, the credible end event consequence such as jet fire, pool fire, toxic release and explosion will engulf overall process area as well as part of non-process area. Most local regulatory, company internal standards and international codes have mandated the requirement for these facilities to be provided with proper passive and active fire protections to minimise escalation and hazards to worker. Traditionally, consequence-based analysis was adopted to determine the requirement of fire protections in process area. However, the outcome of this approach can cause redundancy in fire protection equipment, oversizing of firewater system, as well as large cost to be invested by company due to the extent of consequence results. In brownfield project, this has caused issues especially due to the limited available plot area and limitation of existing firewater system to accommodate additional fire protection equipment.

This paper details out the methodology of Risk-based approach in Fire Safety Design adopted by industry in Malaysia to ensure the fire protections provided is fit for purpose and cost optimized without jeopardizing facility safety. It also gives better indication for fire protections placement, optimized project cost, as well as improvement for emergency response plan strategy development. Using probability of incident with combination of proper vulnerability input, exceedance frequency contours are generated to give insight on the high-risk location that in dire needs of fire protections coverage.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Importance of Effective Management of Change for Safe Operations in Semiconductor Industry

Cassio Brunoro Ahumada and Susana Leon

Abstract

The steady growth in demand for microchip and memory devices have always been a driving force for the semiconductor industry to focus on engineering innovation and improve operating efficiency. Recent developments in artificial intelligence (AI), the internet of things (IoT), intelligence edge, 5G technology, and smart user devices have magnified the need for new developments and increased the market for semiconductors substantially. To maintain competitiveness, companies are challenged to develop, test, and scale-up in a short period new products often referred to as technology nodes or technodes, that are more memory and energy-efficient with a smaller footprint. Their success relies on how fast technode transitions can be executed to meet market expectations and stay ahead of competitors.

As microchip structures reduce in size, patterning the wafers becomes more complex. Advances in chip manufacturing, especially in film deposition, etching, and lithography, are enablers of technode transition and the pursuit of Moore's Law. These advances involve all operational aspects, including the use of new materials, changes to operating conditions and recipes, or utilization of cutting-edge first-of-a-kind (FOAK) tools that enable more complex chip design. Although essential to the business, such changes can be disruptive to standard operations, introducing new hazards or risks that might shift the system into an unsafe state. Therefore, having a systemic process that applies hazard identification and risk mitigation strategies before process modifications are completed is crucial to support safe operations and ensure process reliability. Management of change (MOC) becomes a critical component of semiconductor operations.

Effective MOC programs are critical for preventing unnecessary risks to personnel and process as modifications are incorporated on time. Even though the concept of MOC is simple, its successful implementation is not straightforward. For example, determining the appropriate technical and personnel resources to integrate MOC evaluations can dictate the quality of the analysis, its durations, and comprehensiveness. MOC managers and requestors need to comprehend the knowledge and expertise required to complete a MOC evaluation on time. Besides, not all changes will require a complete MOC evaluation. Companies risk overwhelming their engineering review team rapidly if MOC requests prioritization is not accomplished.

This presentation will discuss some examples where MOC was critical for continuous operations. It will also describe a risk-based approach developed at Micron technology to support effective resource allocation during MOC requests.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Proven Techniques for Effective Implementation of Inherent Safety in Design

Rajender Dahiya, CSP, MIChemE
Professional Process Safety Engineer
Senior Technical Services Manager – Loss Control
AIG PC Global Services, Inc.
Houston, Texas USA
rajender.dahiya@aig.com

Abstract

Inherently safer design (ISD) is a concept that intersects science and art, challenging the status quo to eliminate or reduce risk. Some companies within the oil and chemical processing industries have successfully used ISD as an effective risk management tool to help them achieve world class performance.

This paper speaks to the important role leadership plays in the implementation of ISD concepts and provides insight into how incremental success can help establish a culture that embraces ISD. Scenarios where project teams experienced a challenge in surfacing new solutions through ISD reviews were identified as the author conducted risk assessments with project managers at complex high-hazard oil and chemical processing plants. The author observed that for some organizations the ISD review, once completed, checked the box, and provided an inherently safer design regardless of whether new ideas were brought forward. In others, a robust set of best practices started to emerge, many that emphasize ways that project teams can overcome the status quo, essential for safer operations.

This paper concludes with a list of dos and don'ts to consider as guideposts in the implementation of ISD into major projects and operating facilities within high hazard industries.

Keywords: inherent safety, safer design, hazard elimination

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Operational Excellence begins with Operator Competency

Abstract:

- The loss of knowledge in plants due to retirements and turnover continues to happen, some sites dealing with more severe 'brain drain' than others.
- Our industry continues to experience several challenges around operator competency and procedure clarity, which is exacerbated by the growing knowledge gap.
- These challenges directly impact unplanned downtime and productivity.
- We will take a look at procedure clarity in the industry, showing examples of where generic and ambiguous procedures can lead to incidents.
- We will also show some of the world's biggest chemical and refining companies are investing in digital tools for the field operator to ensure competitiveness and reliability.
- Our presentation will include case studies on the impact on improving procedure clarity and execution, unplanned event reduction, speeding up of operator onboarding and capturing 'tribal knowledge'.

Presenters:

The presentation will be conducted by former plant managers from the industry, who now serve as Directors of Operations with Voovio. Depending on availability: Francis Montemurro (Former DuPont Plant Mgr and Operations Leader with 30+ years manufacturing experience) and Clint Jeffus (Former Snr Operations Leader with BASF with 20+ years manufacturing experience).

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

LNG Piping Cooldown: Common Problems and Mitigation Approaches

Abstract

The article discusses challenges and recent solutions regarding management of the cooldown process in LNG transfer lines. Cryogenic piping cooldown is a complex transient energy transfer process that occurs every time a transfer line is placed into a cryogenic operating mode from a warm condition. Sendout systems, trailer transfer systems, liquefier run down lines, and ship/barge transfer lines may all be subject to periodic warm up and cool down, depending on individual plant designs. Essentially, a cooldown is the piping temperature reduction from ambient to operating through exhausting the ambient energy stockpiled in its materials. Cooldown is almost always accomplished by the introduction of LNG followed by the vaporization and application of the latent heat of the LNG phase change to reduce the piping system temperature to cryogenic levels. Considerable temperature gradients are produced in the radial, hoop, and longitudinal axes, giving rise to complex stress profiles and heat transfer processes. Proper cooldown is necessary either upon initial commissioning of an LNG transfer line, or when restarting after the line has been allowed to warm up to ambient temperature. Problems associated with improper cooldown include overstress of piping systems and supports (resulting in immediate or longer-term fatigue failures), excessive pipe displacement, excessive vapor generation, and unnecessary production delays.

An approach to cooldown optimization is presented that takes into account plant-specific constraints including: the geometry of the piping and support system, LNG supply, vapor handling capacity restrictions, pipe and support materials and design parameters, operational requirements to meet plant performance targets, and control system capability. Examples are shown that illustrate a quasi-3D computer simulation to predict the temperature gradients and corresponding thermal stresses. Consequent solutions to design out (or dramatically decrease) the risks associated with improper cooldown are also explained.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Identifying and transforming underlying causal dependencies for accident likelihood analysis

Mohammad Zaid Kamil[1,2], S. Zohra Halim[2], Faisal Khan[1,2,*], Paul Amyotte[3], Salim Ahmed[1]

[1] Centre for Risk, Integrity and Safety Engineering (C-RISE)
Faculty of Engineering & Applied Science
Memorial University, St John's, NL, Canada A1B 3X5

[2]Mary Kay O'Connor Process Safety Center
Artie McFerrin Department of Chemical Engineering
Texas A&M University, College Station, College Station TX 77843-3122, USA

[3] Department of Process Engineering and Applied Science
Dalhousie University, Halifax, NS, Canada

Abstract

Process safety is crucial in the chemical processing and energy production industries. A mishap will result in loss of life, property damage and environmental degradation. Lessons from previous accidents are a good source of learning. These learnings assist in tracking and avoiding future adverse events. As a matter of learning from past accidents, the great challenge is identifying key parameters and associated features that lead to the causation of previous accidents. Another critical challenge is transforming these parameters and key features into an accident causation model. A methodical approach is needed that can help transform underlying information from the free text (i.e., linguistic expressions) into an accident model. This work introduces a methodology based on natural language processing algorithms to leverage the information available from previous incidents and perform a contextual transformation to develop a quantitative accident model with parametric dependence. The developed model will assist in tracking the accident causation in real-time (in terms of accident likelihood) and activate safety features (when likelihood exceeds the threshold) to prevent an accident. The application of the methodology is demonstrated using a simple process example. The proposed approach will serve as an important tool of Safety 4.0 and a mechanism to enable process safety in the process system digitalization.

Keywords: Process safety, natural language processing (NLP), linguistic expressions, accident causation, safety 4.0

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Frank P. Lees' Handbook on Loss Prevention in the Process Industries How are we doing on Ed. 5, Vol. 2: Risk Assessment and Management?

Hans J. Pasman
TEES Mary Kay O'Connor Process Safety Center
Texas A & M University, College Station, 77843 Texas, USA
hjpasman@gmail.com

Extended Abstract

As mentioned in Michael O'Connor's lecture, the Lees' book will be on a fully new footing and Volume 2 is dedicated to risk prediction and how to manage operational risk. Risk analysis has been performed since the 1970s. Right from the beginning the problem items became clear: consequence models, failure probabilities and human factor influences. In the 1980s and 90s research to improve has been focused on consequence analysis: cloud dispersion, vapor cloud explosion and damage. This was by developing models, conducting field trials, endless discussions on the uncertain equipment failure rates, and performing benchmark trials. The latter showed how unreliable predicted results were, so many became disappointed in the credibility of Risk Assessment outcomes. Yes, no wonder, many variables and a myriad of possibilities determine different outcomes, whereas reality consists of only one set.

