Real Process Safety Culture

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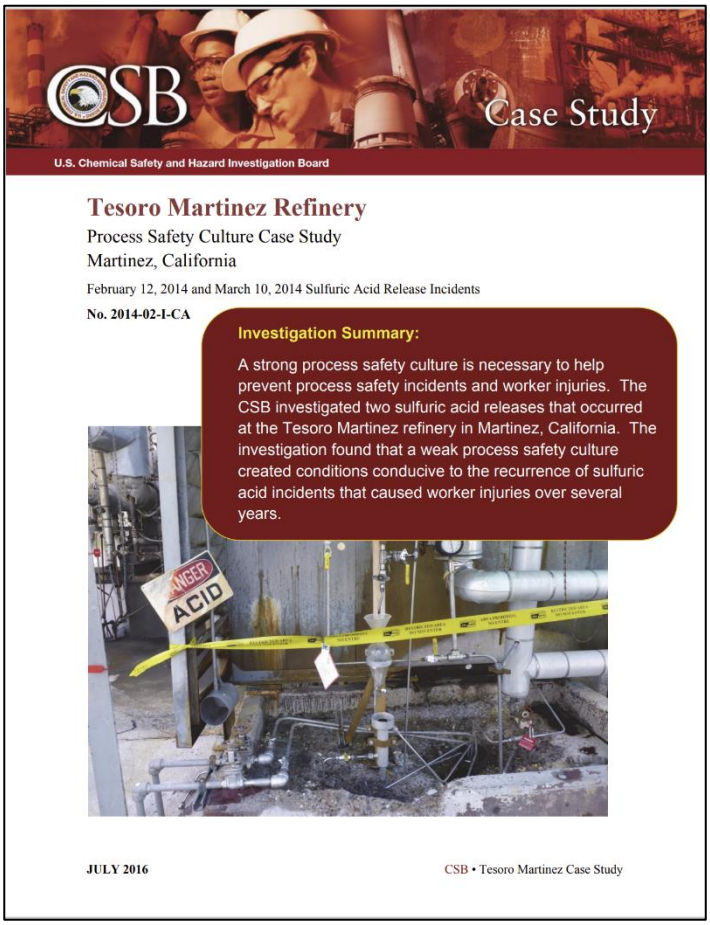
Abstract

Process Safety Culture (PSC) has received considerable attention recently. Many implementers see this as an intangible attribute of a company or site. Some workers see PSC as 'code words" for management not wanting to take responsibility for process safety management. Others see PSC as something that can be affected directly by the actions of management or by an active program targeted directly at the site culture. This paper shows what affects the true "culture" at a site and it shows that tangible, real, activities within a site are what make safety culture a reality. The paper also reviews the approaches to direct and indirect measurement of process safety culture, and the value of these.

Background

February 12 and again March 10, 2014, the Tesoro Martinez Refinery (CA) had major releases of sulfuric acid, resulting in serious injuries. CSB Case Study, 2016[1] found that a weak process safety culture created conditions conducive to the recurrence of sulfuric acid incidents that caused worker injuries over several years (including from the two incidents in 2014). These weaknesses included"

- Minimization of the seriousness of the February 12, 2014, sulfuric acid releases with chemical burns to workers
- Routine worker exposure to hazardous vapors, acids, and caustic
- Taking inherently safer acid sample systems out of service
- Reliance on inadequate temporary equipment or other workarounds
- Failure to provide necessary personal protective equipment (PPE)
- Establishment of site-specific safety policies that were less protective than corporate standards and established industry good practice
- Permit readiness program deficiencies resulting in pressure on workers to expedite work
- Ineffective communication and implementation of lessons learned from previous safety incidents



- Withdrawal from safety programs that workers believed were effective:

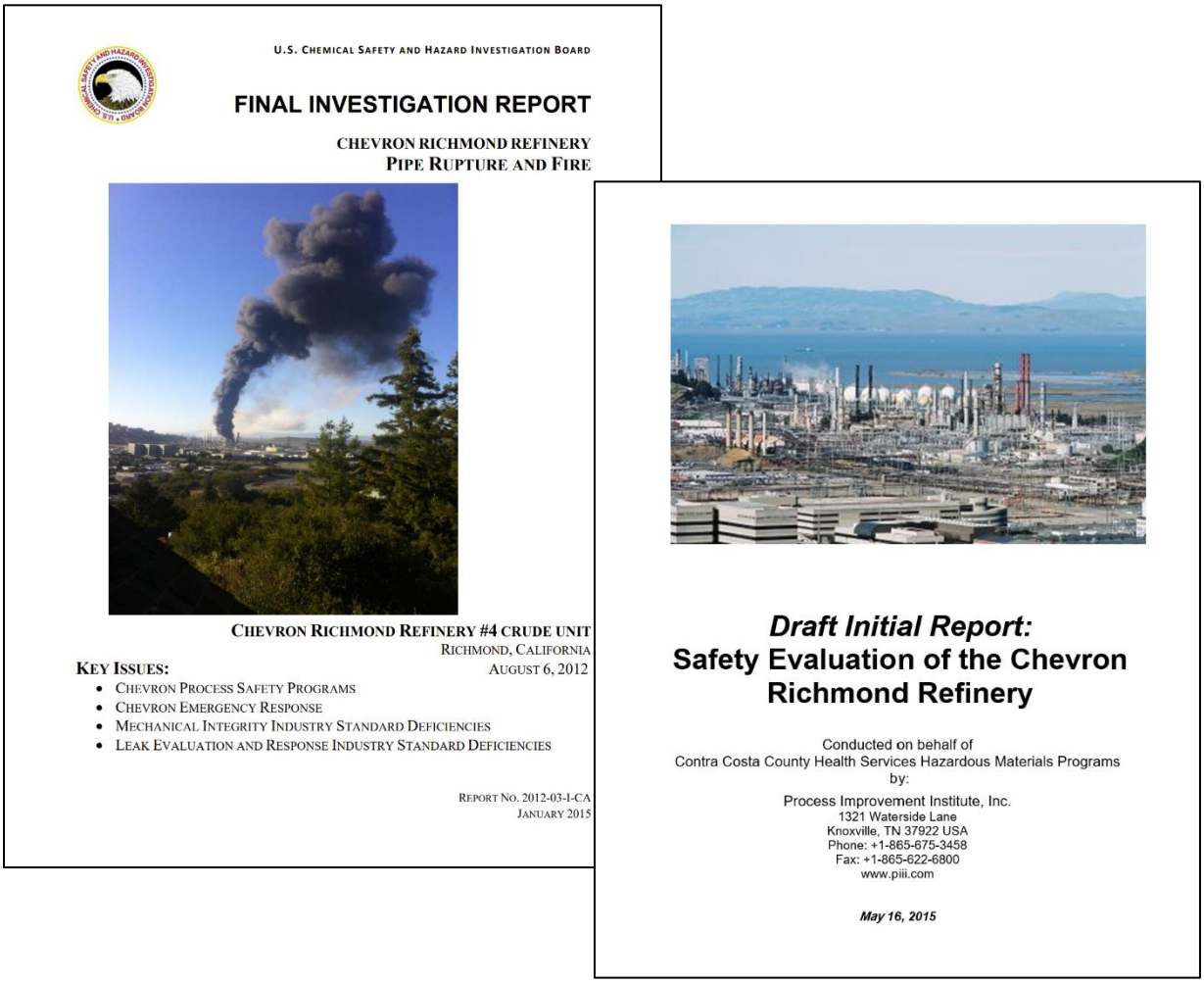
  "The Voluntary Prevention Program (VPP) was on the right track for identifying Safety issues and offering corrective actions when it was discontinued. In 2+ decades in this refinery, VPP was the only safety program that I saw making a difference in the culture"

