How to Ensure Sustainable Process Safety Performance – Strategies for Managing, Maintaining, and Improving PSM Systems

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The process industry has used formal management systems to pursue process safety improvements for over 20 years. Yet, data and experience reveal that few companies have fully mastered it, to achieve and sustain high levels of HSE performance improvements over long periods. Some companies/facilities have had cyclic performance, others have had reasonably good performance, but they have plateaued and have been unable to really continuously improve.

One of the possible reasons for this is that it is easier to simply implement actions to avoid a repeat of a process safety incident rather than embarking on a deeper investigation of the causes that led to the incident, really learning from these causes and embedding the learning in the process safety management system.

In other words we need a systematic approach for Process Safety **Performance** Management, i.e. a process for:

- Early recognition of PS performance degradation
- Diagnosis of the technical, management practice, behavioral and cultural causal factors that affect performance and
- Monitoring long-term slow degradation of organizational HSE performance

The methods to reach this end are relatively straight-forward but need to be employed consistently. We have assisted several oil and gas, chemical, and pharmaceutical companies to:

- Redefine their leading and lagging indicators
- Improve the quality of their incident investigations to extract the cultural root causes and to cross-correlate these with audit findings
- Ensure that the leading indicators have accident prevention value and receive Site Management review on a quarterly basis
- Monitor a real-time measure for overall safety culture

Our process safety performance problem

Many believe that process safety performance as measured by major accident rates is getting worse and not better. And many industry personnel lament the evidence that compliance-only mentalities have been the undercurrent of minimalistic efforts to continuously improve process safety performance. Certainly, many companies find that they are repeating sins of the past.

One reason for this is that current PSM auditing and root cause analysis (RCA) practices sometimes don't go far enough. PSM audits generally issue findings and areas for improvement "at the element level" even though the evidence used may point to deeper problems. Incident investigations identify PSM elements as root causes but don't address safety culture factors. Use of PSM leading indicators is just becoming broadly accepted, but their use for performance management is in the "infant stage." There are plenty of learning opportunities; we need to adjust our learning and performance improvement approaches.

Process safety performance management

To break the status quo, companies should begin focusing on managing performance of process safety; not simply compliance of process safety and to do that, we have to take advantage of all of our learning opportunities and dig deeper to find the root causes of performance problems "further down the accident pyramid." The following is a strategy for Process Safety Performance Management. Monitor the health of your PSM program. For ALL PS learning opportunities, do the following:

- Evaluate PSM failure modes
- Determine PSM failure culture causal factors
- Ensure sustainable PSM/HSE performance improvement
- Avoid organizational warning signs
- Embrace critical success factors for PSM

The following is an approach for determining and classifying the "failure modes" of a PSM system/element.

1. Determine basic PSM element work activity steps
2. Review the element written program
3. Identify life-cycle activities completed and current status

   a. Design and development
   b. Implementation and rollout
   c. Operation
   d. Monitoring and improvement
4. Develop workflow diagram of element work process
5. Review relevant incident root causes for element
6. Review relevant element metrics - leading and lagging indicators
7. Review previous two audit cycle results for element
8. Assign incident, root causes, audit findings and observations, and metrics indicator performance to:
   a. Life cycle phase during which the element performance issue occurred
   b. Workflow process point where element breakdown occurred
9. Highlight element life-cycle phase where performance issues are greatest
10. Highlight work process point where most element performance issues have occurred

Based upon this analysis, we can determine corrective and preventive actions to reduce chance of element performance failure occurring again.

- Implement/redo life-cycle phase in a more reliable fashion
- Improve element work process design
- Create better leading indicators to monitor element performance area
- Improve use of existing relevant metrics to monitor element performance
- Increase management review scrutiny on element performance area

For example, the following is a framework that has been developed to examine the detailed failure modes of MOC systems, including failures that occur during system design, rollout, implementation, and monitoring stages of life.[1,2] Similar tables of failure modes can be created for all other PSM elements.