The last twenty years, and in particular, the last ten years much has been changing. The system approach was introduced, which conceptually helped to take account of human and organizational factors in relation to plant technology. Results from decades of work on artificial intelligence in combination with software development increased the capabilities to deal with uncertain data enormously. Think of Bayesian network that in a structure of cause-event chains can evaluate the probability of an event outcome based on probabilistic basic input events. This enables to solve fault trees, event trees and bowties effortless. Hierarchical Bayesian analysis helped to determine rare event probability. Uncertainty concepts have been further developed and applied. Where in the past only probability theory existed, today three other uncertainty expressions can be used in which extent of uncertainty increases: (1) evidence theory, (2) possibility theory/fuzzy set and logic, and (3) intervals, which can serve to process uncertain data. In addition, from financial, engineering and other disciplines, many methods are adopted of decision making under uncertainty, and under economic and other constraints. And where in the past there was a lack of data, by the digitalization of design and operations there is data abundance. System approach, in combination with data processing by means of machine learning or AI techniques and digital twins, risk analysis improves in accuracy and dynamic adaptation to changing situations. So, prediction is still inaccurate and uncertain, but the uncertainty may in many cases be reasonably delimited and the variables identified for which the outcome is most sensitive. Finally, the concept of resilience gives it all another dimension.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Development and Application of Fuzzy Logic in Risk Assessment and Process Safety Analysis

Ananna Samiha[1], Mahmudul Hasan[1,2]

[1] Department of Chemical Engineering, Bangladesh University of Engineering and Technology (BUET), Palashi, Dhaka-1000, Bangladesh

[2] Department of Chemical Engineering, Pennsylvania State University, 121 Chemical and Biomedical Engineering Building, University Park, PA 16802, USA.

Abstract

Process safety is a basic requirement for ensuring a reliable process in chemical industries where large quantities of hazardous substances are handled. Quality of process safety analysis (PSA), safety and risk assessment and efficient control are essential for a successful management of such process. However, uncertainty of available data, imprecision, lack of sufficient knowledge along with simulation models used in PSA are some of the main issues in safety assessment and may lead to uncertain results. Fuzzy logic which consists of "Fuzzy set analysis" and "Possibility theory" can deal with uncertainty and imprecise data. Consequently, it is an effective tool for solving problems where uncertainty is a possibility. This paper reviews the studies on fuzzy logic for process safety by referring to most of the papers written on fuzzy logic application in process safety, modelling and risk assessment. Additionally, the paper discusses sources of uncertainty, examples and key points in applying fuzzy logic-based tools for process safety.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Active, Shared Learning Models of Accident Causation

Abstract

This presentation will discuss work done in support of General Aviation safety improvement. However, the approach is highly transferable to other industries, providing a systematic means to proactively mine existing databases to prioritize the development of safety innovations and, thus, safety performance improvement.

Based on National Transportation Safety Board (NTSB) data, there were an average of 240 fatalities per year between 2010 and 2019, out of the approximately 19-to-21 million flight hours logged in general aviation. Theoretical causation models were developed by a team of highly experienced aviation and industry experts for two of the most frequent types of undesired events resulting in catastrophic outcomes (fatalities) – loss of control and loss of thrust. This approach was novel in that the selection of these two "classes of accidents" was proactive, based on historical accident data. The models represent a theoretical representation of the possible causes of two major classifications of events rather than being based on specific investigations that address individual incidents, as is the norm in most industries.

The models create a shared and common understanding of potential causes of fatalities across a class of accidents and common causal language transferable across the general aviation community and beyond. However, the breadth and complexity of the models revealed the desire to assign probabilistic weights for each factor to focus safety innovations that achieve the desired outcome – reduction in fatal accidents. Safety innovations should focus on the most probable causes to justify the value of innovation investment. However, since there are no shared causal models, accident investigations and associated data are not gathered or structured to align with these. This makes the understanding and probabilistic analysis of proximate, root, and contributing accident causes more difficult due to inconsistencies found in accident reports.

Ultimately, weighted accident models can be used for "active learning" regarding the state of safety of the system. An active learning cycle transforms traditional, reactive accident investigations and associated databases into a systematic, purposeful, and measurable process for safety performance improvement. Extending this concept to shared causation models across industries, such as aviation and process safety, common safety challenges and potential mitigations to those challenges can be addressed cooperatively.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Incorporation of Safety Assessment in Process Design and Control

Moustafa Ali[a], Xiaoqing Cai[a,b], Yuhe Tian[c], Faisal Khan[b,d], Efstratios N. Pistikopoulos[a,b*]

[a] Texas A&M Energy Institute, Texas A&M University, College Station, TX
[b] Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, TX
[c] Department of Chemical and Biomedical Engineering, West Virginia University, Morgantown, WV
[d] Mary Kay O'Connor Process Safety Center, College Station, TX

* Corresponding Author: Efstratios N. Pistikopoulos (stratos@tamu.edu)

Abstract

The increasing plant complexity and interactivity with novel modular and task-integrated unit operations necessitate advances to accurately quantify the impact of new equipment designs on plant safety to effectively control the safety performance during real-time operation [1-2]. In view of this, several systems-based methods have been proposed to incorporate safety indices as a primary design objective or to apply model predictive control for operational safety [3-6]. Despite these advances, the proposed designs still lack of the following: (i) A fundamental understanding of process design impacts on process safety. (ii) A systematic approach to generate optimal design and operational strategies with guaranteed safety performance under disturbances.

In this work, a dynamic safety-aware explicit/multi-parametric based design and control framework is proposed. The framework features a systematic, process agnostic approach to simultaneously account for process variables and optimal control problems based on a model based multiparametric programming approach [7-9]. The dynamic risk-based fault diagnosis method [10] is selected according to the process analysis and integrated in the parametric space. The goal is to determine the optimal control actions and to effectively control the safety performance during real-time operation through a proactive type of prediction. The incorporation of the dynamic risk-based fault diagnosis in parametric space allows to compute the real time data at normal operation and identify disturbances when it exceeds the threshold defined. For example, the operation variable such as process temperature, can be explicitly formulated as mp-MPC path constraints to identify the maximum set of disturbances and optimal set point selection to theoretically prevent any constraint violation through operation. The extension of this approach for safety-oriented simultaneous design and control optimization will also be discussed based on our recent work in process systems [11]. The proposed approach will be demonstrated on a continuous stirred tank reactor (CSTR) case study for the processing of methylcyclopentadienyl manganese tricarbonyl at T2 Laboratories.

Keywords: Dynamic Risk, Model Predictive Control, Process Design and Control, Safety Management, Risk Assessment

References

[1] Park, S., Xu, S., Rogers, W., Pasman, H., & El-Halwagi, M. M. (2020). Incorporating inherent safety during the conceptual process design stage: A literature review. Journal of Loss Prevention in the Process Industries, 63, 104040.

[2] Pistikopoulos, E. N., Tian, Y., & Bindlish, R. (2021). Operability and control in process intensification and modular design: Challenges and opportunities. AIChE Journal, 67(5), e17204.

[3] Castillo-Landero, A., Ortiz-Espinoza, A. P., & Jiménez-Gutiérrez, A. (2018). A process intensification methodology including economic, sustainability, and safety considerations. Industrial & Engineering Chemistry Research, 58(15), 6080-6092.

[4] Leveson, N. G., & Stephanopoulos, G. (2014). A system-theoretic, control-inspired view and approach to process safety. AIChE Journal, 60(1), 2-14.

[5] Albalawi, F., Durand, H., Alanqar, A., & Christofides, P. D. (2018). Achieving operational process safety via model predictive control. Journal of Loss Prevention in the Process Industries, 53, 74-88.

[6] Venkidasalapathy, J. A., & Kravaris, C. (2020). Safety-centered process control design based on dynamic safe set. Journal of Loss Prevention in the Process Industries, 65, 104126.

[7] Pistikopoulos, E. N., Diangelakis, N. A., & Oberdieck, R. (2020). Multi-parametric Optimization and Control. John Wiley & Sons.

[8] Pistikopoulos, E. N., Diangelakis, N. A., Oberdieck, R., Papathanasiou, M. M., Nascu, I., & Sun, M. (2015). PAROC – An integrated framework and software platform for the optimisation and advanced model-based control of process systems. Chemical Engineering Science, 136, 115-138.

[9] Baris Burnak; Nikolaos A. Diangelakis; Efstratios N. Pistikopoulos, Integrated Process Design and Operational Optimization via Multiparametric Programming, Morgan & Claypool, 2020.

[10] Bao, H., Khan, F., Iqbal, T., & Chang, Y. (2010). Risk-based fault diagnosis and safety management for process systems. Process Safety Progress, 30, 6. https://doi.org/https://doi.org/10.1002/prs.10421

[11] Tian, Y., Pappas, I., Burnak, B., Katz, J., & Pistikopoulos, E. N. (2021). Simultaneous design & control of a reactive distillation system – A parametric optimization & control approach. Chemical Engineering Science, 230, 116232.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Dynamic Simulation for Instrumented Safeguards

Kedar Kottawar, and Angela Summers,

SIS-TECH Solutions LP

12621 Featherwood Drive, Suite 120, Houston, TX 77034
kkottawar@sis-tech.com

Sarah Grace Mitchell, Kiran Unnikrishnan, and Greg Dearwater,
Corys Inc

Abstract

Instrumented Safeguards are implemented to prevent undesirable consequences. Each identified safeguard must be capable of detecting the abnormal condition(s) and taking action on the process quickly enough to avert losses. Determining how fast the safeguard needs to be is an important deliverable that impacts the safeguard selection and setpoint specification. This presentation will provide a brief overview of process safety time concepts and how dynamic simulation can be used to verify the effectiveness of an instrumented safeguard. A case study will be presented to illustrate how the dynamic simulation provides insight into the available process safety time and safeguard response time.

Keywords: instrumented safeguards, simulation, process safety time

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Mission Time: What is the impact and when does it start?

Kevin Klein and Peter Richardel
Chevron Technology Center
1400 Smith St., Houston, Tx.
Kevin.klein@chevron.com, Peter.Richardel@chevron.com

Abstract

For preventive maintenance on safety system IPL and SIF, the mission time is to address all failures not identified during functional testing or diagnostics and related to age or application of the device. What are the factors which should be considered? When does the device start degrading? If the part is a spare sitting on the shelf for 10 years, what should I do before installation? There are a lot of questions about mission time and the effects on the parts and when turnarounds are planned for the sites. This paper will explore the assumptions around the mission time effects for safety systems and Independent Protection Layers and the practical consideration when developing or modifying the preventive maintenance strategies and activities.

Keywords: SIS, SIF, Mission Time, Preventive Maintenance

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

The SIS just broke! What Now?