- Staffing resource limitations due to numerous worker injuries and workforce reductions.

On August 6, 2012, the Chevron Refinery in Richmond, CA experienced a catastrophic rupture of a process line in the crude unit, resulting in large fire ball that engulfed 15 staff, injuring many of them. The Final Investigation Report (CSB, 2015)[2] lists "Process Safety Culture" as a key

issue and offers many observations about Chevron's process safety culture at the time of the accident.

In parallel, the Contra Costa County Health Services Hazardous Materials Programs department together with the City of Richmond, required that a Safety Evaluation of the Chevron Richmond Refinery be conducted to assess the Process Safety Culture at the refinery and to make any necessary improvements (see assessment report issued May 16, 2015[3])



U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

FINAL INVESTIGATION REPORT

CHEVRON RICHMOND REFINERY
PIPE RUPTURE AND FIRE

CHEVRON RICHMOND REFINERY #4 CRUDE UNIT
RICHMOND, CALIFORNIA
AUGUST 6, 2012

KEY ISSUES:
- CHEVRON PROCESS SAFETY PROGRAMS
- CHEVRON EMERGENCY RESPONSE
- MECHANICAL INTEGRITY INDUSTRY STANDARD DEFICIENCIES
- LEAK EVALUATION AND RESPONSE INDUSTRY STANDARD DEFICIENCIES

REPORT NO. 2012-03-I-CA
JANUARY 2015

Draft Initial Report:
Safety Evaluation of the Chevron Richmond Refinery

Conducted on behalf of
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May 16, 2015

The assessment report on process safety culture weaknesses listed the following key recommendations for Chevron Richmond Refinery:

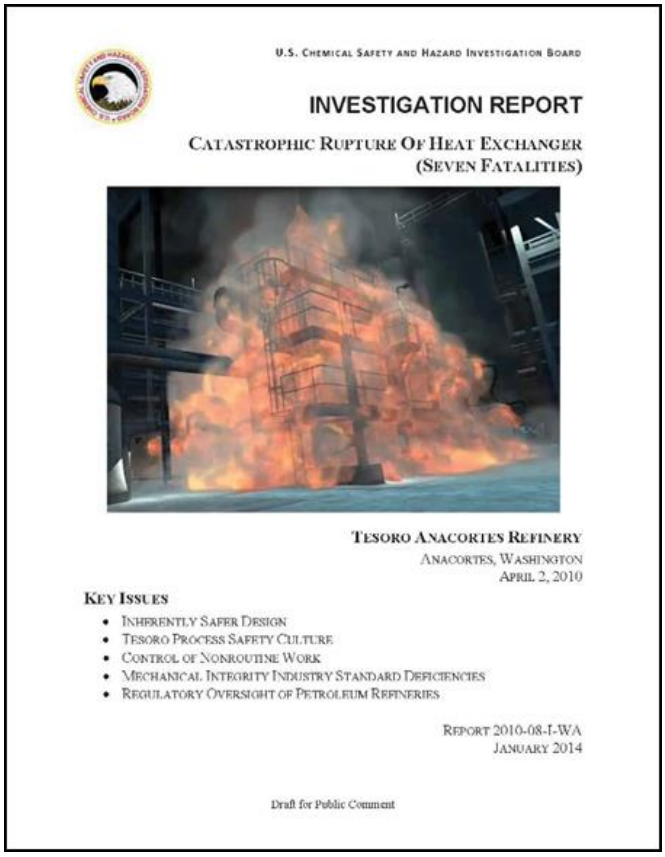
- Improve operating procedures accuracy. Less than 40% were accurate enough and clear enough to fulfill the role of written procedures in controlling human error.
- Expand the risk analyses (PHAs) for the refinery units to address hazards more fully during non-routine operations such as startup, shutdown, and online maintenance. Otherwise, the units will likely not have sufficient safeguards in place to control those hazards.

- Greatly increase the reporting & investigating of near misses to find root causes that will eventually lead to accidents. Near miss reporting is 50 times less than best in class
- Implement more effective control of human factors, especially miscommunication on radios, fatigue, labeling (and other human-machine interface issues), and procedure clarity.
- Improve the mechanical integrity programs across the refinery. Specific improvements identified include:
  - Making sure corrosion and other damage mechanisms are thoroughly identified and corrected.
  - Make sure that all components related to causes and safeguards listed in the PHAs are properly maintained and inspected, including safety-related instruments.
  - Complete the positive identification of the materials of construction in each unit, otherwise the site will not know which components are of the wrong material or grade.
- Implement a more formal program for performing drills of response to critical process alarms and retaining of the results of such drills to ensure that operators can effectively respond to process alarms within the time available for response.
- Expand the Stop Work Authority (SWA) program to include process safety incident prevention. Currently, workers are very reluctant to request a shutdown of a process unit or to delay a restart.

These will require delegating more process safety activities to workers. And this will drive improvements in the actual process safety culture (i.e., how things are done when no one is watching).

On April 2, 2010, the Tesoro Anacortes (WA) refinery experienced a catastrophic rupture of a heat exchanger, fatally injuring seven Tesoro employees working in the immediate vicinity. The Draft Investigation Report (CSB, January 2014)[4] lists "Process Safety Culture" as a key issue and offers the following observations about Tesoro's culture at the time of the accident:

- "Refinery management had normalized the occurrences of hazardous conditions,"
- "The refinery process safety culture required proof of danger rather than proof of effective safety implementation."



