



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

---

20<sup>th</sup> Annual International Symposium  
October 24-26, 2017 • College Station, Texas

---

## **Identifying Safety Culture Deficiencies in Facilities with the Potential for High Consequence/Low Probability Events**

Alek Hamparian and Mardy Kazarians  
Kazarians & Associates, Inc.  
100 West Broadway, Suite 970, Glendale, California  
MKazarians@Kazarians.com

Presenter E-mail: Alek.Hamparian@gmail.com

### **Abstract**

One of the key underlying causes of most major accidents can be traced to deficiencies within the organization's safety culture. The Chemical Safety Board (CSB) has directly identified safety culture deficiencies in their recent investigations including the March 2005 BP Texas City accident and the June 2013 Williams Geismar Olefins Plant accident.

There are many reasons as to why safety culture deficiencies exist within an organization and are not identified and corrected by those working within the organization. An example could be *Drift to Danger* that is often addressed in *Resilience Engineering* related discussion. Another concern is that high consequence/low probability events are rare, which results in a low risk perception by employees within systems that have the potential for severe events.

One could argue that full compliance with current PSM regulations should be sufficient and would have prevented the major events that have drawn industry's attention. However, organizations, especially those that handle highly hazardous materials, should strive to go beyond compliance. This is because regulations are designed as minimum requirements and in principle cannot cover all possibilities. Additionally, all organizations should strive in gaining knowledge (i.e., don't know what you don't know) to improve their operation and safety. Implementation of a well-designed safety culture program that includes periodic assessment and continuous improvement can address this concern.

A well-designed safety culture program should have certain key elements. In this paper the authors put forward the elements of a safety culture program that they have develop and assisted in implementation at their client sites. To achieve the goal of establishing a positive safety culture management should be cognizant of certain concepts. Although each organization has its own specific culture (i.e., habits and practices), safety culture related issues can be grouped into a limited set. These issues include but are not limited to management involvement, communication, competing goals, follow through, etc. In this paper the authors discuss these issues with specific examples from their observations when assisting clients. Safety culture programs implemented at their client site are summarized.

**Keywords:** Safety Culture, High Consequence/Low Probability Events.

## **1. Introduction**

All organizations have a safety culture, regardless if it is recognized formally or not. One of the key underlying causes of most major accidents can be traced to deficiencies within the organization's safety culture. For example, the Chemical Safety Board (CSB) has identified safety culture deficiencies in their investigations of the March 2005 BP Texas City [1] and the June 2013 Williams Geismar Olefins Plant accidents [2]. Generally speaking, it is not possible to definitively state that major accidents would not happen if there were no safety culture deficiencies. However, the likelihood of occurrence and consequences of the events could potentially be reduced if a good safety culture exists within an organization. This is emphasized by Kathleen Sutcliffe, an expert in high reliability organizations, states the following with regards to the Deepwater Horizon accident, "A strong safety culture cannot eliminate all accidents, especially in technologically complex and dynamic industries. There is always a risk that an accident will happen. Strong safety cultures can reduce the likelihood of accidents and the severity of accidents should they occur." [3]

Facilities handling highly hazardous materials, that is facilities subject to high consequence/low probability events, are generally required to comply with Process Safety Management (PSM) regulations [4]. One could argue that full compliance with PSM regulations should be sufficient to prevent the major events. Experience has shown otherwise. Regulations are designed as minimum requirements and in principle cannot cover all possibilities. Therefore, organizations, especially those that handle highly hazardous materials, should strive to go beyond compliance.

High consequence/low probability events are rare events by definition. Often, employees of organizations with operations that have the potential for high consequence/low probability events develop a low risk perception [5]. This is often attributed to the fact that event had not occurred at a site due to its rare nature. This means that the employees believe that it is almost impossible for a high consequence event to occur within their organization and they develop a sense that they are capable of stopping such events before it can result in a high consequence.

Implementation of a well-designed safety culture program can address the key issues and positively affect risk perception of employees, but improving the safety culture of an organization is not a quick or easy process. The impact of safety culture on high consequence/low probability events is addressed in this paper.