Jenna Falco
SIS-TECH Solutions, LP
12621 Featherwood Drive, Suite 120, Houston, TX 77034
jfalco@sis-tech.com

Eloise Roche and Dr. Angela E. Summers
SIS-TECH Solutions, LP

Abstract

The inherently safer response to a detected failure in a safety instrumented system (SIS) is to take the process equipment under its protection to a safe state. Likewise, it is inherently safer to perform all testing and maintenance of the SIS equipment when the process is not operating, so that the process always remains protected during normal operation. However, what if the facility wants to keep operating while the SIS is undergoing maintenance and testing? Taking SIS equipment out-of-service increases the likelihood of the hazardous events the equipment was designed to prevent. The increased event likelihood can result in the risk exceeding the company's risk tolerance limits. To ensure safe operation, the increased risk during this transient period needs to be carefully managed.

Compensating measures are needed when either a bypass of the SIS equipment or the response to a detected fault of the SIS equipment results in a risk gap. Designing these measures can be challenging. The process operation during SIS bypass can be dynamic, with a possibility of increasing the likelihood of human error. For optimum effectiveness, the automation, and procedures necessary to implement the compensating measures should be identified as an integral part of SIS implementation. This paper will discuss some of the challenges posed by continuing operation with SIS equipment out of service and discuss how these challenges may be overcome. A case study will illustrate how a safety system in bypass, without proper compensating measures, can lead to a severe injury event.

Keywords: safety instrumented system, risk management, compensating measures, bypassing

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

"IPS Program Manager or IPS Process Safety Engineer – How the Heck did I get here!?"

Abstract

Nine years ago, I started my personal journey down the IPS (Instrumented Protective Systems) path and developed an IPS management program for Eastman's Texas Operations plant site. An effective IPS management program ensures all SIS, Safety and Non-Safety interlocks meet the safety life cycle and functional safety assessment requirements. I did not realize the consequences of creating a successful program. It has become a "monster", involving personnel throughout the site to complete all the design requirements and ensure on-going operation, maintenance, proof testing, etc.

Am I the IPS Program Manager or IPS Process Safety Engineer? How the HECK did I get here!? The IPS program has become so big, that it will take 4 or 5 engineers IPS design engineer and 1 or 2 competent SIS design engineers to cover all my current responsibilities as an IPS process safety engineer. On top of that, I manage the IPS program that involves working with all the personnel involved with LOPA, contractors, operations, maintenance, proof testing, etc. Not to mention the competency issues involved with SIS compliance to IEC 61511.

What was I thinking nine years ago? Process Safety is extremely important to safety operation of petrochemical plants 24/7. I want everyone to have the best chance to go home after a working their shift at the plant.

The following will be discussed:

1. Hazard and Risk assessment documents (e.g., PHA, LOPA)
2. IPS classification
3. P&ID interlock symbology
4. Interlock logic drawings
5. Interlock documentation
6. Proof-Test procedures

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Modeling of Dust Explosions in Vessel-Pipe Systems

Lorenz R. Boeck*, C. Regis L. Bauwens, Sergey B. Dorofeev
FM Global
Research Division
Norwood, MA 02062

*lorenz.boeck@fmglobal.com

Abstract

Explosions propagating between interconnected vessels often produce more severe consequences than those in individual vessels and can result in widespread damage to industrial facilities. Explosion isolation systems are used to contain and mitigate such events. These systems can be either passive or active in nature, operating based on the pressure buildup and flow generated by the explosion directly or through the use of detection and control systems. For effective isolation, however, these systems must activate rapidly, and a better understanding of flame propagation through vessel-pipe systems is needed to ensure these systems are designed and tested appropriately.

To develop engineering guidance and a methodology to certify explosion isolation systems, an extensive research program is underway at FM Global. Large-scale experiments have been conducted to study the dynamics of both gas and dust explosions in vessel-pipe systems and physics-based models have been developed to predict flame propagation across a wide range of geometries and reactive mixtures. These models will be used to generate engineering guidance for the proper use and installation of isolation systems and a comprehensive test method for evaluating their performance.

The present work addresses the modeling of dust explosions in vessel-pipe systems. A physics-based model was developed that considers dust explosion in a vented vessel with an attached pipe, resolving the process in time using a numerical solver. The features of this model are discussed, and its predictive capability is evaluated by comparing model results against experimental data with a focus on pressure history and flame progress.

Key Words: Gas Explosion, Dust Explosion, Explosion Isolation, Experiments, Modeling

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Ignition due to electrostatic discharge in multi-phase hydrocarbon flows

Authors: Tim Morse, Mike Stern, Harry Watson, Christopher Buehler, Harri Kytomaa

Abstract

The flow of hydrocarbons through pipes and hoses can lead to the generation of static electric charge. If there is an electrically isolated conductor, such as a metal fitting or pipe section, in a hydrocarbon flow, the electrostatic build-up can be sufficient to result in a discharge capable of igniting flammable vapors. This is a well-known hazard in many industrial applications that is typically alleviated through the use of grounding and bonding. There are generally-used equations that quantify the rate of electrostatic charge generation in single-phase flows, but only limited information for multi-phase flows. Multi-phase flow (e.g., a hydrocarbon with air) can occur in the transfer of hydrocarbons for a variety of reasons. This could be due to a hole or breach in the line, or due to air entrainment at a hose or pipe inlet if the hose or pipe is not fully immersed in the liquid to be transferred, such as during the start or end of transfer operations using vacuum trucks.

We performed experimental testing where liquid hydrocarbons were transferred under two-phase flow conditions (hydrocarbon and air) and measured the accumulation of static charge on an isolated metal pipe section. These tests were used to characterize the rate of charge generation, charge dissipation, and the maximum achievable voltage as a function of flow rate, the resistivity of the hydrocarbon, and the presence of water contaminants. Results from these tests were extrapolated using a model to real-world operating conditions for industrial facilities, hydrocarbon transfer stations, or hazardous waste clean-up equipment to assess the potential for electrostatic accumulation and discharge.

We also present a summary of industry standards for addressing the dangers of static electric discharge in multi-phase hydrocarbon applications and discuss how the experimental testing and modeling results relate to these standards.

Keywords: electrostatic, two-phase flow, explosion

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

CORE Focus on Embedding a Process Safety Culture

Abstract

Every organization already has a culture…. it is up to you to determine if Process Safety is embedded into your company or site.

When individual's say they want to embed culture at work, they are seeking ways to create a positive culture — one that combines practices, people, products, and services to feel like second nature, thus embedding culture.

We use CORE as we review a company's core values to create the roadmap for embedding a process safety culture.

Challenge

Organize & Measure

Re-Inspire Resources

Empower

Your company is currently investing in training and risks analysis through MOC, PHA, LOPA, etc. We want to demonstrate looking at unique ways to go beyond the standard classroom. Allocate resources to effect the required change – this could be an allocation of time to implement or manage a desired change or could be an investment of funds in training to assist employees to change a certain behavior.

Learn more techniques to strengthen your business culture with the Core activities to embedding a process safety culture. We will show examples and metrics on implementations.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Assessing the impact of cyber-attacks to the BPCS and SIS in chemical and process plants

Matteo Iaiani[1], Alessandro Tugnoli[1], Valerio Cozzani[1,*]

[1]LISES – Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali, Alma Mater Studiorum – Università di Bologna, via Terracini n.28, 40131 Bologna, Italy.
*E-mail : valerio.cozzani@unibo.it

Abstract

Cyber threats are becoming a growing concern for industrial facilities characterized by a high degree of automation, especially those that rely on Industrial Automation and Control Systems (IACS, e.g. Basic Process Control System (BPCS) and the Safety Instrumented System (SIS)) such as chemical and process facilities. Fixed installations where chemical and petroleum products are manufactured and stored (e.g. Seveso sites in the European Union) are of primary concern since adversaries (e.g. terrorists, activists, criminals, disgruntled employees) may exploit the inherent hazardous conditions and trigger events with severe consequences on workers, population, and the environment. In fact, a cyber-attack, besides economic and reputation damages, can potentially trigger major accidents (e.g. release of hazardous materials) as happened in 2008 where cyber-criminals over-pressurized a section of the BTC (Baku-Tbilisi-Ceyan) pipeline causing an explosion, the release of more than 30,000 barrel of oil in an area above a water aquifer, a fire lasting more than two days and outage losses of $5 million a day.

Though the issue is recognized by regulators (e.g. NIS Directive 2016/1148/EU for the Oil&Gas sector), several authors evidenced the need to develop structured methodologies aimed at the security risk evaluation in process industries supporting the scientifically based identification of weak links, and at the prioritization of risk management resources. General methods for Security Vulnerability Assessment (SVA) or Security Risk Assessment (SRA) used in the chemical and process industry (e.g. VAM-CF methodology, CCPS methodology and the one proposed by API RP 780) provide limited support to the identification and management of cyber risks. Moreover, the ISO/IEC 27000 family of standards on information security management systems and the ISA/IEC 62443 family of standards, specific for IACS, do not address the distinctive features of the process industry (dynamics of the physical process units, behaviour of hazardous materials in conditions out of specification, response of safety devices, etc.). Simplified assumptions are frequently adopted (e.g. considering impacts form the safety assessment), leading to false conclusions.

The present study is aimed at supporting the risk identification due to the malicious manipulation of the BPCS and SIS in chemical and process plants as requested by SVA/SRA methodologies and international cybersecurity standards. In particular, two systematic qualitative procedures for cyber risk identification were developed, exploiting a reverse-HazOp concept: PHAROS (Process Hazard Analysis of Remote manipulations through the cOntrol System) for the analysis of system integrity and POROS (Process Operability analysis of Remote manipulations through the cOntrol System) for the analysis of process operability.

The results can be used within the standard procedure for cyber risk management of chemical and process facilities to support the identification of protection requirements and countermeasures. The methodologies are complementary to current safety and security assessments and are intended for application to front-end design phase as well as to the security review of operating plants. Case studies were developed for demonstrating the potential use of the results.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Extending the Empirical Evidence for Process Safety Climate from Personal Safety Climate

Stephanie C. Payne, Luc Vechot, and Atif Ashraf

Abstract

The process and personal safety distinction is evident in hazards (e.g., sharp instruments vs. heating chemicals), behaviors (e.g., holding a handrail vs. lockout-tagout), and outcomes (e.g., broken bones vs. chemical releases). This distinction has also been applied to safety culture/climate; however, there is limited amount of empirical research assessing both process safety climate (or culture) and personal safety climate in order to reveal when this distinction for organizational climate matters. The purpose of this paper is to extend the science on process safety climate by empirically testing the following research questions using survey data and organizational records from a large-scale survey of an oil and gas company. (1) How related are personal safety climate and process safety climate? (2) Compared to personal safety climate, how strongly does process safety climate relate to safety-related events (e.g., injuries, spills, fires)? (3) Does process safety climate predict safety events above and beyond personal safety climate?