Table 1 - MOC Program Failure Modes by Management System Life-Cycle Stage

1. MOC System Design/Development

- Inadequate workforce involvement
- Inadequate design basis - wrong change types, inadequate review/authorization protocols
- MOC use rate not considered when establishing MOC resources
- Inadequate MOC resources designated
- MOC protocol complexity inappropriate for change types, resources, or workforce culture
- MOC system roles and responsibilities inadequate
- Scope of application of MOC program inadequate

2. MOC System Rollout

- Inadequate workforce involvement
- Inadequate awareness training of workforce, including contractors
- Inadequate detailed training of MOC system participants
- Insufficient MOC system tools/forms/resources provided

3. MOC System Operation

- Failure to identify a proposed change - system circumvented
- Change classified as an emergency change when it did not meet established criteria
- Mistakenly included a RIK in the MOC review process
- Proposed change improperly classified - type or review path
- MOC origination information inadequate
- MOC initial review not completed or inadequate
- Inadequate MOC reviewers
- Wrong MOC review method used
- MOC hazard review path step missed, out of order, or incomplete
- MOC hazard evaluation inadequate - hazards missed or risks improperly evaluated
- Emergency MOC review procedure not finished
- MOC authorization inadequate - wrong, missing or risks accepted are inappropriate
- PSI not updated based upon change
- Personnel not informed of change
- Personnel not trained on change
- Wrong communication or training provided to personnel
- Temporary change left in place too long without further review
- Failure to restore system to original condition after a temporary change
- MOC review records inadequate or missing
- MOC delayed or lost in the system

4. MOC System Monitoring

- MOC metrics not properly developed or used
- Inadequate management review/oversight of MOC system
- MOC not addressed sufficiently in PSM audit

To support development of CCPS's ***Guidelines for Management of Change for Process Safety***[1], we conducted an industry survey (30+ member companies) to elicit data on the most frequent MOC problems that surfaced as incident root causes or findings in a PSM audit. The following Table 2 summarizes the conclusions of this benchmarking effort. These data show the most frequent MOC failure mode contributor do to "technical" causes. But, the process safety performance management approach described in this paper advocates correcting not only the technical root causes, but also the cultural causal factors. A case study below will illustrate this feature.

Table 2 – Top MOC Problems in the Operating Life-Cycle Phase	
MOC System Failure Mode	**% of MOC Problems Caused***
Failure to identify a proposed change - system circumvented	61 %
Temporary change left in place too long without further review or failure to restore system to original	43 %
Personnel not informed of change	35 %
MOC delayed or lost in the system	23 %
MOC hazard evaluation inadequate - hazards missed or risks improperly evaluated	18

Some performance problems contributed to more than one MOC failure mode category, so % add to >100%

Incident root causes, audit findings, and metrics deviations involving MOC failures are "decomposed" into one or more of these failure modes. Knowing which failures modes (usually more than one and during more than one life-cycle stage) is a critical input to determining effective corrective and preventive actions.

This approach can be applied to each element in a PSM program. Yet, even if we do this for every incident, audit finding and chronic PHA finding, all of this may not be enough. Unless we address behaviors/culture, the sins of the past are likely to repeat.

Evaluating process safety culture weaknesses contributing to PSM failures

The CCPS has formalized a framework for understanding, evaluating, and improving culture (Table 3) based upon an evaluation of major organizational accidents over the past 40 years (e.g., Flixborough, TMI, Piper Alpha, Bhopal, Chernobyl, Challenger/Columbia, BP Texas City and others).[3,4] This framework is embedded in the Process Safety Culture RBPS element. ***While many culture frameworks address positive, desirable organizational and individual attributes, this is the only published model that evaluates safety culture based on systematic evaluation from a "failure perspective."***

Table 3 – Essential Features of a Good Safety Culture

1. Establish safety as a core value
2. Provide strong leadership
3. Establish and enforce high standards of performance
4. Formalize the safety culture approach
5. Maintain a sense of vulnerability
6. Empower individuals to fulfill their safety responsibilities
7. Defer to expertise
8. Ensure open and effective communications
9. Establish a questioning/learning environment
10. Foster mutual trust
11. Provide timely response to safety issues and concerns
12. Provide continuous monitoring of performance

When pursuing any goal, it is often helpful to keep in mind a picture of what a better condition would look like. The same can be said for pursuing culture improvements. Using the CCPS 12 Essential Culture Features, the following is a paradigm of what a compliant and first-class, strong safety culture would resemble:

1. ***Establish safety as a core value***

People at a plant or a company possess shared values about the importance of safety. These values give rise to commitment and a pride in the way that the organization approaches safety issues. Performance tends to be good and improving. Everyone says that "you can stop production without killing the messenger", and there is evidence to demonstrate that the plant has shut down a process or not started a process in order to be certain that it is safe. If it cost them a lot of money, they still praised the individual who took the action.