U.S. Chemical Safety and Hazard Investigation Board

INVESTIGATION REPORT

CATASTROPHIC RUPTURE OF HEAT EXCHANGER
(SEVEN FATALITIES)

TESORO ANACORTES REFINERY
ANACORTES, WASHINGTON
APRIL 2, 2010

KEY ISSUES
- INHERENTLY SAFER DESIGN
- TESORO PROCESS SAFETY CULTURE
- CONTROL OF NONROUTINE WORK
- MECHANICAL INTEGRITY INDUSTRY STANDARD DEFICIENCIES
- REGULATORY OVERSIGHT OF PETROLEUM REFINERIES

REPORT 2010-08-I-WA
JANUARY 2014

Draft for Public Comment

But poor process safety culture is not a new phenomenon.

On March 23, 2005, the BP Texas City (TX) refinery experienced the most serious U.S. workplace disaster of the past two decades, resulting in 15 deaths and more than 170 injuries. The Baker Panel reported that deficiencies in "BP's corporate safety culture, corporate oversight of process safety, and process safety management systems" were contributing factors to this and other incidents which had previously occurred at BP facilities. [5]

On January 28, 1986, the space shuttle Challenger exploded killing all 7 astronauts on board. The Rogers Commission reported that NASA's organizational culture failed to prevent this accident. Seventeen years later, on February 1, 2003, the space shuttle Columbia disintegrated upon re-entry of the Earth's atmosphere killing all 7 astronauts on board. The Columbia Accident Investigation Board (CAIB) reported that "In our view, the NASA organizational culture had as much to do with this accident as the foam." The CAIB also found "disturbing parallels remaining" from seventeen years earlier, making the determination that "NASA had not learned from the lessons of Challenger." [6]

Defining Process Safety Culture

Our collective history is filled with tragic accidents, life altering events, fatal injuries, and incidents affecting entire communities and industries. The origin of the root causes of many of these can be traced to flawed leadership decisions which are exhibited as poor organizational culture.

As industrial safety and accident analysis expert Andrew Hopkins states in his book *Safety, Culture and Risk*, the safety culture perspective "does not replace the system perspective, it augments it. No one is saying, 'ignore systems, all we need to do is get the culture right'; on the contrary, the right culture is necessary to make safety systems work." [7] Though this premise may seem reasonable on the surface, the authors of this current paper would restate the premise as "investing in and maintaining the right process safety systems results in the right process safety culture, which in then robust enough to survive longer term to keep process safety implementation from faltering, even in the face of management change."

Culture is defined by Merriam-Webster as "the set of shared attitudes, value, goals, and practices that characterizes an institution or organization." Process safety culture is defined by the Center for Chemical Process Safety (CCPS) as "How we do things around here." "What we expect here." And "How we behave when no one is watching." [8]

But the best definition of process safety culture from a practical, working level, and the one used by PII, is stated in the *Safety Evaluation of the Chevron Richmond Refinery, for CCHMP, in May 2015*:[3]

> **Safety Culture is not what we feel; it is what we as an organization do. The site leaders (management) create the culture by what they do and what they pay attention to. The repetition by leadership of doing the right thing and making the right decision establishes the culture at a site.** [3]

Culture exists and is influenced on many levels. Individuals within an organization have their own set of beliefs and values based on their personal biases and experiences. Leaders within an organization have their own set of individual beliefs and values as well, but they also have a broader accountability for the organization's well-being. Leaders influence others daily through their conversations, their decisions, their behaviors, and their actions.

On a Concept level, groups within an organization shape their own cultural identity through the perceptions, interactions, and behaviors of their group members. Individual values may be suspended in certain circumstances to maintain favor, status, and even membership within the group. Organizational culture may reflect the collective values of individuals and groups, the personalities of charismatic leaders, shifting priorities based on the perceived scarcity of resources or actions necessary for survival, or a long-storied history of successes, behaviors, myths, and legends.

But, on a Practical level (implementation level), the process safety culture is set fundamentally as stated earlier: **The site leaders (management) create the culture by what they do and what they pay attention to.** The repetition by leadership of doing the right thing and making the right decision establishes the culture at a site. [3]

In short, culture is a very complex Concept, and it can be very difficult to get the concept across. But, from a Practical perspective, process safety culture is a direct outcome of proper process safety leadership and accountability. Therefore, it is possible to identify, measure, analyze, and improve certain activities and characteristics that are recognized as key components of a positive process safety culture.

In studying the NASA Space Shuttle Disasters, the CCPS (March 2007) identified six core principles necessary to maintain a positive safety culture. These are:

- Maintain a Sense of Vulnerability
- Combat Normalization of Deviance
- Establish an Imperative for Safety
- Perform Valid/Timely Hazard/Risk Assessments
- Ensure Open and Frank Communications
- Learn and Advance the Culture

The six core principles are likely true, but they are too focused on the Concept level of process safety culture.

The Baker Panel[5] report organized their findings into slightly different, and more measurable, categories for evaluating process safety culture. These are:

- Process Safety Leadership
- Employee Empowerment
- Resources and Positioning of Process Safety Capabilities
- Incorporation of Process Safety into Management Decision-Making

Regardless of the model structure chosen or the descriptions assigned to different categories, rest assured that process safety culture is the result of very real, finite, and tangible activities which can be measured, monitored, and improved over time. Proactively working toward a more positive process safety culture will minimize process safety incidents, and this will save lives.

Examples of Process Safety Culture

Since process safety is difficult to comprehend from definitions and descriptions, it is helpful to provide examples that illustrate good and poor process safety culture attributes.

Process Safety Leadership

Some organizations choose to develop their leaders through broad but brief exposure to many different business situations and challenges. While this may create successful leaders conversant in a wide variety of disciplines and business models, it may not create leaders who relate to the people they lead and who are committed to long-term, sustainable process safety goals. It also may not give them time to build a core competency or appreciation for process safety. Their rapid fire, goal-oriented decisions may yield strong quarter-to-quarter results, but too often these leaders have moved on to their next challenge long before the true impact of short-term thinking has been realized.

> ***Example:*** Management decision to reduce costs (staffing, maintenance, and capital budgets). While this may increase near-term profits, what are the longer-range impacts of neglected equipment, deferred investments, and lost human talent? To paraphrase a renowned process reliability expert, there has never been a case where cutting critical talent has saved an organization; in fact, it speeds its demise. [9]

Rapid management turnover may also create a frenetic "programs of the day," characterized by slogans, banners, key chains, and revised individual goals and objectives. As revolving managers compete for boardroom attention, scarce organizational resources are redeployed on the latest management fads. An overloaded and confused workforce is left with minimal guidance and no long-term direction; given enough changes like these, workers distrust any new initiative. Both short-term thinking and frequent site management changes (every 10 months on average) were listed as safety culture deficiencies at BP Texas City in the Baker Panel report[5] and CSB investigation[10].