## **2. Safety Culture**

### **2.1 Definition**

The safety culture of an organization can be described as how work is typically conducted or behaviors when others are not watching. . A more formal definition for safety culture is provided by the UK Health and Safety Executive (UK HSE) as, "The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies and patterns of

behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management.” [6]

## 2.2 Influencers of Safety Culture and Good Traits

Factors that influence an organization's safety culture relevant to high consequence/low probability events are the following:

- Management commitment and style,
- Employee involvement,
- Training and competence,
- Communication,
- Compliance with procedures,
- Organizational learning,
- Equipment maintenance,
- Prioritizing risk assessments,
- Management of change,
- Ensuring proper operation of safety devices,
- Maintaining robust emergency response capabilities,
- Prevention through design and hierarchy of controls analysis process,
- Control of contractor and procurement process.

These factors coincide with those listed by the UK HSE [7] and with elements of PSM regulation. They are discussed below in the context of safety culture.

Management commitment and style is the most important influencer of an organization's safety culture. If the management of an organization is truly committed to a good safety culture and prioritizing safety, then employees typically follow the example set by management and prioritize safety. If an organization has slogans that state safety is a priority, but the actions of management demonstrate otherwise, the safety culture of that organization suffers. If employees notice that management's actions do not demonstrate a true commitment to prioritizing safety, then safety conscious employees are discouraged from speaking up about safety issues. Another effect of a lack of demonstrating a commitment to safety is that those employees who are not risk averse will continue in their ways.

Management style can also dictate the safety culture within an organization. If management outright dismiss safety issues brought up by employees without properly investigating the concern, employees are discouraged and will stop bringing up concerns as the concerns will not be addressed.

Employee participation is the most important influencer after management commitment and style. This is well recognized within the safety community and has been specifically noted in ANSI Z10-2012 [8] of the American National Standards Institute (ANSI). The standard contains the following list of barriers to employee participation:

- “Disregarding the fact that all injuries and illnesses result from exposure to hazards.

- Perception by employees that management is primarily interested in disciplining “un-safe” acts without adequately addressing hazards and root causes.
- Personnel actions, such as promotions, compensation, demotions, disciplines, and re-assignments that are administered in such a way as to reduce or undermine the commitment to safety.
- Treating worker behavior as though it is a root or underlying cause rather than identifying hazards or system-related causes.
- Administering a post-accident program, such as drug testing, in a way that discourages injury reporting
- Not implementing hazard recognition and control measures and/or ignoring the hierarchy of controls.
- Blaming employees with undue emphasis on discipline instead of implementing system changes.
- Uneven accountability – focusing on the line/hourly worker and not addressing “behavior” of supervisors, senior management and corporate leadership.
- Employee perception that production takes precedent over safety and health.”

Each bullet item above describes actions that should be avoided in order to ensure that an organization has proper employee participation in the safety management system.

Training and competence is the next important influencer. In this context, training and competence apply to both management and employees and for all aspects that can affect the safety of a system. A couple examples of training and competence include proper operation of the system and hazard identification.

If a manager that is responsible for the safety of employees is not equipped with the proper training and competence for the duty, than the safety culture of the organization will suffer as employees will follow the untrained managers’ guidance or will be forced to deviate from the managers’ guidance. If employees working within a hazardous system are not equipped with the proper training and competence for the duty, than the probability for an accident is increased as the untrained employee may not take the proper actions required to run the system safely. Additionally, employees with proper training and competence are able to identify safety issues or signals that the system is not operating properly so that proactive actions are taken to avoid an accident.

Communication is the next important influencer. If there is open communication between employees and management regarding safety issues, management is informed and able to be proactive to reduce risk. In addition, employees are not afraid to discuss safety issues with management as they are aware of the proactive nature of the organization to reduce risk. Open communication between managers from different parts of an organization is important as that promotes discussions on different approaches to solving safety issues. Also, open communication between employees within or outside of a group (i.e., group within a company) promotes cross fertilization of ideas and approaches.

The importance of communication comes across in Sidney Dekker's discussion on good management is one that has a grasp on "work as imagined versus work as actually done" [9]. If there is a large gap between management's understanding as to how work is actually performed, this indicates an inability to understand and react to risks personnel are exposed to. [9] If there is open communication between management and employees, the gap should become small. If management has a better gauge on how employees' perform work, management is better equipped to identify deficiencies in the work process and conditions and address any issues.