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Dynamic safety assessment in nonlinear, non-Gaussian, and multimodal process systems using probability adaption-based Bayesian network

Md Tanjin Amin[1] and Faisal Khan[2]
[1]Centre for Risk, Integrity and Safety Engineering (C-RISE)
Faculty of Engineering & Applied Science
Memorial University, St. John's, NL A1B 3X5, Canada

[2]Mary Kay O'Connor Process Safety Center
Artie McFerrin Department of Chemical Engineering
Texas A&M University, College Station, TX, USA

*Presenter E-mail: mta257@mun.ca

Abstract

Continuous process monitoring or fault detection and diagnosis (FDD) is crucial for dynamic process safety assessment. Integrated with failure path analysis, FDD enables to realize how a deviation in process variables can affect system safety. Although the current progress in process safety analysis is noteworthy, there lacks a methodology that can handle nonlinear, non-Gaussian, and multimodal datasets for process safety analysis. This work aims to overcome these issues and presents a methodology to detect any abnormal process behaviour. Also, it can show how a fault will lead to a process failure. The Bayesian network (BN) is used for FDD and failure analysis. A probability adaption mechanism is used to estimate the conditional probabilities in each time slice. The complexity of estimating conditional probabilities is handled using a combination of copula theory and Bayes' theorem. Unlike the other applications of BN in process safety, the current work can be applied to nonlinear, non-Gaussian, and multimodal process systems. Additionally, using a BN holds the advantages of causality representability and uncertainty handling capacity. Hence, it provides a robust mechanism for dynamic safety assessment. The proposed framework is validated using numerical and simulated datasets.

Keywords: Safety analysis, risk assessment, process monitoring, failure analysis, Bayesian network.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A new approach to numerically simulate CO2 dispersions considering the metastability and molecular vibration during depressurization

Raphael I Tsukada, Denis A. Shiguemoto, Sávio S.V. Vianna

UNICAMP - University of Campinas
Cidade Universitária" Zeferino Vaz"
Av. Albert Einstein, 500 - CEP 13083-852 Campinas - SP - Brazil
Tel: +55 19 3521-3947 Fax: +55 19 3521-3910
Presenter E-mail*: svianna@unicamp.br; savio.vianna@cantab.net

Abstract

More recently, the discovery of the Pre-Salt oil reservoir and the need to develop technology to reduce CO2 emissions thrusted the research towards the accidental release of CO2. The CO2 has a low triple point and it can coexist in the three phases when going through depressurization. This behavior led to the development of source models for leak rate that either consider that the depressurization process occurs under thermo-fluid dynamics equilibrium or that the process considers non-equilibrium conditions. In the current work, we consider that the molecular vibration during the leakage plays an important role in the modelling.. Moreover, we also take into account the metastability effects and the vibrational relaxation time as well as the phase transition during the release. The source model is coupled with Computational Fluids Dynamics (CFD). Dispersions simulations are conducted considering that CO2 is stored at supercritical conditions. Good agreement with experimental data is observed for the leak rate calculation. We provide a detailed procedure to perform CO2 dispersion simulations using CFD. The approach is straightforward to implement.

Keywords: CO2 dispersion, CFD, Source model

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Multi-SINDy for Modeling and Monitoring of Li-ion Batteries

Bhavana Bhadriraju*, Joseph S Kwon, and Faisal Khan
Mary Kay O'Connor Process Safety Center
Artie McFerrin Department of Chemical Engineering

**Presenter E-mail:* bhavanabvns@tamu.edu

Abstract

Capacity prediction and remaining useful life (RUL) estimation of Li-ion batteries are of utmost importance for enhancing their performance and reliability. However, due to operational uncertainties and interdependent dynamics at varying time scales, it is challenging to attain an accurate prediction of capacity and RUL. In this work, we propose a data-driven battery modeling and monitoring framework based on sparse identification of nonlinear dynamics (SINDy). Specifically, we propose a two-level SINDy model called multi-SINDy that accounts for the coupled inter and intra-cycle dynamics evolving at varying time scales. The inter-SINDy model predicts the battery capacity degradation at the end of each cycle, and utilizing this prediction, the intra-SINDy model approximates the state of charge (SOC) and voltage evolution within each operating cycle. Moreover, we implement the multi-SINDy algorithm in an adaptive fashion so as to cope with operational uncertainties. This will improve the prediction accuracy while accounting for both fast and slow time-scale battery dynamics in a computationally efficient manner.

Keywords: Remaining Useful Life, Li-ion Battery, Sparse Model, Deep Learning, Health Monitoring, Prognostics

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Understanding Standard Operating Procedures (SOP)

D. C. Breeding, PhD, RPE, CSP, CHMM
Texas A&M University
4472 TAMU
College Station, TX 77843-4472, USA

*Presenter E-Mail: bree@tamu.edu

Abstract

Well-conceived, documented Standard Operating Procedures (SOPs) are widely required by regulations, codes, and standards to clarify in logical sequence the inherent steps requisite to safe, compliant, and successful accomplishment of tasks and procedures. Clearly written SOP's are a critical tool for safely and successfully completing any task. Even when not mandated, effective SOPs make good business sense. Standard Operating Procedures (SOPs) are an engineered logical sequence of instructions for safely and expediently completing a task or operation while reducing risk and ensuring compliance, and are frequently the output of hazard evaluation, risk assessment, and other safety evaluation.

Standard Operating Procedures (SOP's) are an effective method of providing quality and consistent guidance to employees within an organization. An SOP is a set of instructions or steps someone follows to complete a job safely.

For over fifteen years, Dr. Breeding has been teaching the art and science of developing SOPs at Texas A&M, for professional associations, and for employers both domestically and internationally. In this session, Dr. Breeding will lead participants toward understanding and getting started with developing SOPs, and present a standardized protocol for approaching SOP development in any scope or venue. By participating in this session, individuals will gain a better insight and understanding of the proper design and maintenance of effective SOPs, and insight into the creation, review and implementation of good SOPs.

Keywords: Standard Operating Procedures, SOP, Compliance, Risk Management, Risk Assessment, Risk Communication

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Analysis of Coatings and Coating Applications Techniques in Harsh Environments

Yakubu A.M [a,b], Faisal Khan[a]. Susan Caines [a,c]

[a] Safety and Risk Engineering Group, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NL, Canada A1B 3X5

[b] National Agency for Science and Engineering Infrastructure Development, Abuja, Nigeria

[c] School of Ocean Technology, Memorial University of Newfoundland, St. John's, NL, Canada A1B 3X5

Abstract

Coatings play a key role in the protection and continued performance of assets. However, coating performance is not always as expected in different operating environments. For operations in the North Atlantic, supplier information on life expectancy for coatings is not always what is observed in practice. The reasons for this, are the harsh conditions of operations of Northeast Canada (Newfoundland and Labrador specifically) and limited information on the long-term performance of coatings in these harsh environments. Coatings are an important defense against corrosion with many different types and application techniques. To begin to understand the impact harsh environments have on the life of coatings, a comprehensive study on different coatings types and application techniques has been analyzed. This study highlights the gaps in understanding for coating life expectancy in North Atlantic operations and the impact of application methods on coating performance.

Keywords: Coatings, Application Techniques, Harsh environments, Coating standard, Coating Durability

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Reframing PSM in the Context of Operational Risk Management and ESG Sustainability

Michael Marshall, PE
Oil & Gas Industry Consultant
Michael Marshall LLC

Abstract

The regulatory climate changed considerably following the highly publicized incidents at BP Texas City in 2005, Tesoro Anacortes in 2010, Chevron Richmond in 2012, and ExxonMobil Torrance in 2015. Each happened not due to a failure of equipment, instrumentation, facility siting, operator, procedure, communication, supervision, or training, but rather a failure of all those things together, i.e., a management system failure. In addition to tens of millions of dollars in enforcement actions, legal consequences are now getting personal as was the case for plant management in the aftermath of the 2011 Chevron Pembroke incident. Systemic failures were cited in a May 2019 sentencing hearing at Swansea Crown Court with the plant declared "fundamentally unsafe" due to a series of errors and failings that contributed to a multi-fatality incident.

Companies are now increasingly being asked by investors and external stakeholders to engage in a broader Environmental, Social, Governance (ESG) landscape relative to environmental, health, and safety (EHS) performance, and risk reduction in the context of asset integrity and process safety human factors (the "organizational incident") is at the core of that expectation. To that end, companies are currently seeking to ensure holistic, enterprise-wide visibility and accountability for dynamic ESG programmatic efforts, materiality assessments, and sustainability solutions.

To date, no data management system or tool exists which effectively converges the highly interlinked EHS, compliance, and enterprise risk platforms with an asset integrity (and performance) predictive analytic framework. To get there, industry must reframe PSM and EHS management systems in the context of "operational risk management (ORM)," i.e., a broader risk reduction management system which more effectively integrates equipment with worker and production process data to better identify, analyze, and control risks at the physical asset level.

As for today's EHS software platforms, they aggregate only a limited amount of data from process safety and environmental workflows - incident reporting, near miss data, safety processes, environmental spills and releases - as necessary to satisfy regulatory compliance reporting requirements. Their inability to effectively integrate asset integrity and equipment-specific RAGAGEP, e.g., risk-based inspection (API 581 RBI), integrity operating windows (API 584 IOWs), fitness for service (API 579 FFS), corrosion control data (API 571 damage mechanism review [DMR]), equipment specific inspection data, etc., is an impediment to satisfying the full complement of ORM and ESG sustainability expectations. There is clearly a need to move towards

a consolidated enterprise information management platform architecture which consists of risk reduction solutions and decision support functionality by "giving voice to equipment."