Effective leadership seeks to understand true root causes and permanently resolve issues with solid solutions, not temporary and ineffective "bandages". CSB concluded that at Tesoro Anacortes, management complacency had normalized the routine occurrence of hazardous conditions by using steam dilution to mitigate heat exchanger leaks rather than investigating and resolving their root cause. Leaks and other mechanical issues had become so common that additional operators were routinely assigned to assist with leak detection and leak management during startup of the unit. "This past practice contributed to the presence of the six additional workers in the unit during the April 2010 incident." [4]

> ***Example:*** *Effective management would take these lessons learned and turn them into concrete key performance indicators. In the Tesoro Anacortes example this could include measuring and monitoring Temporary Leak Repairs (TLR), those repairs that are not permanent, with an overall target of zero TLRs that are older than one month. Then, one category of TLR would be heat exchanger leaks, another clamps on lines, and another clamps on flanges. Measuring the number of uses of steam dilution for reducing the flammability of leaks would help to track effective improvements in leak prevention.*

Effective management is committed to the underlying health and well-being of the organization. Slogans and banners are replaced by high standards, shared values, and core-beliefs which sustain the organization regardless of who is in charge. Safety, quality, and efficiency become the cornerstone upon which all decisions rest. Effective management leads by asking the questions that matter about the things that matter, by recognizing, rewarding, and engaging those who uphold the right values and beliefs, and by setting the example for others to follow through their actions, and decisions.

Employee Empowerment

The term "empowerment" may be a favorite buzzword of Dilbert's pointy haired boss, but it remains a critical component of a positive safety culture despite the word's overuse. Front line employees are already heavily invested in process safety since they are the people with the highest potential for exposure and the greatest personal risk. Involving employees at all levels of the organization in process safety management ensures that it is widely understood and supported. This has the added benefit of recruiting additional resources (with intelligent minds and experienced hands) to support the often-overwhelming multitude of tasks that must be completed, such as hazard evaluations, incident investigations, procedure validation, and training. Spread the wealth, share the knowledge, release the reins (allow workers to be in charge of key activities/programs), and reap the benefits.

In a positive process safety culture, empowerment often begins with instilling the authority in EVERYONE to question decisions which are being made about process safety.

> ***Example:*** *In the CCHMP report[3], one of the most widely supported initiatives is called "Stop Work Authority" (SWA). Every employee has the right to call time-out whenever they are uncomfortable with the safety of anything that might be going on. Work is immediately stopped, a meeting of knowledgeable people is convened, the concerns are discussed, and work proceeds only when everyone agrees that appropriate measures have been taken and it is safe to move ahead. There are no repercussions to invoking SWA and in fact, favorable stories are frequently shared where the worker is cast as hero by preventing a potential incident from occurring. Unfortunately, the implementation of SWA for maintenance tasks (typically related to occupational safety impacts) has worked great while the implementation of SWA for operational issues (typically related to process safety impacts) is not as effective. Management will sometimes start, restart, or fail to stop a process even when workers are very concerned over the lack of adequate safeguards for the current situation. In the eyes of the*

employees, management's unwavering support of SWA appears to wane as the financial consequences of stopping work (i.e., halting production) increase. So, at this refinery, the SWA program illustrates that the occupational safety culture is strong while the process safety culture is weak.

Some less-effective organizations embraced a "whatever works" approach where the ends justify the means. Standard operating and maintenance procedures and stop work policies were ignored in the interest of saving time or money (short-term). Errors and failures go unreported because reporting these will get a worker or their friend in trouble. Supervisors looked the other way when shortcuts are taken, reacting only when required to do so because a poor result, an injury, or a loss event could no longer be hidden.

Example: *Operations has a chattering high-level alarm. Some individuals might disable the alarm for now, deferring action for as long as possible, hoping it will either go away or at least wait until the next shift arrives. Unfortunately, deferred action often increases the potential process risks (eliminating an independent protective layer) and results in even greater losses, since the real issue (a failed bottom's pump for example) continues undetected until it can no longer be ignored.*

In a positive process safety culture, individuals acknowledge the problem immediately, manage the risks appropriately, investigate the potential causes, and take corrective action to restore the system to a safe operating posture. **They know that timely and permanent fixes are less expensive and less hazardous than temporary measures**, and they don't need a supervisor to tell them to follow procedures and rules. They hold themselves and each other accountable because it is the right thing to do. They value the training they receive; they freely share their knowledge and experience with new colleagues, and they proactively take action to resolve any problems they encounter.

Less effective organizations are characterized by a culture of making excuses and assigning blame. An unhealthy climate exists where the first question asked is "who made the mistake" and the automatic response was "not me, I didn't see a thing." In this environment people lacked trust in each other and in their leaders. Real issues are hidden, if possible, people are afraid to show weakness by asking for help, and people are hesitant to accept positions of accountability. Workers often the first ones blamed when things inevitably went wrong.

Example: *An incident occurs which appears to be caused by a shortcut taken from the written procedures. The individual is disciplined, the entire work group is retrained in the correct procedure, and management gets to show how tough they are on enforcing adherence to procedures and on quick correction of poor safety performance. Never mind the fact that 25% of the procedure steps are inaccurate so no one uses the written procedure anymore, and/or a missing tool has been on back order for two months, and/or the supervisor himself had taken the same shortcut last month earlier when he thought no one was looking.*

In a positive process safety culture, the first questions following an incident are what and why, not who. Those are followed by asking how we can improve the procedures, task design,

practices, equipment, and other management systems to prevent this from ever happening again. All incidents (especially near misses) are reported and investigated without blame. Root causes (management system failures) are identified, and corrective measures are taken to implement sustainable and permanent solutions. Trust and collaboration are high because the ***culture*** is blame free when it comes to mistakes. People ask for help when they need it and give help without being asked.

> **Very high near miss reporting rates (such as 50 per field staff per year) is the most consistent measure of excellent Process Safety Culture.**

One of the keys is for Management to commit to a blame free ***culture*** for near misses reported and for investigation findings (except for sabotage, of course). If this is set and management sticks to it, then near miss reporting will go up and empowerment to fix problems will go up, because people are no longer ducking for cover knowing someone will be blamed for every human error. Management needs to learn and teach to all workers that Errors cannot be avoided when humans are involved and that not recognizing, and reporting errors and failures will simply increase the overall risk. If errors and failures are reported, then the root causes of the human errors can be found, and the error rates lowered, or the human errors mitigated in some way.

Resources and Positioning of Process Safety Capabilities

Almost all organizations talk about their commitment to maintain a safe workplace. Their walls are covered with banners that say *Safety First*, *Zero Incidents*, and *Think Before You Act*. One true test of organizational culture lies in the meaningful commitment of time and resources necessary to make those slogans mean something. Do they "put their money where their mouth is"?