Compliance with procedures is the next important influencer of an organization's safety culture. Organizations should have properly written procedures for all tasks associated with a system that has the potential for severe consequences. If these procedures are not reviewed by competent personnel and updated periodically to match the work, then this is a sign of a weak safety culture. No system stays the same throughout its lifetime from its original design. Systems change and procedures must be updated to adapt to the changes in order to assist employees in avoiding accidents. If procedures are not updated to match the work as actually done, then employees will stop using the procedures and will adapt and follow their own unwritten process to complete tasks. Management may not realize that employees do not use procedures until an accident happens and the incident investigation process identifies the issue.

A sign of a good safety culture is one in which both management and employees are aware of the importance of correctly written procedures and ensure that the work as actually performed in the field is documented within procedures.

Organizational learning is the next important influencer of an organization's safety culture. How an organization reacts after an incident or near miss is an indicator of their safety culture. If an organization blames the individual (without a thorough investigation) for an incident and does not gain any knowledge or take any action to prevent a future similar incident, the organizational learning aspect of their safety culture can be considered as poor. If an organization thoroughly investigates the incident to gather all possible information and takes action to prevent a future similar incident, the organization learning aspect of their safety culture can be considered as strong.

Organizations should also consider incorporating the hierarchy of controls into their organizational learning process. If a system or task has experienced multiple incidents or near misses due to what was considered "human error", it is more than likely that the system or task needs to be redesigned to reduce the likelihood for "human error". Blaming personnel for an incident instead of reviewing whether or not the system had set personnel up for failure does not improve the safety of a system.

Additionally, organizations should seek to learn from incidents that have occurred within other organizations so that similar systemic errors are not repeated. If an organization distances themselves from another organization (within a similar field) that has experienced an incident instead of seeking similarities to learn from, the organization's learning aspect of safety culture can be considered as lacking.

Equipment maintenance or mechanical integrity is a key element of the PSM [4] regulations. Proactively replacing or conducting periodic maintenance on equipment reduces the probability that equipment will prematurely fail and release hazardous materials. Organizations with a good safety culture understand the importance of investing in equipment to prevent their premature failure. For example, the BP Texas City CSB Final Incident Investigation Report found a deficiency in the organization's mechanical integrity program.[1]

When employees continuously request for worn down equipment to be replaced or maintained to no avail, employee morale is adversely affected resulting in the opinion that management cares more about saving money than running safely.

Prioritizing risk assessments is the next important influencer of an organization's safety culture. Organizations with a good safety culture understand the importance of conducting risk assessments to identify, understand, and mitigate risk. It is not enough to merely conduct risk assessments. Organizations with good safety cultures review all unacceptable risks identified in risk assessments and take proactive actions to mitigate risk to as low as reasonably practicable. Risk assessments include reviewing the system as a whole, including equipment design, human factors related issues, etc. when estimating risk. Process Hazard Analysis (PHA), a type of risk assessment, is a PSM regulatory requirement. However, risk ranking within this analysis is subjective. Organizations influence employees participating in a PHA based on their attitude from past PHA recommendations. If management pushes back on recommendations made in past PHAs or discredits employee's opinions, employees may be demoralized and lack the motivation to participate in future PHAs as it is unlikely for management to listen to concerns. If management listens to employees and addresses all concerns brought up in a PHA, employees will be motivated to seek new issues in the system that need to be addressed.

Management of change is clearly identified in the PSM regulations. There are many events in the process industry with improper management of change as an important part of the root cause. One example is the Williams Geismar Olefins Plant accident in which changes were made without a proper change process [2]. Change is a constant in every organization. Personnel within a system always strive to improve system operation and efficiency. It is important for organizations to instill a culture in which personnel prioritize safety on the same level as improvements in operation and efficiency. Additionally, organizations with a good safety culture have a proper Management of Change (MOC) process to ensure that new or unacceptable risks are not introduced due to system changes.

Ensuring proper operation of safety devices reduces the risk of an accident. Hazardous systems have different types of safeguards inherent or added to the system as layers of protection to reduce the probability of accidents. It is important for organizations to maintain and test these safeguards routinely to ensure that they properly operate if they are needed. Additionally, it is imperative for

organizations to have procedures and processes in place to ensure that safeguards are always in service or that modifications are temporarily made to the system to ensure safety during testing and maintenance of safeguards. Organizations with a good safety culture ensure that there are systems in place to prevent bypassing or disconnecting safeguards.