2. Provide strong leadership

This feature is marked by people throughout the organization that lead by example. They do not simply talk about the importance of safety; their daily actions show that they believe it. For example, management provides sufficient resources to support safety programs. Plant manager and operations managers are frequent visitors, they ask questions, and people feel comfortable telling them what they think. Supervisors and hourly workers speak up in safety meetings and voice their concerns or praise for those that have acted in support of the company safety goals.

3. Establish/enforce high standards of performance – prevent normalization of deviance

The feature is marked by evidence that an organization holds itself accountable for the requirements and standards of care that it accepts. Documentation (procedures, records, etc.) are kept up-to-date. If you ask someone or observe work, you notice that the practices they use are always consistent with procedures. Shortcuts are not encouraged and if someone does, their peers call them out on it. Typically, the plant has excellent housekeeping. Personal safety equipment is ALWAYS used and employees (and contractors) take action if they see it is not being used.

4. Formalize the safety culture approach

For this feature, the plant/company has taken action to understand and improve its safety culture. Company web sites, policies, and communication refer to the importance of safety and the company has a plan for periodically evaluating culture. For example, they have done a culture survey or have sponsored some seminars/training on safety culture.

5. Maintain a sense of vulnerability

This feature is marked by a pervasive awareness of the hazards of the plants they operate and the activities undertaken. Everyone has an idea of the worst case scenario. People remember notable incidents at the site or in the company/industry and what was important about them to prevent recurrence.

6. Empower individuals to successfully fulfill their safety responsibilities

Company management provides the training, tools, resources, and - most importantly – the time for people to do their job safely. Everyone says that "you can stop production if you think there is a safety problem without retribution". Evidence exists that people have used company resources to improve safety. Safety training is taken seriously and is current.

7. Defer to expertise

Employee involvement in planning, preparing and executing safety activities is the norm. Workers say that their opinions matter. If a labor union is on site, its leadership is engaged with management. When important decisions are made, people always take the time to seek out evidence or experienced people to provide their input.

8. Ensure open and effective communications

There are multiple, active lines of communication frequently used – up and down the organization and across departments. Workers say that their supervisors and management frequently ask for their opinions. There are frequent, effective town hall meetings.

9. Establish a questioning/learning environment

Workers are not afraid to ask their supervisors for reasons why they make certain decisions or perform certain actions. They speak up often and are engaged in process hazard review meetings. Safety meetings where incident lessons are discussed are remembered by the workforce. Executives and senior management respond to tough questions about their decisions in a non-defensive manner.

10. Foster mutual trust

There is a strong spirit of teamwork in place at the plant. The constructive discipline process is implemented in a just manner. Workers say they trust each other and their supervision and management.

11. Provide timely response to safety issues and concerns

When you look around the work site, it is apparent that housekeeping is important. Backlogs of work requests and corrective actions are low. Safety metrics relating to inspections are "in the green". Audit findings are taken seriously and responses are completed quickly, not waiting for the last minute.

12. Provide continuous monitoring of performance

Metrics exist, are used throughout the departments and are visible to all employees. Employees are aware of the safety performance. Management reviews are frequently conducted on-site and at corporate offices to encourage good performance and refocus on areas that need improvement.

Once the technical performance and culture issues are identified, then you should “map” element performance issues to cultural features. Likewise, we compare performance to known culture weaknesses to identify which culture features appear to be contributing to element performance lapses. To ensure sustainable PSM/HSE performance Improvement, we should make technical corrections to PSM element performance and implement culture improvement activities to address culture weaknesses. Finally, we should monitor the technical and culture change and improvement to make certain that they are effective and long-lasting.