In a strong process safety culture, accountability for process safety is assigned in a direct line that runs from the CEO through the unit managers and straight to the process operator. An unwavering commitment is made to develop and provide expertise at every level of the organization, decisions are consistently guided by their potential impact on process safety, and individual goals incorporate process safety metrics (leading indicators, not lagging indicators like number of losses and injuries) as a primary measure of performance. Promotions and rewards are unquestionably connected to demonstrated commitment to process safety.

Weaker organizations might commit resources on paper, but then **fill those roles with ineffective or incompetent people**. For example, trainers may show up on the organizational chart as a full-time position. In reality, in weak PSC organizations, trainers are often used as utility staff, handling special projects, greeting visitors, leading tours, and working on new initiatives. Training materials become obsolete, drills and training sessions get delayed, computer-based training (CBT) replace instructor-led classes in the interest of "efficiency," and over time the knowledge and preparedness of staff at all levels erodes. Stronger cultures understand the importance of training and they invest in developing and maintaining the skills of their people.

Strong organizations will measure resources and financial investment as a leading indicator of process safety culture. Examples are inspection, testing and preventive maintenance (ITPM),

budgets, capital investment, operating procedures, and emergency preparedness. A quick walk around the plant can give some measure of process safety culture. Are fences in good repair? Are tanks and lines labelled and painted? Are pipe supports clearly intact and maintained? If not, first impressions are often a good early indicator of a crumbling infrastructure and deterioration within. Of course, for a deeper measure of culture, an in-depth audit of the ITPM plans, programs, and procedures is necessary. Measure the timeliness of correcting deficiencies, adherence to ITPM schedules/procedures, and the expansion of problems detected in one area to investigate similar applications in other areas.

Incorporation of Process Safety into Management Decision-Making

Weaker organizations focus primarily on lagging indicators of safety performance, without considering how results are achieved. Loss of containment events, occupational injuries, and regulatory citations are used to measure performance and reward success. Safety prizes are handed out whenever a new milestone is achieved. Compliance with the regulations is good enough. They may be reluctant to conduct safety audits because audits find things that need to be fixed and fixing things costs money. Training is done only when required, it is done as expediently as possible and always with an eye on the costs. Programs that focus on employee behaviors are popular because they cost very little to implement, and they may be effective in the short-term in reducing some types of injuries. Unfortunately, these also inadvertently and wrongly blame error rates on "individual behaviors and attitudes" rather than management systems and controls designed to minimize human error rates. Each individual is responsible for their own behavior, right? Well in a general sense, this is true enough; but the statement is often misused to imply that perfect control of human error is a possibility and even a valid expectation. **Zero human error rates are NOT a possibility**. That is why we need multiple layers of protection against major accidents.

> ***Example****: The lowest measured limits for human error rates are in the airline industry. Pilots performing routine tasks multiple times per day with excellent control of human factors have demonstrated error rates as low as 1/200 mistakes per step (0.5% error rate). In the process industry it is generally believed that error rates as low as 1/100 (1%) are achievable with excellent control of human factors, although this error rate is not that common at chemical sites. Error rates increase with the influence of poor human factors such as high task complexity (up to 5 times), low experience and training (up to 10 times), or high fatigue (up to 20 times). Fortunately, both airplanes and process units have multiple layers of protection which limit the probability that a single human error will become a major loss event. These layers of protection must include effective control of human factors to allow humans to perform as close as possible to optimum levels.*

So, another key is:

> ***An organization with strong process safety culture understands that human errors (1) can be minimized with strong controls of each human factor and (2) that elimination of human error is not possible so features in the design (other protection layers) will be necessary to compensate for the errors that will occur.***

In a positive process safety culture, organizations understand that the "process" (the path) is inseparable from the "product" (the result); if they do the right things right, then the results will follow. They monitor leading performance indicators through periodic audits of compliance and ongoing measurement of activities – and they tie individual promotions, recognitions, and rewards to achieving these goals. They evaluate the accuracy of procedures, the completeness of permits, and the condition of the workplace. They measure completeness, timeliness, and effectiveness of training, preventative maintenance tasks, action items and repairs, and hazard evaluations. They make sure that inherently safer, long-term fixes are expedited rather than continuing to rely on temporary measures. They measure the level of employee engagement, the number of safety meetings held, the ratio of near losses to loss incidents, and the number of investigations completed. When an accident does occur, they don't panic and run for cover (neither the workers of the leaders) – they learn from their failures, and they strengthen their defenses.

Example: Process Safety Metrics - leading indicators of a positive PSC (note that of course these are also leading indicators for process safety performance)

Mechanical Integrity

- *Timely completion of ITPMs including documentation/analysis/follow-up on "as-found" data*
- *Backlog of process safety and process integrity work orders - should be low and/or decreasing*
- *Maintenance emergency repairs and break-in work versus planned maintenance - should be low and/or decreasing*
- *Temporary leak repairs - should be very low or zero*
- *PMI inspections performed - should be 100% for new components and new welds*
- *Effective "bad actors" program*

Action Item Follow-up

- *Timely completion of recommendations and action items (from all sources including PHAs, IIs, PSSRs, MOCs, Compliance Audits)*
- *Audit of closure process for completeness and effectiveness*

Management of Change

- *The time from initial request for a change and initial decision is very short and decreasing*
- *Timely completion of temporary and permanent MOCs*
- *Audit/review of maintenance and project work orders for proper use of MOC system*
- *Audit/review of DCS programming changes for proper use of MOC system*

Process Safety Competence

- *Timely completion of process safety training*
- *Evaluation of operator response during drills for each critical alarm (one drill per alarm per operator per year)*

- *Field verification and validation of operating and maintenance procedures (95% and higher accuracy of the content and 90% score on following human factors rules for clarity)*
- *Reporting ratio of near loss incidents to loss incidents - below 5 is very poor and greater than 25 is good and greater than 50 is excellent*[9]
- *Timely completion of incident investigations*
- *Analysis (trends) and follow-up on incident investigation results*
- *Contractor compliance audits*

Human Factors Control[10, 11]

- *Compliance with fatigue management guidelines (overtime hours, consecutive days worked)*
- *Observation of pre-job planning activities, shift turnovers, and radio transmissions (communications)*
- *Evaluation of Human Machine Interfaces (HMI)*
- *Staffing, vacancies, absenteeism*
- *Job experience, certifications, and training levels*
- *Effective use of "Management of Organizational Change" processes*

Practical Examples of GREAT Process Safety Culture

Kemya (Al-Jubail Petrochemical Company; SABIC affiliate, partnered 50/50 with Exxon) - example of GREAT culture from day one, with continuity; stemming from initial and continued excellent leadership.