Maintaining robust emergency response capabilities allows well drilled response to all events. Major accidents are possible within any facility that manages highly hazardous materials. Although these major events are rare, organizations with a good safety culture understand the importance of maintaining robust emergency response capabilities to reduce the consequences of a release if it ever occurs. This includes proper firefighting equipment, sufficient firewater for the worst-case scenario, and written emergency response procedures for plausible scenarios and well trained personnel.

Prevention through design and hierarchy of controls analysis process is recognized as an important element of a good safety culture. National Institute for Occupational Safety and Health (NIOSH) promotes the Prevention through Design concept that has been incorporated in ANSI Z10 [8] in which risk is reduced by designing out or minimizing the effects of hazards. [10] Organizations with a good safety culture understand the fact that using hindsight bias to blame an employee after an incident or near miss does not benefit the organization or employee in the long run. Implementing prevention through design concepts by adding more reliable controls to a system should reduce risk significantly.

Control of contractor and procurement process is the next important influencer of an organization's safety culture. The PSM [4] regulations and the ANSI Standard [8] all require implementation of a contractor safety program. The ANSI Standard [8] also requires a formal procurement safety program. It is important that contractors that work on hazardous systems be properly trained to perform their duties and have formal safety programs to reduce the probability of a major accident.

Regarding proper procurement, hazardous systems are designed based on strict specifications and it is important for equipment to stay within those bounds. For this reason, a formal procurement safety program must be developed and implemented to ensure that equipment being purchased from vendors meet certain specifications and expectations to ensure the integrity of hazardous systems.

### **2.3 Process Safety Regulations**

In the United States, facilities that contain certain hazardous materials above a certain quantity must comply with the Process Safety Management (PSM) [4] and Risk Management Plan (RMP) [11] regulations. Both regulations require for regulated facilities to develop and maintain a process safety management plan to reduce the risk of a major accident. The PSM and RMP regulations do not require for a safety culture assessment and improvement program to be developed and implemented.

California has updated their version of the PSM [12] and RMP [13] regulations addressing oil refineries separately that includes a Process Safety Culture Assessment (PSCA) program requirement. Both regulations require the PSCA to evaluate process safety leadership according to the following elements::

- (1) Hazard reporting program;
- (2) Response to reports of hazards;
- (3) Procedures to ensure that incentive programs do not discourage reporting of hazards, and
- (4) Procedures to ensure that process safety is prioritized during upset or emergency conditions.”

The California RMP regulation, in addition to the four elements listed above, also requires an evaluation of “Management commitment and leadership.” [13]

## **2.4 Unintended Consequences of a Safety Culture Program**

It is important for those responsible with introducing and implementing a safety culture program to ensure that the program is not misconstrued. The program cannot immediately reduce the number of incidents and near misses. It is not possible for a safety culture program to create immediate change within an organization and immediately reduce the number of incidents. Safety culture change takes time and an organization should not expect incident and near miss rates to reduce drastically in the short term. If an organization experiences a drastic reduction in incident and near miss rates, it is possible that employees are not reporting incidents and near misses to please management. A study conducted by The Center For Construction Research and Training found that there are some employees who do not report minor injuries to avoid negative consequences within their work environment. [14]

For a safety culture program to be effective, the focus should shift away from counting incidents and near misses and focus on truly creating an organization where risk is managed properly. In other words, risk is reduced due to a good safety culture. It is not possible to not report serious injuries or fatalities within an organization. However, a reduced incident and near miss count due to underreporting can lead to a false sense of security within an organization that the safety culture program has reduced risk in a short period of time. It is not possible for a safety culture program, without true safety system management improvements, to reduce risk in a short period of time. Additionally, a lack of incident and near miss reporting prevents the organization from conducting incident investigations to identify and address root causes of the events.

## **3. Risk Perception**

### **3.1 High Consequence/Low Probability Events**

Accidents such as the ones that occurred in March 2005 at BP Texas City [1] and in June 2013 at Williams Geismar Olefins Plant [2] can be considered as high consequence/low probability events. These types of events rarely occur within a plant, but have tragic consequences. Within organizations with the potential for high consequence/low probability events, accidents do not occur for long periods of time, if ever at all. This has the unfortunate result of creating a very low sense of vulnerability within employees and management [5]. Due to the low sense of vulnerability within the organization, certain issues may be allowed to progress as employees and management do not believe the issues can result in an accident. This low risk perception is one example of a deficient safety culture and can be claimed to be an indication of safety culture deficiencies being allowed to proceed unchecked.