When evaluating cultural causal contributors to MOC being a root cause of an incident, the following (**RED** and underlined) are the most likely candidates from the CCPS list of culture features:

Table 4 - Top MOC Cultural Causal Factors

1. Establish process safety as a core value
2. Provide strong leadership
3. **Establish and enforce high standards of performance**
4. Formalize the process safety culture emphasis/approach
5. **Maintain a sense of vulnerability**
6. **Empower individuals to successfully fulfill their safety responsibilities**
7. Defer to expertise
8. Ensure open and effective communications
9. **Establish a questioning/learning environment**
10. Foster mutual trust
11. Provide timely response to safety issues and concerns
12. Provide continuous monitoring of performance

So, to correct problems associated with MOC being a root cause of a single or trend of incidents or audit findings, companies should address both the (1) technical failure mode of the MOC work process and (2) the cultural causal factors and human behaviors that contributed to the MOC failure modes. Other PSM elements and failure modes will have different sets of cultural causal factors associated with those potential failures.

Ensuring sustainable PSM/HSE performance improvement

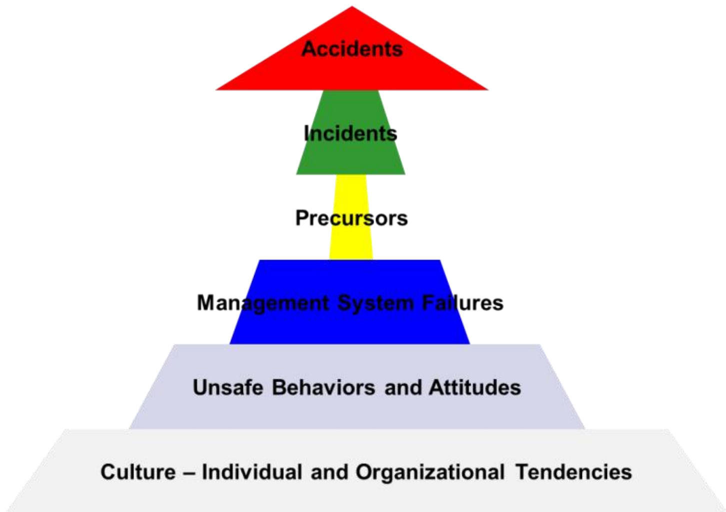
Once we have fixed our technical, management system and culture issues and back on the road of improving PSM performance, we should monitor early-warning signs for performance degradation. One important way to help ensure that a company is not heading down the wrong process safety performance road is to have a robust picture on a complete process safety performance pyramid. AVOID loss of visibility or fidelity in performance evidence sources – maintain a well-shaped and complete pyramid.

The following are some examples of warning signs.

- Organizational change/stress without sufficient HSE impact evaluation and mitigation
  - External-induced - Regulations, enforcement, economics, disasters, M&A target, etc.
  - Internal-induced - Competency, memory, resources, focus loss, initiative overload, M&A, leadership instability, demographics shift, turnover, absenteeism
- Loss of visibility/fidelity in performance evidence sources – maintain a good pyramid
- Poor reporting, trending, sharing, monitoring
- Poor culture
  - People hide things
  - Kill messengers
  - Fail to question/learn
  - Procedures not followed without consequences
  - Mixed/improper safety/production messages
  - Complacency
  - Low trust

  - Silo mentality
  - Misplaced safety ownership
  - Invisible, ineffective leadership
- PSM leading indicators
- Safe work practice non-conformance rate
- At-risk behavior/BBS observation trend
- Improper safety system bypass rate
- Operating procedure/envelope deviations

FIGURE 1 - EXAMPLE OF A FAULTY PYRAMID

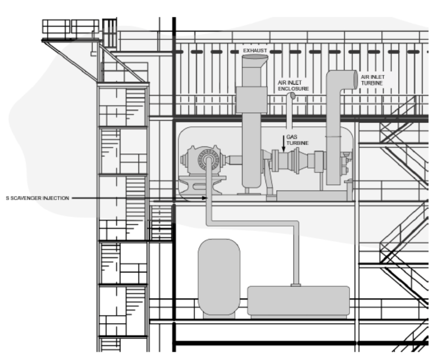


The main thesis of the **<u>Process Safety Performance Management</u>** approach is to sense, learn, and correct the problems seen at a high level in the performance pyramid by implementing corrective/preventive actions THROUGHOUT the lower levels of the pyramid – in particular at the behavioral and cultural levels. The following case studies give an example of (1) how a company did this for a specific incident and (2) how a company implemented this approach globally to achieve improvements in overall process safety performance.