- Operating since 1985. Petrochemical process in Jubail, Saudi Arabia, making ethylene, polyethylene
- Established strong process safety culture in first year(s) and maintained consistent management vision from the initial startup
- PSM designed around Exxon Operating Integrity Management System (OIMS)
- Invested in strong initial process safety engineering and process safety management competencies
- Invested (continual) in empowering workers to take the lead on writing procedures, helping to manage changes, investigations, near miss reporting, etc.
- New workers immediately begin building competencies in process safety.
- Workers help train each other to "fix" a procedure or task instruction rather than "oh, let's not follow that because the steps are not correct in it"
- Thorough risk review of all hazards and tasks
- They score high on process safety competencies and PS culture on interviews
- Same for occupational safety competencies (workers learn to do JSA in their first few months onsite)
- Their 29-year record in safety and especially process safety is best in class!

One key is that leadership at Kemya today sustains the same vision as was established originally; no-one has come in and slashed the programs that sustain the equipment and competencies and maintain the equipment; it is always possible that this could occur since it has at other sites, we have been to that went from great PSM to poor PSM. One safeguard against this is the collective history and collective culture instilled in all workers and staff at the site,

BP Cherry Point Refinery - example of GREAT culture with good vision for sustainability; stemming from good investment on process safety competencies for all levels at the refinery.

- Cherry Point, WA, USA
- About 800 workers onsite; produces gasoline, diesel, and other fuel products from crude oil
- Operating since 1971
- Establish strong process safety culture early (24 years ago, under Arco) and maintained consistent management vision since then
- Refinery management did not compromise on budgets for critical competencies and critical activities (such as maintenance)
- PSM designed initially around WISHA (Washington State, USA) PSM standard
- Invested for the past 12years (continual) in empowering workers to take the lead on writing procedures, helping to manage changes, investigations, near miss reporting, managing changes; provided skill training and coaching on all topics for the workers involved in these activities
- One operator from each refinery unit rotates every two years into a process safety group that manages process safety day-to-day (tracking and shepherding of MOCs, risk reviews for MOCs, investigations, procedure updates, human factors evaluations, etc.)
- Provided training to all staff at levels on process safety, human factors, tailored to each group:
  - Process engineering
  - Management/Leadership
  - Operators
  - Maintenance
- New workers immediately begin building competencies in process safety
- Workers help train each other to “fix” a procedure or task instruction rather than “oh, let’s not follow that because the steps are not correct in it”
- Thorough risk review of all hazards and tasks
- Leadership today sustains the same vision as the past 12+ years; no-one has come in and slashed the programs that sustain the equipment and competencies and maintain the equipment
- They score high on process safety competencies and PS culture on surveys (highest scores on PS Culture during the Baker Panel surveys across all of BP USA)

- Their process safety performance in the past 12+ years is best in class!

Process Safety Culture - Qualitative Assessment Methods (Pros & Cons)

Many quantitative measures of process safety performance, such as the process safety leading indicators discussed earlier, are also indicators of an organization's process safety culture. Often, these can be compared across different facilities and even across different industries to establish standards and gauge the relative effectiveness of organizations.

Many so-called experts push for what they feel is direct measurement of culture such as by "written surveys filled in my site staff." With these it is very difficult to compare results and establish qualitative standards across different work units, and further a relatively good result (like a B grade on a report card in school) may make management feel good, the reality is the actual score on accident prevention by be a failing score (an F on the school report card).

Various data collection and scoring methods for process safety culture consist of:

- Written surveys
- Focus Group Interviews
- Individual Interviews
- Process Safety Metrics

Written surveys, such as the Baker Panel Survey Instrument, are thought by many to be useful for comparing and measuring shifts in employee perceptions over time, or even for benchmarking to other companies. Written surveys have the advantage of being easy to administer and analyze, and they can be useful in measuring perceptions. However, written surveys are limited by their impersonal nature, the limited scope of the questions, and the inability to follow up with additional questions to better understand why people feel the way they do.

Example Questions from the Baker Panel Written Survey

- *I have received training on hazard identification, control, and reporting in the last 12 months.*
- *I believe a culture exists as this facility that encourages raising process safety concerns.*
- *Management puts a high priority on process safety through actions and not just empty slogans.*
- *There is usually sufficient staff in my work group to perform my job safely.*
- *In my work group, process safety concerns are secondary to achieving production goals.*
- *Written operating procedures (or checklists/job aids) are regularly followed.*
- *Interlocks, alarms, and other process safety-related devices are regularly maintained.*
- *Workers sometimes work around process safety concerns rather than report them.*
- *The process safety training that I have received allows me to recognize when a process should be shut down if safety critical interlocks, alarms or other process-safety devices fail or become unavailable during operation.*

Un-reliability of Results from PS Culture written Surveys. PII has used and reviewed the results of many such surveys and have found them to be essentially useless in accurately assessing

process safety culture or in making improvements in culture. They are popular with management who want to have a document that portrays the company as interested in improving culture, which having to do the hard work and investment in real process safety implementation that in fact will lead to lower risk while at the same time establish good process safety culture.

As a specific example, consider the Baker Panel Written Survey as applied at Chevron Richmond in 2014. The results of a section of the survey are shown in the graphics below: [3]