### **3.2 Drift into Failure**

One metaphor that can explain why accidents occur is known as drift into failure. This concept is described by Sidney Dekker as follows:

*“Drifting into failure is a metaphor for the slow, incremental movement of systems operations toward (and eventually across) the boundaries of their safety envelope. Pressure of scarcity and competition typically fuel such movement and uncertain technology and incomplete knowledge about where the boundaries actually are, result in people not stopping the movement or even seeing it.”[9]*

Systems adapt and change over time. Due to resource limitations and other pressures, safety may be incrementally compromised without anyone within the system recognizing the shift. Organizations with a good safety culture have a better chance of identifying the drift into failure and taking proactive actions to prevent an accident.

## **4. Implementing a Safety Culture Program**

### **4.1 The PDCA Approach**

A common approach to implementing a safety culture program borrows from the quality program, where a plan is devised, applied, checked and updated in an ever on-going cycle. This is also known as the Plan-Do-Check-Act (PDCA) Cycle. The ANSI Z10-2012 Occupational Health and Safety Management Systems Standard [8] and the Draft ISO 45001 Occupational Health and Safety Management System Standard [15] recommend this approach. Draft ISO 45001 states the following about using the PDCA Cycle within an Occupational Health and Safety Management System [15]:

*“The PDCA model is an iterative process used by organizations to achieve continual improvement. It can be applied to a management system and to each of its individual elements, as follows:*

- *Plan: establish objectives, programmes and processes necessary to deliver results in accordance with the organization’s OH&S policy.*
- *Do: implement the processes as planned.*
- *Check: monitor and measure activities and processes with regard to the OH&S policy objectives, and report the results.*
- *Act: take actions to continually improve the OH&S performance to achieve the intended outcomes.”*

### **4.2 Planning Phase**

During the Planning Phase, a timeline must be established as to when to progress to the next step within the PDCA Cycle, objectives of the safety culture program, responsibilities must be established within the formal safety culture program, how information will be communicated with employees and managers, when and how training will be provided, how all aspects of the safety culture program will be documented, how the safety culture program will be audited, etc.

The planning process of developing a formal safety culture program requires for an organization to decide which elements or influencers it will use to guide the safety culture. Section 2.2 of this

article discusses important safety culture influencers that can be used to develop the safety culture goals of an organization. There are other sources that can be used to establish what elements or influencers the organization will use to determine where the safety culture currently stands and the safety culture goal wished to be attained as part of the formal safety culture program.

Another part of the planning process for an organization is to understand where the organization sits on the safety culture spectrum. There are different recommendations of a safety culture spectrum. The Shell Oil Company has developed a Safety Culture Ladder that has the following spectrums in order of effectiveness:

*“Pathological – Who cares as long as we’re not caught*

*Reactive – Safety is important, we do a lot every time we have an accident*

*Calculative – We have systems in place to manage all hazards*

*Proactive – Safety leadership and values drive continuous improvement*

*Generative – HSE is how we do business round here” [16]*

During the Planning Phase of developing a formal safety culture program, an organization needs to determine the criteria to use when determining the current safety culture spectrum and the safety culture spectrum hoped to be attained by adopting the safety culture program. Organizations must be wary of placing themselves within the best safety culture spectrum. If an organization truly believes that they have no safety culture deficiencies, it would be wise to request assistance from outside the organization to confirm that belief. One important note to make is that an organization should not consider ranking themselves as being higher than “Calculative” spectrum if they frequently violate their internal safety procedures and applicable safety regulations.

After an organization has determined their current safety culture spectrum, it then determines how to implement a change process to improve or increase the safety culture spectrum. Improving safety culture within an organization can be completed by using the eight steps described in John Kotter’s *Leading Change* [17]. It is important to note that the Eight Step Change Process is not a short or easy task. Sufficient resources must be allocated to complete the change process so that the organization attains the safety culture spectrum goal set during the planning phase.