"Data Rich & Insights Poor" is a characteristic observation in too many organizations not fully or properly deploying digital analytics and transformation tools. The ineffectiveness of incident reduction processes, tools and software applications in use today can be characterized as follows:

- A lot of data is being generated, but is not categorized, risk ranked, and prioritized by economic impact for data-driven systemic root cause analytics, thereby enabling whole classes of defects to be resolved across a plant as well as enterprise-wide
- Lots of emphasis on compliance, but too little focus on process safety risk reduction
- Inability to normalize data and KPI development relative to performance and process parameters
- Not built on an asset/equipment framework which integrates inspection and condition monitoring data as well as API 581 RBI, API 584 IOW, and API 571 DMR programs, thereby lacking business perspective regarding the impact of asset integrity on process safety and risk/incident reduction
- Other than API 754 Process Safety Event (PSE) Tier 1 and 2 KPI comparisons, there is little evidence of competitive KPI/indices benchmarking of the much more numerous near miss and unsafe conditions data of "free lessons" Tier 3 and 4 PSEs
- Failure to use process safety RAGAGEP like the AIChE CCPS Risk Based Process Safety PDCA management systems approach for systemic risk/failure mode analytics and enterprise-wide KPI benchmarking
- Insufficient evaluation of process safety as a function of mechanical availability and associated economic impact (lost production cost is a huge driver for process safety risk reduction)
- Lacking risk reduction solutions and failure modes decision support functionality based on industry best practice standards (including API 754)
- Not utilizing a predictive approach involving algorithmic correlation relative to causation
- Incapacity to link condition monitoring and failure analysis from data historians (e.g., OSIsoft PI) for predictive analytics, advanced pattern recognition, machine learning, artificial intelligence and time-series event frame annotations
- Lacking functionality and a highly configurable user interface for custom KPI trending, reporting, alerts/notifications, action planning and follow-up

Process plants are built around a myriad of machine and equipment assets like pumps, compressors, heat exchangers, piping, vessels, control valves and instrumentation, with the integrity of those assets being key to properly managing plant reliability and process safety risk. Given the demands of PSM program elements like mechanical integrity, hazard assessment, procedures, change management, incident investigation, and information management, it can be difficult for plant personnel to keep up. Today's digital transformation movement coupled with analytic tools holds the promise to help.

The convergence of information technology (IT) and operations technology (OT) data has been greatly facilitated by the proliferation of low-cost sensors and internet-protocol-enabled devices. Connecting people, processes, and equipment is the next wave of the industrial revolution which has been called the Industrial IoT (IIoT), or Industry 4.0. It is here, and it will be the early adopters who gain the competitive advantage in this new frontier.

Again, no data management system or tool exists on the market today which effectively converges the highly interlinked EHS, compliance, and enterprise risk platforms with an asset integrity (and performance) predictive analytic framework. Market surveys have confirmed that there is clearly a need for a software solution which couples the management systems of asset integrity and process safety (AIM + PSM = AIPSM) into an ORM/ESG compliant analytic framework which can be queried to inform real-time, risk-based analyses and decision-making relative to safety, environmental as well as profitability impacts. At a minimum, such an "AIPSM" framework for driving risk reduction program effectiveness, maturity, and continuous improvement should encompass the following:

- Analytics and KPI benchmarking specific to asset integrity, performance, and process safety
- System for categorizing, prioritizing, and risk ranking by economic impact/lost profit opportunity
- Enabling problem solving teams to resolve high value deep-dive systemic problems
- Failure modes decision support functionality
- IIoT data-driven predictive modeling capability
- KPI reporting, alerts/notifications, and action planning
- Fully integrated API 754 including culture, human factors, and the "organizational incident" involving complex equipment and systems
- High degree of configurability for customizable KPIs, reports, data trending and alerts

So, with predictive analytics at the core of an asset integrity and process safety management AIPSM framework, this paper discusses methods, metrics, performance analyses, KPIs and benchmarking techniques for driving ORM and ESG sustainability as they relate to the ultimate concern of any PSM program, i.e., loss of primary containment and associated impacts to production, profitability, and process safety.

Keywords: asset integrity, process safety, software, incident management, metrics, KPI benchmarking

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Integration of new instrument and automation technologies into existing facilities

Patrick Skweres, TBD, will consist of representatives of 4 process industry companies

Abstract

- What is potential impact to existing plant infrastructure, would they be minimal or extensive, how to plan and manage
- Culture
  - Setting and managing expectations pertaining to behaviors and positive reinforcement to achieve long term success
- Cybersecurity issues
  - Safeguards for normal operations
  - Safeguards for safety applications
- Operations and Maintenance training
  - What new skill sets are required or need to be refined?
  - Supplier/manufacturer support involving multiple suppliers, secrecy agreements, etc.
- Methodology on capturing data (digital variables/diagnostics) and transforming into actionable information.
  - Level setting the "why" or purpose of adding new technologies to the existing facility.
  - Input to work process on how instruments are chosen and monitored.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

WORKSHOP "Case study - SIL-3 Safety Block Valve failures in a New Installation"

Abstract

This will be a workshop will discuss the failure of SIL-3 safety block valves in a new installation and how the SIS safety lifecycle becomes important to the design, operation, maintenance, and repairs. Once a SIS is installed, commissioned, and verified, what are processes to ensure IEC 61511 requirements are met to ensure the SIS meets the risk reduction required by the LOPA when a SIS component (sensor, logic solver or final element) has failed.

The following will be discussed:

1) Hazard and Risk assessment
2) LOPA requirements
3) Engineering Design and documentation
4) Software programming
5) Installation, commissioning, and verification
6) Proof testing
7) Operation
8) Maintenance

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Are all our pools circular? How to properly address your hazard from a pool fire

Vinicius Simoes, Drew Botwinick, Scott Davis

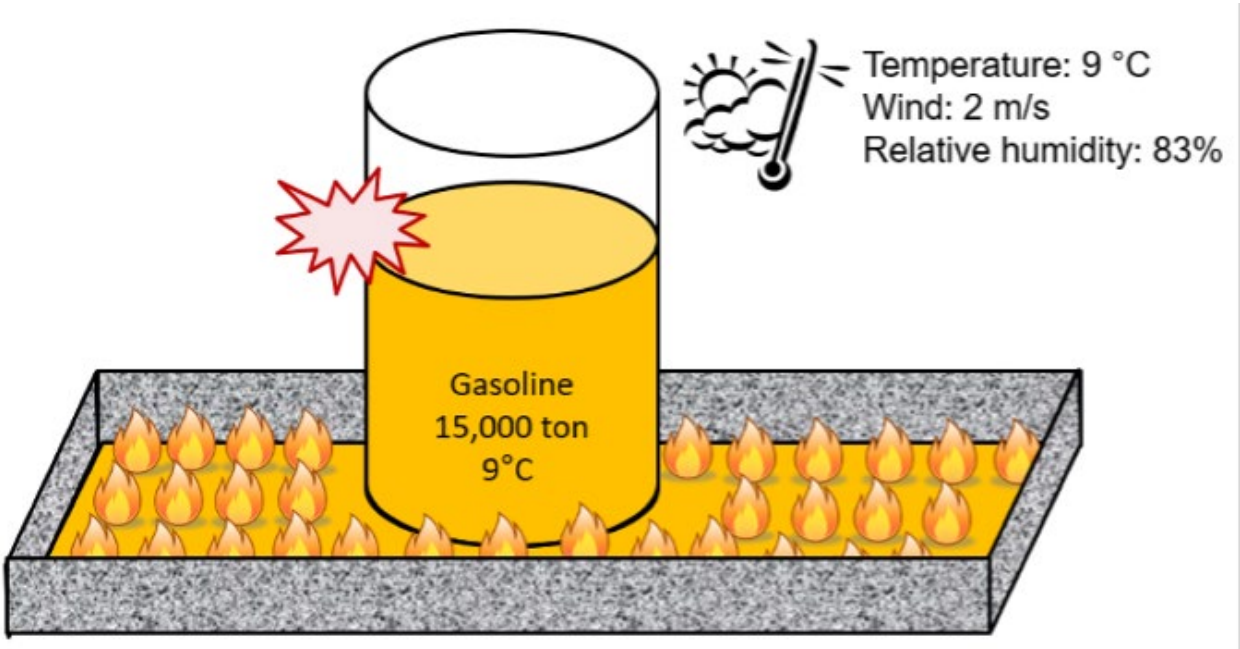
Gexcon

Abstract

A real issue in the industry is to determine the real impact that a possible hazard will impose in your equipment, building and personnel. The pool fire phenomenon is often very relevant for commonly used liquid, flammable materials such as gasoline and hexane. But even for a pool fire event, we can still distinguish between several different appearances.

The idea of this paper will be to provide a proper way to evaluate the impact coming from pool fires, a lot of the models and empirical tools available limit the evaluation to a circular pool. The idea is to show how can the proper hazard can be addressed using squares, rims and even polygons.

Simulating a polygonal shaped pool is particularly useful to account for the tank pit fire scenario, allowing you to draw the shape of the bund (dike) that contains the spill of flammable liquid.



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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Wind Tunnel Study of the Ensemble Behavior of Passive, Time-Limited, Area Source Releases

Tom Spicer, Ph.D., P.E.
Ralph E. Martin Department of Chemical Engineering
University of Arkansas, Fayetteville, AR

Jessica Morris, Ph.D.
Exponent, Inc.
Chicago, IL

Proposed for presentation at the

2022 Mary Kay O'Connor Safety & Risk Conference
College Station, TX
5-7 October 2022

Abstract

A series of experiments were conducted at the Chemical Hazards Research Center ultra-low speed wind tunnel facility to study the ensemble behavior of time-limited, area source releases of a passive gas. Concentration time histories were measured at multiple downwind distances in repeated experiments. The time histories were averaged as a function of time across the ensemble of releases to study the transient time history of the ensemble. Ensemble releases of different duration were compared to better understand how time limited releases disperse in the atmosphere, particularly considering how the time-limited releases approach steady behavior of a continuous plume or an instantaneous puff. This comparison highlighted how traditional approaches to interpreting field experiments of puff releases could be misleading. Constant release rates were used in the experiments, and the process of promptly starting and stopping releases produced repeatable experiments that enabled the ensemble behavior to be studied. This work has application to the understanding of field experiments as well as guidance on the dispersion modeling of time-limited releases.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Consequence Prediction of Battery Thermal Runaway Failure with Chemical Equilibrium Analyses

James C. Thomas, Olivier Mathieu, and Eric L. Petersen
J. Mike Walker '66 Department of Mechanical Engineering, Texas A&M University
College Station, TX, USA