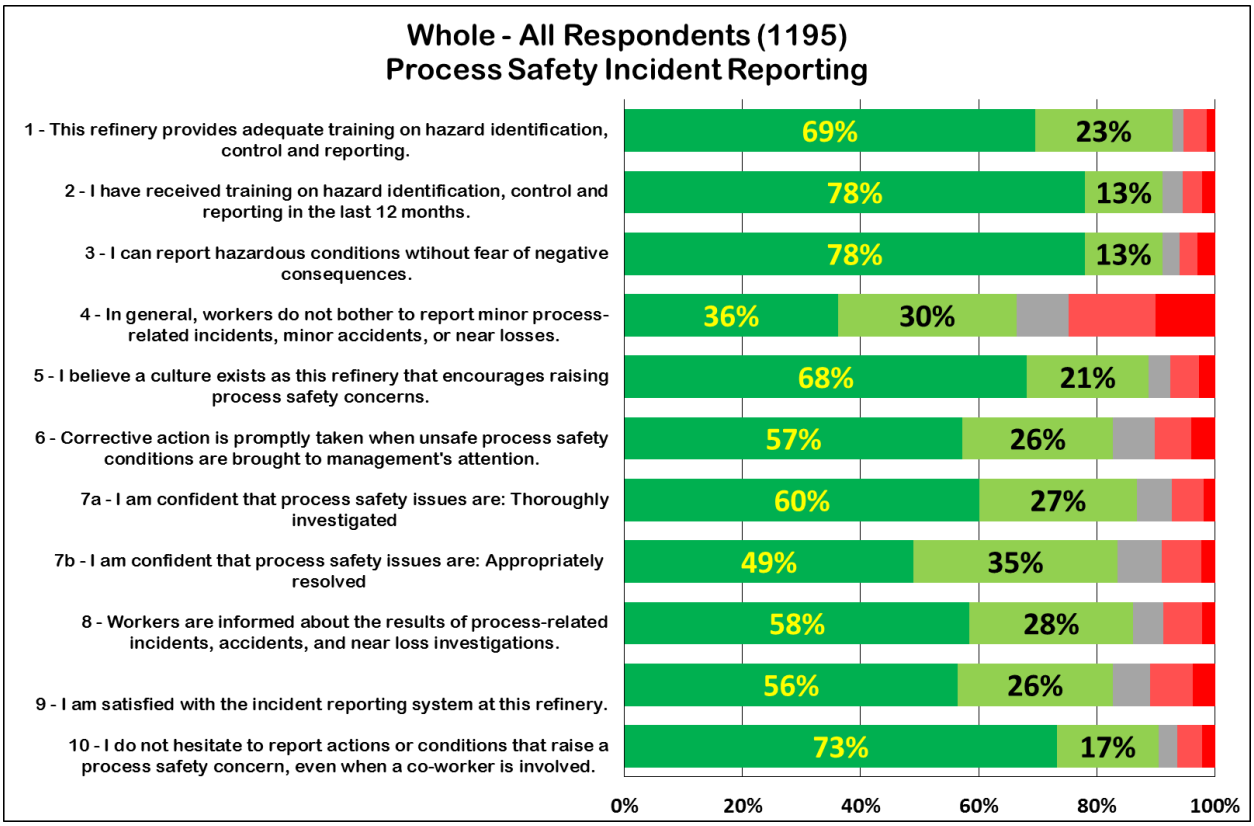


Figure 1. Process Safety Incident Reporting

NOTE: Some responses were reversed to account for negative wording of a question, so the higher the score, the better the respondent thought the refinery was doing on getting near misses reported.

In the written survey responses, Process Safety Incident Reporting was seen as the most favorable category – 86% of all responses were favorable (9% unfavorable). This result starkly contrasts with the evidence of low near miss reporting at the refinery and the safety-culture interview results (see the assessment report for details, 2015[3]).

Six of 11 questions in this category indicate that Chevron needs to improve reporting of incidents and incident investigations, which comes across in the survey results as "not a critical deficiency." By contrast, Chevron had 800 near misses on average reported each year from 2007 through 2012, whereas for a refinery this size industry minimal targets would be about 10,000 near misses and best practices would be about 50,000 near misses.[11] So, comparison of Chevron results to industry indicates that in that period, near miss reporting at Chevron Richmond was Poor, not "Good with some improvement needed."

The data analysis above reinforces what PII has seen across the industry: *Written survey results consistently provide poor measures of Process Safety Culture.*

Focus group interviews are a potentially valuable tool for obtaining qualitative clues and insights into how people feel or think about an issue or concept. The participants are selected because of a common relationship to the topic being analyzed. For example, people with similar organizational roles (supervisors, mechanics, or operators) or people within a common work group (a common process unit or department). The moderator's role is very important in guiding the discussion, asking open-ended questions, staying on task, encouraging full engagement, avoiding dominance, and seeking alternate perspectives. Participants often build on each other's ideas, bringing issues to the table which might otherwise lay dormant. But some individuals may not be as forthcoming with conflicting or sensitive information in this setting. The presence of management representatives, attorneys, union representatives or other outsiders will negatively influence the openness of the discussion and is likely to cause a bias in the results in favor of "good culture here."

Individual interviews often provide more candid and concrete examples of behaviors, actions, events, and stories that support individual perceptions and feelings. The interviewer must be able to establish rapport, assure confidentiality, ask open-ended questions, and avoid judgmental or leading responses. Enough interviews are necessary to ensure that the findings are representative of the work group being studied and to help protect the identity of individuals. A sample size of 5-10% is usually necessary to establish statistically significant results. As with Focus Groups, the presence of management representatives, attorneys, union representatives or other outsiders will negatively influence the openness of the discussion and is likely to cause a bias in the results in favor of "good culture here."

When conducting safety culture interviews, it is useful to provide the interviewer with a guide to help keep the conversation flowing on relevant topics. Following is an example of an interview guide developed by PII for use with a specific client:

EXAMPLE: Question Categories for Individual Process Safety Culture Interviews

- *Accountability (Responsibilities well defined, challenges for meeting them?)*
- *Learning (Competence, time allocated to training, too much, too little, cancellations?*
- *Corrective action program (Issues are addressed, timely appropriate?)*
- *Commitment (Management support, importance of safety, personal involvement?)*
- *Reporting and environment for raising concerns (Near misses, willingness, practices, hesitation, and retaliation?)*
- *Change Management (reorganization, organizational changes preparedness, effectiveness)*
- *Work control, work practices (empowerment, being able to stop processes, direct instructions, procedure quality)*

Process safety metrics (and especially measuring the effectiveness of process safety implementation) are by far the most valuable source of data for evaluating an organization's process safety culture. This data collection includes the process safety metrics mentioned earlier,

as are not to be confused with leading indicator/metrics. For this purpose, we mean "**assessing each activity and program for process safety implementation to see how well process safety is being implemented at the site."** Of these measures, one of the best indicators of strong process culture is the ratio of the number of near misses reported compared to the number of loss events (accidents) that occur (as mentioned earlier). If the ratio is low, say below 5, then the trust between workers and management and low, normally the empowerment of workers is low, and therefore the process safety culture will be poor. If the ratio is high (say about 50), then leadership must be doing many things correctly to achieve the high level of trust from the workers to report so many near misses, and so it is likely that process safety culture is very positive.

Process safety culture can be qualitatively measured using various methodologies such as surveys, interviews, and process safety implementation assessment. However, it is important to note that the perceptions and opinions surveys and interviews do NOT necessarily reflect the culture itself. Attempts to compare perception data across different organizations has and likely will continue to be misleading.

EXAMPLE of Process Safety Culture Measurements Required by a US *regulator CCHMP:*

*The **Contra Costa County Health Services Hazardous Materials Program** (CCHMP) is one of the elite regulatory agencies in the United States. Located in a densely populated and environmentally sensitive region on the Northeastern shores of the San Francisco Bay, CCHMP is charged with the mission of protecting "human health and the environment by promoting pollution prevention, increasing process safety knowledge and environmental awareness, responding to incidents, and implementing consistent regulatory compliance and enforcement programs."*

CCHMP oversees compliance with both the Contra Costa County Industrial Safety Ordinance (ISO) and the City of Richmond Industrial Safety Ordinance (RISO). These ordinances require regulated facilities to implement programs to prevent chemical accidents from occurring that could have a detrimental impact to the surrounding communities. These ordinances are above and beyond the requirements of California Accident Release Prevention (CalARP) program requirements (which in turn are nearly identical to US EPA RMP and US OSHA PSM regulations).