Case study 1 – Offshore gas compressor module failure

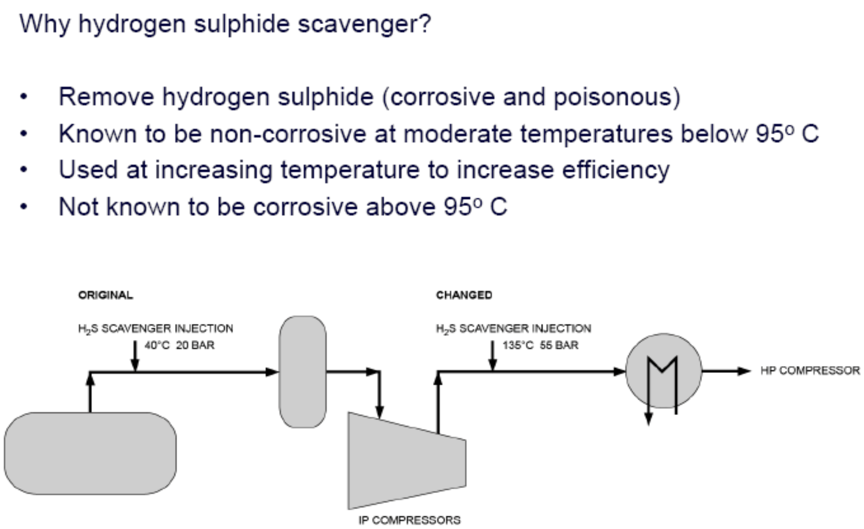
Case Study 1 involves a company that operated an offshore fixed oil/gas platform (Figure 2). On one platform, there was a compressor module within which an H_2S scavenger was injected in the compressor suction line.

FIGURE 2 – OFFSHORE GAS COMPRESSOR MODULE CROSS-SECTIONAL VIEW



A suggestion was made to reposition the injection point to the compressor discharge so this scavenger would do a more effective job. This was not identified as a change to be evaluated as part of the company's MOC program (Figure 3).

FIGURE 3 – UNRECOGNIZED CHANGE LED TO A GAS RELEASE



Within hours of the completion of the modification, the compressor discharge line experienced a loss of containment resulting in a gas release to the enclosed module and subsequent explosion (Figure 4). Fortunately, no one was injured because all the workers on that part of the platform had gone to lunch.

FIGURE 4 - GAS RELEASE RESULTED IN A "LUCKY EXPLOSION"

A subsequent incident investigation determined that MOC failure was a root cause. Our follow-on evaluation determined that the following MOC failure modes had occurred during the MOC life-cycle:

- ***Development Phase*** – failure to account for this change type in the MOC work process design
- ***Rollout Phase*** – precursors occurred during the MOC program pilot test period and rollout
- ***Operation Phase*** – personnel failed to recognize and then failed to evaluate this modification as a bona fide change

In addition, during our process safety performance assessment, we noted that the company had developed and used a number of Process Safety metrics, including some leading indicators related to MOC and this incident:

- Number of open MOCs
- MOC action item aging
- Process piping inspection aging

Our conclusion was that none of these metrics effectively addressed monitoring the technical performance aspects of MOC that contributed to the incident. In other words, the company was not effective in monitoring the health of its MOC work process.