Abstract

Lithium-ion batteries (LIBs) are widely utilized for energy storage in a broad range of applications, such as handheld electronics, emobility, spaceflight vehicles, etc. Thermal runaway (TR) and subsequent combustion of LIBs represent several significant hazards to consumers, including substantial energy release, jet flames, toxic gases, airborne particulates, and secondary explosions. Numerous experimental investigations in the literature have measured the energy release and chemical composition of off-gasses during LIB TR, but little theoretical work has been completed to this end. The current study focuses on prediction of product chemical composition, flame temperature, and energy release for LIBs undergoing TR failure through implementation of chemical equilibrium analyses (CEA). Theoretical compositions and total energy releases are compared to experimental data available in the literature. Initial results indicate CEA could prove a useful tool in evaluating alternative LIB chemistries and potential consequences of their failure.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Study on Accidental Gas Releases at Pipelines- CFD Simulation, and Its Validation

Burak Ayyildiz *[a], Ziyan Sherif [a], Muhammad Azizur Rahman [a,b], , Adolfo Delgado[a] ,Ibrahim Hassan [b], Hazem Nounou [b], Mohamed Nounou [b]

[a] Texas A&M University

[b] Texas A&M University at Qatar

ABSTRACT

For decades, natural gas (NG) leak detection has been a predominant issue, resulting in severe environmental and economic impacts. The present study has two steps to determine the observable leak trends and predict the gas release rate for various leak/pipe diameter ratios and operating pressures. The first part is a laboratory-scale experimental setup for baseline experiment (use air as working fluid) and statistical analysis. In steady operational stages, the mass balance method calculates the leakage mass flow rate in the experimental setup. In addition, pressure point analysis (PPA) with two dynamic and one differential pressure gauge is used to detect chronic/ small leaks at transient stages. This method is cost-effective and easy to maintain compared to expensive acoustic leak detection systems. Second, the computational fluid dynamics (CFD) simulations of pinhole leaks in a low-pressure air pipeline have been performed using a 3-D transient DES (detachable eddy simulation) model of a commercial CFD code ANSYS Fluent R3. This model is compared with the experiment result for validation. Then, the validated model uses pure methane as a working fluid to mimic Natural Gas. Finally, a new correlation has been proposed based on leak size, pipe diameter, and pipe pressure to predict the leak nominal volume flow rate for a high range of pressure and pipe sizes. The percentage of error between the CFD and correlation values fluctuates between 5 to (-2) %, which implies high accuracy of the derivate correlation.

KEYWORDS: CFD simulation, Chronic leak detection, NG pipeline leakage, Numerical investigation

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

When is going beyond an empirical consequence-based facility siting needed?

Vinicius Simoes, Drew Botwinick, Scott Davis

Gexcon

Abstract

Most facility siting analyses start with a basic, worst-case empirical consequence analysis. And as it turns out, many of those studies quickly demonstrate that the impact to buildings exceeds the acceptable criteria and require further analysis. The next level of analyses includes various techniques to rebalance conservatism and realism including quantitative risk-based studies that produce exceedance curves, etc. However, because the basis of these studies is generally trying to reach the acceptable criteria from the worst-case direction while minimizing the changes to the consequence modelling effort itself—it is not uncommon for these studies to result in design loads that require expensive retrofits to buildings. As a final step, some of these studies will turn to computational fluid dynamics (CFD) to justify avoiding these expensive retrofits. By following this process, the cost of the facility siting study is maximized and there is a higher chance that expensive building retrofits that don't actually pass a cost-benefit analysis might be forced to move forward.

This paper will demonstrate some of the benefits of using more realistic CFD modelling earlier in the process to more accurately reflect the real extent of potential building damage. When using the right mix of empirical modelling and CFD up-front as part of a risk-based analysis, facility siting studies can more realistically reflect the potential harm and provide greater cost-benefit—i.e., reduce the true overall cost of the study while also being more realistic about when it may be required to retrofit buildings to meet certain design accidental loads.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Numerical investigation of hydrogen auto- ignition upon pressurised release into partially confined spaces

Parth Patel[a*], Til Baalisampang[a], Ehsan Arzaghi[a], Fatemeh Salehi[b], Vikram Garaniya[a], Rouzbeh Abbassi[b]

*Corresponding Author, Email address: parthambalal.patel@utas.edu.au

[a]College of Sciences and Engineering, Australian Maritime College, University of Tasmania, Launceston 7248, Australia

[b]School of Engineering, Macquarie University, Sydney, NSW 2109, Australia

Abstract

Hydrogen-auto ignition is considered the primary ignition source in several previous hydrogen-related fire and explosion accidents. Thus, the hydrogen auto-ignition upon pressurized release is a major safety concern that inherently impedes the safe and sustainable hydrogen infrastructure. This numerical study proposes a framework to model imperative conditions for hydrogen auto-ignition without an ignition source. The proposed model was validated against an experimental study of hydrogen gas release in a partially confined space, which was extended by introducing an obstacle in the hydrogen flow path to generate multi-dimensional shock waves. The case study results revealed that the hydrogen could ignite automatically even without an ignition source if the accumulation effects of "Joule-Thomson Inversion Temperature" and "Multi-Dimensional Shock Waves" exceed the auto-ignition temperature threshold. The study can assist in modelling the most likely mechanism for hydrogen auto-ignition upon subsonic release in any facilities to ensure the safety and sustainability of hydrogen economy.

Keywords: Hydrogen Safety, Computational Fluid Dynamics (CFD), High-pressure hydrogen release, Joule-Thomson inversion temperature, Multi-dimensional shock waves, Spontaneous ignition; Auto-ignition.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Stop the Insanity!

Moving the Process Safety Focus from Fear and Compliance to Value Creation and Profitability

Jimmy Miller, CFSE, FS Eng (TÜV Rheinland)

North America Process Safety Business Leader

Yokogawa Corporation of America

Sugar Land, TX

Jimmy.miller@yokogawa.com

Abstract

We're better than this, folks! It's 2022 and many in the Process Industry still insist on beginning any discussion regarding process safety with pictures and videos of industrial accidents. If it's not pictures and videos, it is strong warnings about potential fines, loss of company image, lawsuits or loss of license to operate. The OSHA Process Safety Management Regulation was introduced in 1992. Since then, there has been increasingly high levels of Fear, Uncertainty and Doubt injected into the Process Industry, yet process safety incidents still occur. Unfortunately, the industry has not been successful scaring the inherent risk out of our processes. Perhaps it's time to change the narrative and shift our focus from regulatory compliance and fear to something that every Process Industry Manufacturer understands – business improvement and profitability.

This presentation explores the history of process industry incidents and their causes while drawing parallels to the early days of the automotive industry and their own struggles with safety. Much can be learned from that evolution, and it mirrors many of the same challenges we face regarding process safety. By utilizing more inherently safe design concepts and better capturing increased diagnostics and operational data, safety and business decisions can be made more quickly and efficiently. This leads to inherent regulatory compliance and increased business improvement.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A Multiscale Framework for the Resilient-Aware Design of Distributed Manufacturing Networks

Natasha J. Chrisandina[a], Shivam Vedant[b,c], Eleftherios Iakovou[b,d], Efstratios N. Pistikopoulos[a,b], Mahmoud M. El-Halwagi[a,b,e]

a) Artie McFerrin Department of Chemical Engineering, Texas A&M University, 3122 TAMU, 100 Spence St., College Station, TX 77843, USA
b) Texas A&M Energy Institute, Texas A&M University, College Station, TX, 77843, USA
c) Department of Multidisciplinary Engineering, Texas A&M University, College Station, TX, 77843, USA
d) Department of Engineering Technology and Industrial Distribution, Texas A&M University, College Station, TX, 77843, USA
e) Gas and Fuels Research Center, Texas A&M Engineering Experiment Station, College Station, Texas, USA

Abstract

Distributed manufacturing (DM) networks are sets of geographically-dispersed manufacturing facilities along with associated suppliers, intermediaries, end users, and the transportation links and modes that connect them [1]. DM networks can be used to support decentralized energy production in the pursuit of more localized, sustainable energy systems [2]. To ensure business continuity and consistent service levels, a resilient network that has the adaptive capability to prepare for unexpected events, respond to disruptions and recover from them as quickly as possible is highly desirable. A major bottleneck in designing resilient DM networks is the lack of understanding on how sub-network level decisions affect network resilience as a whole. A multiscale system engineering approach allows for an integrated decision-making process with consideration to the different levels of operations involved in a DM network [3].

In this study, we argue for the need to study resilience of DM networks by considering multiple scales of operation: molecular, unit, process, and whole network. To that end, we propose a multiscale framework for designing cost-effective and resilient DM networks by integrating: 1) facility location decisions in the face of specific disaster scenarios; 2) individual process plant design choices using modular process units; and 3) considerations of multiple objectives such as economic performance and environmental sustainability. The proposed framework unveils possibilities to enhance the resilience of DM networks through targeted, cost-effective strategies at the sub-network scale. A study on the Texas-Louisiana hydrogen grid is presented to demonstrate the applicability of the framework. (244 words)

References

1. Srai, Jagjit Singh, et al. "Distributed manufacturing: scope, challenges and opportunities." *International Journal of Production Research* 54.23 (2016): 6917-6935.
2. Adil, Ali M., and Yekang Ko. "Socio-technical evolution of Decentralized Energy Systems: A critical review and implications for urban planning and policy." *Renewable and Sustainable Energy Reviews* 57 (2016): 1025-1037.
3. Demirhan, C. Doga, et al. "A multi-scale energy system engineering approach towards integrated multi-product network optimization." *Applied Energy* 281 (2021): 116020.