### **4.3 Do Phase**

In the Do Phase of the PDCA Cycle, the implementation of the objectives and process established during the Planning Phase begin. The objectives, criteria, influencers, etc. established during the Planning Phase are communicated to all employees and managers within the organization. Additionally, Kotter’s Eight Step Change Process mentioned above is initiated in order to reach the safety culture spectrum goal established during the Planning Phase. Those placed in charge of the Do Phase must meet periodically to determine where they stand within Kotter’s Eight Step Change Process and what resources are needed and barriers encountered that need to be addressed. A method should also be established in which employees and managers can anonymously submit comments regarding issues being encountered with safety culture program implementation. The comments received by the personnel responsible for implementation of the safety culture program should be acted upon immediately or during the Check Phase if the issue is not required to be addressed immediately.

#### **4.4 Check Phase**

As part of the Check Phase of the PDCA Cycle, an audit of the formal safety culture program needs to be conducted to establish the plan has been implemented and whether the intended results are achieved. The audit should be performed by personnel that do not have direct responsibilities within the formal safety culture program and individuals who will not benefit if the audit scores the organization as having an incredible safety culture. The audit should be conducted both in the field and via surveys sent to all employees and managers within the organization. The surveys should contain questions to assess the organization's performance for each safety culture influencer identified in the organization's formal safety culture program. The surveys should be anonymous to ensure that personnel do not fear any repercussions due to their survey responses. The field audit should include observing how personnel work as part of their normal duties. Additionally, the field audit should include interviews of employees who work in the field to assess whether or not there are any safety culture deficiencies. The field audits should remain anonymous as well. The good safety culture traits described in Section 2 should be used to identify whether or not the organization is acting contrary to those traits.

#### **4.5 Act Phase**

As part of the Act Phase of the PDCA Cycle, the organization should develop recommendations to correct the safety culture deficiencies identified in the Check Phase of the PDCA Cycle. The Act Phase allows an assessment of the strides made to an organization's safety culture after implementation of a formal safety culture program.

### **5.0 Observed Safety Culture Traits**

As part of auditing organizations for compliance with the PSM and RMP process safety regulations, the authors of this paper have noticed many poor safety culture traits. A frequently observed poor safety culture trait includes hesitation to invest in safety improvements. Companies with good safety cultures understand the business case for safety and act on that belief. Additionally, OSHA describes the benefits of investing in safety programs as follows:

*“Employers that invest in workplace safety and health can expect to reduce fatalities, injuries, and illnesses. This will result in cost savings in a variety of areas, such as lowering workers' compensation costs and medical expenses, avoiding OSHA penalties, and reducing costs to train replacement employees and conduct accident investigations. In addition, employers often find that changes made to improve workplace safety and health can result in significant improvements to their organization's productivity and financial performance.” [18]*

During audits to identify safety culture deficiencies, the auditor should listen for statements demonstrating how an organization views investing in safety and how much actual investment has been made in safety compared to other organizations of similar size and risk. Safety culture auditors should ascertain how much push back employees receive from management when they recommend implementing safety measures that require investment. If management often refuses to invest in safety, employees will eventually stop communicating needed safety improvements to

management. This results in a gap between how the employees and management understand system operation.

Another frequently observed safety culture deficiency is a culture in which management blames employees for incidents and near misses instead of trying to understand the system deficiencies that led to the event. The blame is not always blatant. If incident investigation reports frequently recommend employee retraining on procedures, this is an obvious sign that the organization is not learning from events. Many times, an event that recommended retraining will recur in the future once the focus on that event has subsided and personnel resume their routine. Companies that demonstrate good safety culture traits understand that after an event, the system needs to be redesigned following prevention through design concepts to reduce the probability of future recurrence.

Another frequently observed safety culture deficiency involves contradiction in written safety slogan. Often we see a placard reading “Safety is the Number 1 Priority”. In general, companies are in business to make a profit. If a company does not make a profit, it cannot exist. Therefore, in practice safety cannot be number 1 priority. This truth is not missed by the employees. Management’s behavior often determines where safety is placed with respect to profitability and productivity.

## **Conclusion**

High consequence/low probability events generally involve highly hazardous operations. The low probability aspect of these events arises from the implementation of programs and practices based on current Process Safety Management (PSM) and Risk Management Plan (RMP) regulations and industry practices. Despite all the efforts to eliminate such events, industry has experienced a string of major events. Investigation of these events has often led the investigators to issues related to safety culture as a root cause of the environment that produced the event. Only in a few isolated cases, regulations address safety culture and in those cases not all relevant issues are brought forth.