Recognizing the importance of PSC in preventing process accidents, ISO was amended in June 2006 to include the requirement that facilities conduct an initial Safety Culture Assessment, and then at least once every five years thereafter. The amendment also allows CCHMP to "perform its own Safety Culture Assessment after a Major Chemical Accident or Release or the occurrence of any incident that could reasonably have led to a Major Chemical Accident or release or based on CCHMP audit results." [11]

The Contra Costa County Guidance Document for Safety Culture Assessment (Section F, June 15, 2011)[11] *allows a great deal of latitude to facilities in selecting an assessment methodology, if the following attributes are assessed:*

- *Management Commitment and Leadership*
- *Individual Performance and Accountability*
- *Peer Perception and Accountability*
- *Safety Program Performance*

The first three components (leadership, individual, and peer-to-peer) can be measured qualitatively through interviews, surveys, and observations of the organization. The fourth component (performance) can be measured directly through leading and lagging performance metrics such as timely closure of process safety recommendations and action items, completion of scheduled inspections, tests, and preventative maintenance tasks, and the ratio of near miss (near loss) incidents to accident (loss incidents) reported and investigated.

PII Guide to excellent Process Safety Culture

Step 1. Note that the first element of RBPS is Process Safety Culture.[8] Naming the element such was to put more focus on establishing PSC. But PII feels this may have been mistake as the term culture is not tangible. It is better to rename the first element of RBPS as "PS Leadership and Accountability" as there are tangible activities that can be judged to see if company and site leadership are properly focused on process safety and are investing the capital and human resources to identify all risks and control them to acceptable risk levels.

Step 2. Invest in the staff, activities, and hard assets needed to control process safety, remembering that process safety culture is (initially) a reflection of process safety implementation. Over time, the staff will become the anchor that is grounded solidly in good process safety culture – such grounding has shown to not allow subsequent poor-minded managers to take the site to poor process safety implementation.

Good PS Implementation + Time ➔ Good PS Culture ➔ Sustainably Good PS Implementation (even in the face of poor PS leadership)

Step 3. Ensure only experts in a PS discipline make the decisions for that discipline. Don't allow management titles to have authority for technical standards and technical specifications.

Step 4. Empower and equip hourly workers to drive most of the PS activities; empower and train/coach them on tasks such as leading investigations, leading RCAs, writing trouble-shooting guides, writing operation and maintenance work instructions, managing changes, etc.

Step 5. Similarly, do Not allow management to over-ride recommendations from risk assessment or investigations / RCAs and do not allow management to change the root cause analysis results (except in rare cases and with the full review of the workers/staff first).

Step 6. Ensure the major PS gaps are avoided by assuring the following:

- PHAs cover all modes of operation, especially startup, shutdown, and online maintenance.

- Very high near miss reporting (about 50 per field staff per year)
- RCA do not place blame on individuals
- Procedures are highly accurate (95% or better)
- Addressing all human factor categories[14]

Note that the current paper builds upon an earlier paper by the authors (2014).[13.]

Acronyms Used

AIChE – American Institute of Chemical Engineers
CCHSD -- Health Services Division of Contra Costa County, California, USA
CCHMP – Contra Costa County Hazardous Materials Program, California, USA
CCPS – Center for Chemical Process Safety (of AIChE)
CSB – US Chemical Safety and Hazard Identification Board
ITPM – Inspection, Testing, and Preventive Maintenance
MOC – Management of Change
PHA – Process Hazard Analysis
PS – Process Safety
PSC – Process Safety Culture
PSI – Process Safety Information
PSM – Process Safety Management
RAGAGEP – Recognized and Generally Accepted Good Engineering Practice
RBPS – Risk-Based Process Safety
RCA – Root Cause Analysis
US EPA – United States Environmental Protection Agency
US OSHA – United States Department of Labor, Occupational Safety and Health Administation

References

1. U.S. Chemical Safety and Hazard Investigation Board, *Process Safety Case Study: Tesoro Martinez Refinery*, Martinez, CA, Report No. 2014-02-I-CA, July 2016

2. U.S. Chemical Safety and Hazard Investigation Board, *Chevron Richmond Refinery Pipe Rupture and Fire*; Final Report No. 2012-03-I-CA, January 2015.

3. Contra County Health Services Hazardous Materials Programs (CCHMP), *Draft Initial Report: Safety Evaluation of the Chevron Richmond Refinery*, May 16, 2015; authored by Process Improvement Institute, Inc. (PII).

4. U.S. Chemical Safety and Hazard Investigation Board, *Investigation Report: Catastrophic Rupture of Heat Exchange (Seven Fatalities)*, Tesoro Anacortes Refinery, Anacortes, WA, Report No. 2010-08-I-WA, Draft for Public Comment, January 29, 2014

5. Baker, James A., et.al, *The Report of the BP U.S. Refineries Independent Safety Review Panel*, January 2007.

6. *Columbia Accident Investigation Board (CAIB) Report*, NASA, August 2003.

7. Hopkins, Andrew. *Safety, Culture and Risk; The Organisational Causes of Disaster.* Sydney, New South Wales: CCH Australia Limited. 2005; p 5.

8. *Risk-Based Process Safety*, CCPS/AIChE, John Wiley & Sons, Inc.; Hoboken, NJ, 2007.

9. Moore, Ron, *What Tool? When? A Management Guide for Selecting the Right Manufacturing Improvement Tools,* Elsevier, 2007.

10. U.S. Chemical Safety and Hazard Investigation Board, *Investigation Report: Refinery Fire and Explosion, BP, Texas City, TX*, Report No. 2005-04-I-TX, March 2007.

11. Bridges, W., *Gains in Getting Near Misses Reported (Updated)*, 8th GCPS, AIChE, 2012.

12. Contra Costa County Hazardous Materials Program (CCHMP), *Contra Costa County Industrial Safety Ordinance, Section F Safety Culture Guidance*, June 15, 2011.

13. Cheung, Burch, and Bridges. "Process Safety Culture – Making This a Reality." *10th Global Congress for Process Safety Proceeding (GCPS).* American Institute of Chemical Engineers (AIChE), 2014.

14. Tew, R. and Bridges, W., *Human Factors Missing from PSM*, 6th GCPS, AIChE, 2010.