Keywords: Resilience, sustainability, multiscale modeling, distributed manufacturing

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A Cutting-Edge Cloud-Based Alarm Management Solution

Abdula Abulaban, Syed Imtiaz, and Salim Ahmed
Center for Risk Integrity and Safety Engineering (C-RISE), Department of Process Engineering, Memorial University of Newfoundland, St. John's, NL, Canada

Abstract

Modern data acquisition systems are capable of capturing a large amount of data from processes. The sensor readings provide the process variables, which decide whether or not an alarm is present in the system based on predefined limits. Process data, A&E log, operational records and piping and instrumentation diagram (P&ID) contain wealth of information about the process. Often this information remains under-utilized due to the absence of appropriate data mining tools. In this paper, an integrated cloud-based framework can be incorporated to facilitate data collected from many sources into a unified database, to be processed, analyzed, and presented in expressive interactive visuals. Large sets of data can be analyzed by the application in an efficient manner. Four main functions are included: "Data Selection" to select processing units, variables, time periods, and parameters tuning; "Visualization," the results of analyses recorded in process readings and A&E log data are presented; "Alarm Design" can modify the alarms associated with specific process parameters; "Causality Analysis" identifies correlations between process variables and identifies the fundamental cause of a multi-alarm occurrence. An industry case study was used to demonstrate the platform's efficacy and applicability.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Dynamic Functional Resonance Analysis Method (FRAM) approach to resilience assessment of chemical process systems

Hao Sun [1,2], Ming Yang[2,*], Haiqing Wang[1,*]

*Corresponding authors: 1. Haiqing Wang, College of Mechanical and Electronic Engineering, China University of Petroleum (East China), Qingdao 266580, China, email: wanghaiqing@upc.edu.cn; 2. Ming Yang, Delft University of Technology, The Netherlands, email: m.yang-1@tudelft.nl

[1.] College of Mechanical and Electronic Engineering, China University of Petroleum (East China), Qingdao, China

[2.] Safety and Security Science Section, Department of Values, Technology, and Innovation, Faculty of Technology, Policy, and Management, Delft University of Technology, The Netherlands

Abstract

Chemical process systems are becoming more and more automated and complex in the digital age. These changes lead to increased interaction and interdependence between the functions of sub-systems of process systems. This urges the need for updating the safety assessment method by treating "safety" as an emergent property of a system, which within its boundary is socio-technical, i.e., consisting of hierarchical organizational layers, and human and machine interactions. Besides, when a system becomes more complex, it may also bring more uncertainty in its operation. Given risks, resilience strengthening is a potential solution to the above problems. This paper proposes a comprehensive resilience assessment method based on a dynamic version of Functional Resonance Analysis Method (FRAM). FRAM is utilized to model the system operation to reflect the relationship between functions. FRAM captures the time-dependent variability in complex operations. Resilience quantification is performed based on the variability index. The proposed method is applied to a case of process system operation.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A Tale of Two BPCS Credits
A Bayesian Case Study

Keith Brumbaugh
aeSolutions
250 Commonwealth Drive, Suite 200, Greenville, SC 29615
keith.brumbaugh@aesolutions.com

Abstract

Have you ever had the problem of having a perfectly functional BPCS* interlock that you *know* is highly failure immune, yet when it comes time for the Hazard Analysis, you may only take one credit? Unfortunately for facilities following the IEC 61511 safety lifecycle, any interlock not designed according to the standard is limited to one risk reduction credit. This can make meeting extremely low total mitigated event likelihood targets (such as $1x10^{-5}$ or $1x10^{-6}$) very difficult.

What can you do if you do not want to redesign your BPCS interlock to meet the IEC 61511 requirements? The only thing left is to seek out a deviation, though you better have good justification.

This case study will examine the approach used for one client to justify two risk reduction credits on their robust BPCS interlock in two basic steps. The first step was to determine a reasonable probability of failure using a Failure Mode and Effects Analysis technique (FMEA). All relevant failure modes including the ubiquitous human component were examined. Next, plant operating history was reviewed and applied in a Bayesian analysis to determine an upper credibility (confidence) limit. The overall FMEA and Bayesian analysis process, including the "why," "how," and results will be provided.

As a bonus, the methods used in this case study can be directly translated into a case for Prior Use Justification, data collection, and user-customized and maintained failure rate data.

*BPCS = Basic Process Control System

Keywords: Process Safety, Bayes Rule, Bayesian Credibility Analysis, Confidence, IPL, Independent Protection Layer, LOPA, Layers of Protection Analysis, SIS, Safety Instrumented System, BPCS, Basic Process Control System, FMEA, Failure Modes and Effects Analysis, FMEDA, Failure Modes Effects and Diagnostic Analysis, Prior Use Justification, Data Collection, Failure Rate Data, Quantitative Risk Assessment, QRA, Frequency Techniques, Interlocks & Safety, Safety, Reduction of Risk.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A Tutorial on the Proportional, Integral, Derivative (PID) Controller

James Beall
Emerson Automation Solutions
Austin, Texas
*Presenter E-mail or Presenters E-mails: james.beall@emerson.com

Abstract

Abstract Body
Proportional, Integral, Derivative (PID) controllers are the mainstay in controlling many industrial processes. There are many variations in the implementation of the PID as well as many options to be selected. The terminology in the industry is often confusing or even conflicting! A new International Society of Automation (ISA) subcommittee 5.9 to write a Technical Reference (TR) to explain the many implementations and options and to standardize the terminology. This tutorial will explain the basic operation of the PID controller and some of the common options based on the proposed ANSI/ISA-TR-5.9.

Keywords: PID, Tuning, Process Control

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

How to Implement Feed Forward with PID Controllers

James Beall
Emerson Automation Solutions
Austin, Texas
**Presenter E-mail or Presenters E-mails:* james.beall@emerson.com

Abstract

PID controllers are the mainstay in controlling many industrial processes. While the PID controller can provide great performance in most cases, the addition of feed forward control for large measured disturbance can greatly improve the response to the disturbance. This workshop will explain the limitation of PID controller performance, the benefit of feed forward and how to implement feed forward with a PID control scheme. Exercises will be provided to explain the implementation and plant examples will be used to illustrate the concepts and results.

Keywords:
PID, Tuning, Process Control, Feed Forward

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Specific is Better than General: Improving Decision Making using LOPA by the Use of Plant Data

Abstract

Often industrial guidance on failure rates for use in Layer of Protection Analysis (LOPA) comes from AICHE-CCPS *Guidelines for Initiating Events and Independent Protection Layers for Layer of Protection Analysis*. The values established in this book were often by committee consensus because the amount of failure rate data published in the open literature was sparse. The committee deliberations on these values were measured and reasonable. While these values are well accepted across the industry, in many cases they can cause concern that they are too conservative. The predicted failure rates do not appear to match the real-world experience of those conducting, contributing too, or evaluating the results of LOPAs.

Guidelines for Initiating Events and Independent Protection Layers for Layer of Protection Analysis does clearly indicate, however, that failure rates derived from actual data will provide a more accurate view of the frequency of events and therefore risk than the generic values provided in the text. This paper reviews the general methodology for collection and use of plant data for improving risk estimates. Example applications are provided where this approach has yielded results in risk analysis more reliable than those predicted using generic industrial wide data.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Integrating Psychosocial Risk Management with Process Hazard Analyses

Author: Dana Garber, Senior Solutions Strategist, Risk - VelocityEHS

Abstract

In a 2018 study published in *Safety and Health at Work*, the analyses showed that employee-reported levels of mental well-being positively correlate with their understanding of workplace risks and controls and the resources available to address safety risks. The study also provides recommendations for building a robust system to manage psychosocial risks in industry.

Psychosocial risks are the anxiety stressors of workers that stem from their workplaces and work arrangements. In the last few years, the impacts of these stressors have been felt across the globe and have spurred additional studies on this topic. Organization leaders are taking note, and more programs to improve employee well-being are being implemented.

Health and Safety professionals are looking to incorporate a Total Worker Health (TWH) approach to these programs. They're getting serious about integrating identification and control of psychological risks into their safety management systems.
In the process safety space, this understanding of risks is catalogued in HAZID and HAZOP studies. Most people familiar with HAZID and HAZOP processes understand the main benefits and outcomes, including:

- improving design through inherent safety opportunities
- improving operability
- establishing critical decision input

However, those responsible for managing HAZIDS and HAZOPs are often unaware of the additional benefits of those studies for improving psychological safety.

During this presentation, experts in process safety and risk management will demonstrate how HAZID and HAZOP workshops can reduce the psychosocial risk of operations personnel. They will provide a qualitative assessment on the social dynamics of PHA workshops and recommend techniques to improve the quality of your PHAs through better team participation and candor.

Attendees will learn:

- practical advice on how to address psychosocial risk, specifically at high-hazard facilities in the petrochemical industry
- strategies for improving workshop engagement and therefore the quality of your HAZID/HAZOP outputs
- how a better understanding of risks and controls can lead to overall improvement in site safety, including psychological safety

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Assessment of human performance variability in the safety of complex systems

Esmaeil Zarei [a], Faisal Khan [a,b*], Rouzbeh Abbassi [c], Yahui Zhang [a]

[a] Centre for Risk, Integrity and Safety Engineering (C-RISE), Faculty of Engineering and Applied Science Memorial University of Newfoundland, St. John's, NL, A1B 3X5, Canada

[b] Mary Kay O'Connor Process Safety Center (MKOPSC), Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, TX, 77843-3122, USA

[c] School of Engineering, Faculty of Science and Engineering, Macquarie University, Sydney, NSW, Australia

Corresponding author; fikhan@tamu.edu; fikhan@mun.ca

Abstract

Human performance plays a vital role in system safety and resilience of critical systems. It has been studied from two distinctive perspectives of human reliability or human factor. This study aims at developing a Bayesian Network-Functional Resonance Analysis Method (BN-FRAM) model to analyze the system safety and human performance in sociotechnical systems. First, the system is characterized based on functional structure, and dependencies among system functions using the Functional Resonance Analysis Method (FRAM) and potential variabilities. Subsequently, Bayesian Network (BN) model is developed for a range of internal and external performance variability shaping factors. A new aggregation rule along with Monte Carlo simulation are employed to quantify the dependency variability under uncertainty. The various operating scenarios concerning the sociotechnical system's elements (e.g., human, task, organization, environment) are considered to model actual performance variability and identify critical variabilities. The proposed model is tested on an actual maintenance operation in oil and gas facility. Finally, a comparison with the conventional human reliability assessment techniques is performed to highlight the advantages of the developed methodology in human performance modeling.

Keywords: Human performance; System safety; Human reliability; Human factor.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Condition Monitoring and Risk assessment of Cyber-Physical Process Systems

Rajeevan Arunthavanathan[1], Ahmed Elkady, Syeda Halim, and Faisal Khan

Mary Kay O'Connor Process Safety Center,
Artie McFerrin Department of Chemical Engineering,
Texas A&M University, College Station, TX 77843-3122, USA

[1]Centre for Risk, Integrity, and Safety Engineering (C-RISE)
Faculty of Engineering and Applied Science
Memorial University of Newfoundland, St. John's NL A1B 3X5, Canada.