Safety culture is a nebulous idea and there is a large variation on how it is implemented and measured. However, it is possible to break down the concept of safety culture into its elemental parts (e.g., management commitment, training and management of change). Each part requires its own method for implementation but collectively they establish the safety culture of the organization.

To measure whether a safety culture program is *good* is also difficult. Several methods and criteria have been developed and generally they are based on reviewer’s opinion. Despite these difficulties, it is possible to establish whether on safety culture is better than another if the differences are large.

Safety culture has much similarities with a good quality assurance program. The Plan/Do/Check/Act (PDCA) cycle developed for quality programs can be applied here as well. Similar to quality program, it requires management involvement and can be achieved over time with much patience and determination. The safety culture program should address all aspects or elements within an organization that affect risk (e.g., management commitment to safety,

employee participation, hazard reporting, etc.). If the safety culture program strives to identify and address deficiencies within all elements that affect risk within an organization, then risk reduction can be realized.

In summary, culture change has been studied for decades and it is concluded that improving the safety culture within an organization is not a quick or easy process. Safety culture change requires commitment from the highest levels within an organization, planning, time, and financial investment.

## References

1. “*Investigation Report – Refinery Explosion and Fire – BP – Texas City, Texas*”. U.S. Chemical Safety and Hazard Investigation Board, Report 2005-04-I-TX, March 2007.
2. “*Case Study – Reboiler Rupture and Fire – Williams Geismar Olefins Plant – Geismar, Louisiana.*” U.S. Chemical Safety and Hazard Investigation Board, Report 2013-03-I-LA, October 2016.
3. Kathleen M. Sutcliffe, October 17, 2011, for the United States District Court for the Eastern District of Louisiana, MDL No. 2179, Section: J, re. Oil Spill by the Oil Rig “Deepwater Horizon” in the Gulf of Mexico, on April 20, 2010, p 92.
4. “Process Safety Management of Highly Hazardous Chemicals”, 29 CFR 1910.119, 1992.
5. Floyd, Anna, Floyd, Landis. *The Value of Vulnerability: Helping Workers Perceive Personal Risk*. Professional Safety: Journal of the American Society of Safety Engineers. April 2014.
6. “ACSNI Human Factors Study Group: Third report - Organising for safety”, HSE Books 1993
7. <http://www.hse.gov.uk/humanfactors/topics/common4.pdf>. Accessed August 2017.
8. “*Occupational Health and Safety Management Systems*” ANSI Z10-2012, American National Standards Institute and American Industrial Hygiene Association, . Falls Church, Virginia, 2012.
9. Dekker, Sidney “*Resilience Engineering: Chronicling the Emergence of Confused Consensus*” Edited by: Hollnagel, Erik, David D. Woods, and Nancy Levenson. Chapter 7 of *Resilience Engineering: Concepts and Precepts*. Aldershot, England: Ashgate, 2006.
10. <https://www.cdc.gov/niosh/topics/ptd/default.html>. Accessed August 2017.
11. *Risk Management Programs for Chemical Accidental Release Prevention*. U.S. Environmental Protection Administration, 40 CFR Part 68.
12. *Process Safety Management for Petroleum Refineries*. California Occupational Safety and Health Administration, California Code of Regulations, Title 8, §5189.1.
13. *California Accidental Release Prevention (CalARP) Program*. California Governor’s Office of Emergency Services. Title 19 of CCR Division 2, Chapter 4.5.
14. [https://www.cpwr.com/sites/default/files/publications/MooreWorkersReasonsNotReportingInjuryKF\\_0.pdf](https://www.cpwr.com/sites/default/files/publications/MooreWorkersReasonsNotReportingInjuryKF_0.pdf). Accessed August 2017

15. International Organization for Standardization, (2016). *Draft Occupational Health and Safety Management Systems Standard*. Geneva, Switzerland.
16. Rob Holstvoogd, Shell Global Solutions Gerard van der Graaf, Robin Bryden, Volkert Zijlker, Shell Exploration and Production Patrick Hudson, Leiden University. *Hearts and Minds Programmes The Road Map To Improved HSE Culture*. Shell Global Solutions International B.V. 2006
17. Kotter, John P. *Leading Change*. Boston, MA: Harvard Business Review, 2012. Print.
18. <https://www.osha.gov/dcsp/products/topics/businesscase/benefits.html>. Accessed August 2017.