Abstract

Industry 4.0 in the process systems and plant architecture has led to the cyber-physical process systems (CPPS) where physical processes and information and communication technologies are strongly coupled. Therefore, considering the risk assessment in the advanced process plant, safety and security are considered key properties. Security focuses on protecting the systems from purposeful attacks, whereas safety focuses on protecting the systems from accidental failures to avoid risks. When applying CPPS concepts into the process systems, safety and risk assessment following issues are considered: i. Traditional risk and safety assessment in process systems mainly considered sensor, actuator, controller equipment degradation, or component failure while failure due to cyber-attacks was not part of the design process. Such attacks were extremely unlikely or even impossible in a traditional process plant (probability considered closer to zero.). ii. Cyber-physical interdependencies need to be considered in CPPS where the system components, collaborative robots, and humans need to communicate for collective decision-making. Any exploitation or malfunction of one device may trigger a cascade of unexpected and often undesired changes of other devices and extend to the entire control network, introducing cascading failures. Therefore, traditional safety analysis and risk assessment methods are inefficient to assess CPPS based process systems safety and security. In this work, a novel integrated risk assessment method proposes to investigate the system's safety and security. First, it analyzes corresponding security features for the possible CPPS architecture in the technology advancement of Industry 4.0 and then adds to the traditional risk assessment methods. Finally, this work evaluates and compares the risk in both the traditional and CPPS systems.

Keywords: Process Safety, Cyber-Physical System, Condition Monitoring, Risk Assessment, Safety 4.0

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Effects of Seafarer's performance during the Maintenance Operations of Marine Engines in Harsh Environment

Rabiul Islam; Md Tanjin Amin; Mohan Anantharaman; Til Baalisampang, Sidum Adumene; Faisal Khan; and Vikram Garaniya

Abstract

Human error is a crucial factor in the shipping industry and numerous errors occur by the seafarers during the maintenance operations of marine engines. Over the past two decades, many accidents happened during the maintenance operations of the marine engine due to human error. To mitigate injuries and incidents during the maintenance operation of marine engines it is important to determine the likelihood of human error. There are many techniques available to estimate Human Error Probability (HEP). The Success Likelihood Index Method (SLIM) is used in this study to determine the HEPs due to the unavailability of human error data for maintenance operations of marine engines. In this study, HEP is estimated in two different conditions (i.e., normal environment and harsh environment) and compared the results to identify the effect of harsh environment on seafarer's performance. The results of this study show that there is a significant impact of the harsh environment during the maintenance operations on seafarer's performance. The results of this study will help to identify the failure-prone activities based on higher and lower HEP. The seafarers can prioritize the activities with higher HEP and make a better plan for maintenance scheduling to reduce human error and in turn, it reduces maritime accidents.

Keywords: Seafarer's performance; Maintenance operations; Marine Engine; Harsh Environment.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

A Study of The Fixed Choke Position Method for Riser Gas Handling

Chen Wei, Louisiana State University. **Yuanhang Chen**, Louisiana State University.

Abstract

Riser gas events happen during offshore drilling operations and are considered very hazardous and challenging to control. During the past decade, the increased adoption of Managed Pressure Drilling (MPD) equipment has significantly enhanced the safety and efficiency of offshore drilling operations and influx management. The objective of this research is to evaluate the performance of the fixed choke position method, as one of the most discussed and positively perceived pressure control methods for riser gas handling currently in the industry, to provide an improved understanding of this method.

A transient two-phase flow simulator based on a Drift Flux Model was developed to simulate the fluid dynamics in a riser. Measurement data (including distributed fiber optic sensing data) from a set of full-scale experiments conducted at the Petroleum Engineering Research and Technology Transfer (PERTT) Laboratory at Louisiana State University (LSU) was used for the calibration and validation of the simulator we used for sensitivity analyses in this study. A riser gas event was simulated in the experiments by injecting gas from the bottom of an experimental well. The two-phase flow dynamics using the fixed choke position method with different operational scenarios are simulated and analyzed.

The performance of the fixed choke position method is evaluated based on multiple key parameters, including the riser bottom and surface pressures, surface gas and liquid flow rates, and the efficiency of riser gas handling. The simulation revealed that the pressure control strategies should be determined based on riser depth, gas influx size, and the pressure rating and capacity of both surface and subsea equipment. This study improves the understanding of the fixed choke position method for safer and more efficient riser gas handling. The decision-making framework proposed in this study helps to better understand and improve the design of the fixed-choke-position-based riser gas handling strategies.

Keywords: Riser gas event, Fixed choke position method, Drift Flux Model, Managed Pressure Drilling

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Safer Ocean Energy System by Integration with Wave Energy Converter Systems

Aghamarshana Meduri, HeonYong Kang

Abstract

In response to global climate challenge, the ocean energy development started expanding to renewable energy such as offshore wind, waves, and currents. Based on the huge energy potential with beneficial features such as steady availability and high energy density, the wave energy is regarded as one of promising energy resources to develop. Although the wave energy conversion will reduce wave height and subsequently wave loads while extracting the renewable energy, proportional to wave height square, the influence of the wave energy conversion on neighboring ocean energy systems such as offshore oil and gas platforms or wind platforms has scantly been studied until now. In this study, we present an ocean energy system, which comprises a floating platform, presenting either the offshore oil and gas or wind platform, and an array of innovative wave energy converters, Surface Riding Wave Energy Converters (SR-WEC) that uniquely adapts the pitch natural frequency for varying irregular waves so as to produce the maximum average electricity. The SR-WECs surrounds the floating platform with soft connections such as hawsers, and the ocean energy system is investigated in terms of the wave energy conversion performance, wave loading change on the platform, and safety improvement of the platform by the wave energy conversion. Global performance simulation of the ocean energy system is employed on time domain to solve the coupled interactions of the floating platform, SR-WECs, random waves, and nonlinear mooring system. Moreover, the SR-WECs' dynamics includes nonlinear dynamics of linear generators optimized in terms of power-take-off coefficients. The safety is assessed by monitoring loads, measured at stress hotspots, and kinematics, measured at operation areas of the platform.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Panel Session: Safety Instrumented System Prior Use Failure Rate Data - Industry Status

Mike Scott, PE, CFSE
aeShield
mike.scott@aeshield.com

Abstract

This moderated panel session will include end user SME's representing a variety of industries (e.g., chemicals, refining, exploration, etc.), as well as, consultant SMEs who support the process industry.

IEC 61511 clause 11.9.3 states: *The reliability data used when quantifying the effect of random failures shall be credible, traceable, documented, justified and shall be based on field feedback from similar devices used in a similar operating environment*.

This panel session will explore the process industries current practices at end user sites, as well as, on major capital projects with regards to failure rate data selection / basis. The topic of discussion will also address what are the various users / consults seeing happening in industry today with regards to proof testing, failure classification and / or failure data analysis required to leverage prior use failure rate data in their end user organization. Are Digital Transformation initiatives backed by corporate IT aligned with abilities to leverage Prior Use Data in the business? Is Prior Use data desirable to the end user community and why or why not? With regards to major capital projects what is happening today with regards to failure rate data used by consultants / EPCs during detailed design? The session will be interactive and allow for audience questions and answers.

Keywords: Functional Safety, Prior Use Failure Rate Data, Failure Classification, Digital Transformation

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Prevention of Catastrophic Electrical Failures Using Advanced, Real-time Diagnostics and Health Monitoring of Power Circuits

Dr. B. Don Russell
Department of Electrical and Computer Engineering
Texas A&M University

Abstract

A reliable and resilient electricity distribution system is key to the continuous, safe operation of plant processes and facilities. Electric faults and failures of apparatus interrupt production, create safety hazards, and can result in fires and explosions.

Traditional monitoring and protection systems do not have the capability of detecting incipient, low-magnitude conditions that often precede catastrophic failure and outages.

Research by the Power System Automation Laboratory at Texas A&M University has revealed that the failure of common electric distribution components including connectors, cables, switches and similar apparatus may develop failure mechanisms that begin days or weeks in advance of a high magnitude fault that trips protection. This finding comes from analysis of captured recordings of naturally occurring failures on hundreds of electrical circuits some of which were monitored continuously for over 10 years.

This paper presents the development of new real-time diagnostic technology called Distribution Fault Anticipation. The DFA system is capable of continuous health monitoring of electrical distribution circuits and apparatus including overhead lines, cables, switchgear, and transformers. Multiple examples of early detection of incipient failures are presented including examples of actual catastrophic failures that could have been prevented. Details are provided on how actionable information is provided in real-time to operators. DFA technology is under active use by over 20 companies.

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

25th Annual International Symposium
October 05-07, 2022 | College Station, Texas

Sensor-to-Cloud MQTT + LTE CAT1 Platform Offers Next-Generation Remote Monitoring Solution for the Industrial Sector

By Sandro Esposito, SignalFire Telemetry

Abstract

Cloud connectivity removes barriers in collecting data from assets in impassable locations. A new IoT cellular transmitter utilizing the latest LTE CAT M1 technology now connects industrial sensors to the cloud for remote monitoring, control and alarming from any web browser including mobile devices. Monitor a variety of assets, including pipeline pressure, ESD valve position, wellhead pressure, tank farm monitoring, and irrigation pump control – to name a few.

Designed to work with a range of sensor brands and types (4-20mA transmitters, switches, and HART) as part of a remote monitoring solution, this cellular-based transmitter connects directly to the cloud and bypasses local networks to offer a more secure connection. A built-in GPS receiver reports the device location to the cloud, providing a map of all connected assets.

The sensor-to-cloud platform is very simple to setup and makes it easy to quickly access your measurements with the least amount of hardware. Plug and play, the transmitter needs no programming. The use of LTE CAT M1 technology supports IoT devices by connecting directly to a 4G network, without a gateway, using the built-in batteries or optional external solar panel.

The presentation will explain the technology behind the new transmitter, connectivity from the sensor to the cloud, benefits and examples of its use in meeting the need for monitoring isolated measurements or 'lone rangers' where it is cost-prohibitive or complicated to simply get a reading from a sensor.

Topics:

- Advantages of recent IoT Cellular Technologies – LTE CAT M1 + NBIoT
- Benefits of MQTT based sensors & sensor hubs
- Deploying and integrating MQTT/Cellular sensors in SCADA
- Examples & Lessons learn from thousands of installations