In addition, several safety culture issues were uncovered (via interviews) that contributed to the MOC system failures:

- Lack of a sense of vulnerability
- Failure to empower individuals
- Lack of a questioning/learning environment
- Normalization of deviance

Our team's conclusions from this study were:

- MOC is a critical PSM element
- MOC performance management (audits) often don't provide sufficient improvement information
- Leading indicators supported by frequent management review are needed
- Companies should examine MOC failure modes to support continuous improvement
- MOC failure prevention should consider "life-cycle improvements
- Culture and behavior issues should be addressed for sustainable improvement

As a result of this review, the company implemented technical and cultural improvements to prevent this failure from occurring again, improving its MOC system, and increasing the chance of having sustainable improvements in future process safety performance.

Case study 2 – Global company process safety performance improvement

In 2009, ABS Group became involved with a global chemical company that was experiencing a higher rate of safety incidents rather than a continuous improvement in safety performance. This company was Arch Chemicals, Inc. (Arch), a member of the American Chemistry Council (ACC). They subsequently published a presentation at the 2011 Responsible Care (RC) conference documenting this phase of their "journey to zero", adopting the Process Safety Performance Management approach described in this paper.

The Responsible Care® program at Arch is directed towards a vision of zero – zero injuries, zero process incidents, zero distribution incidents and zero environmental incidents. Towards this end, Arch created a "Goal Is Zero" culture among its employees intended to push every individual towards a self-sustaining cycle of improvement in safety performance.

In 2008, Arch senior leadership expressed a concern that the employee injury/illness frequency rate had plateaued, and took steps to drive the frequency rate towards an ACC Best in Class level. A "Goal Is Zero Vision Statement" was created and communicated throughout the corporation. To facilitate improvement, Arch committed to implement a Responsible Care Management System (RCMS) at all Arch facilities world-wide that would encompass the Goal Is Zero vision and continual improvement. Within the RCMS model of continual improvement, Arch determined that the root cause preventing improvement in safety performance was failures in the underlying culture of Responsible Care®.

The Responsible Care® culture that Arch desired was a tendency in all employees to want to do the right thing in the right way at the right time, ALL the time – even when no one is looking. In mid-2009 Arch initiated the identification of behavioral and cultural causes of safety performance stagnation by retaining ABS Group to conduct a culture evaluation throughout the company and to visit representative Arch manufacturing, research, and office locations throughout the world to interview management and employees about their culture of safety. Incident summaries and statistics, EHS audit findings, and inspections were used to evaluate existing sources of historical safety performance. Based on the findings of the culture survey, interviews, and the evaluation of historical performance, Arch was able to identify "cultural causal factors" and rank their significance based on the results of the survey. Primary cultural causal factors were determined to be the lack of discriminating leading indicators based on quality rather than quantity of data, a normalization of deviance, and the perceived lack of management responsiveness to safety concerns.

Based upon the identification of significant causal factors, Arch developed objectives to improve workforce at-risk behaviors and safety culture issues. Leading key performance indicators were established to evaluate the "health" of facility safety programs. Rather than require facilities to report a specific number of safety observations, each facility was given the task of developing their own goals, objectives, improvement plans, and reporting on the quality of their own program. Facilities were required to establish and report on the quality of safety near miss programs and the quality of observation and contact programs.

Facility key performance indicator improvement plans were required to be included in the facility RCMS goals and objectives. The status and effectiveness of the KPI improvement plans and progress against the RCMS goals and objectives are tracked monthly. The culture survey was repeated in December 2010, and adjustments to the program were made as a part of the 2011 Corporate RCMS goals, objectives, and targets. All facilities were encouraged to review progress against their own programs and include KPI improvement plans in their RCMS goals, objectives, and targets.

When Arch began in 1999, its global employee recordable injury frequency rate was over 4.0 and in the fourth quartile for an ACC mid-sized company. Through Arch's Goal is Zero initiative, other process improvements and this culture evaluation, the rate was reduced to near the ACC average. Since the renewal of the Goal is Zero initiative and the emphasis on the underlying safety culture which were linked to RCMS continual improvement initiatives, Arch Chemicals, Inc. employee injury/illness frequency rate has moved to the ACC first quartile (0.42), with every expectation of improving to an ACC Best in Class position. As of February 2011, Arch has achieved 33 months without a process safety incident, and 21 months without an environmental incident.

FIGURE 5 - ARCH RESPONSIBLE CARE® EMPLOYEE RECORDABLES FREQUENCY RATE – 2/2011

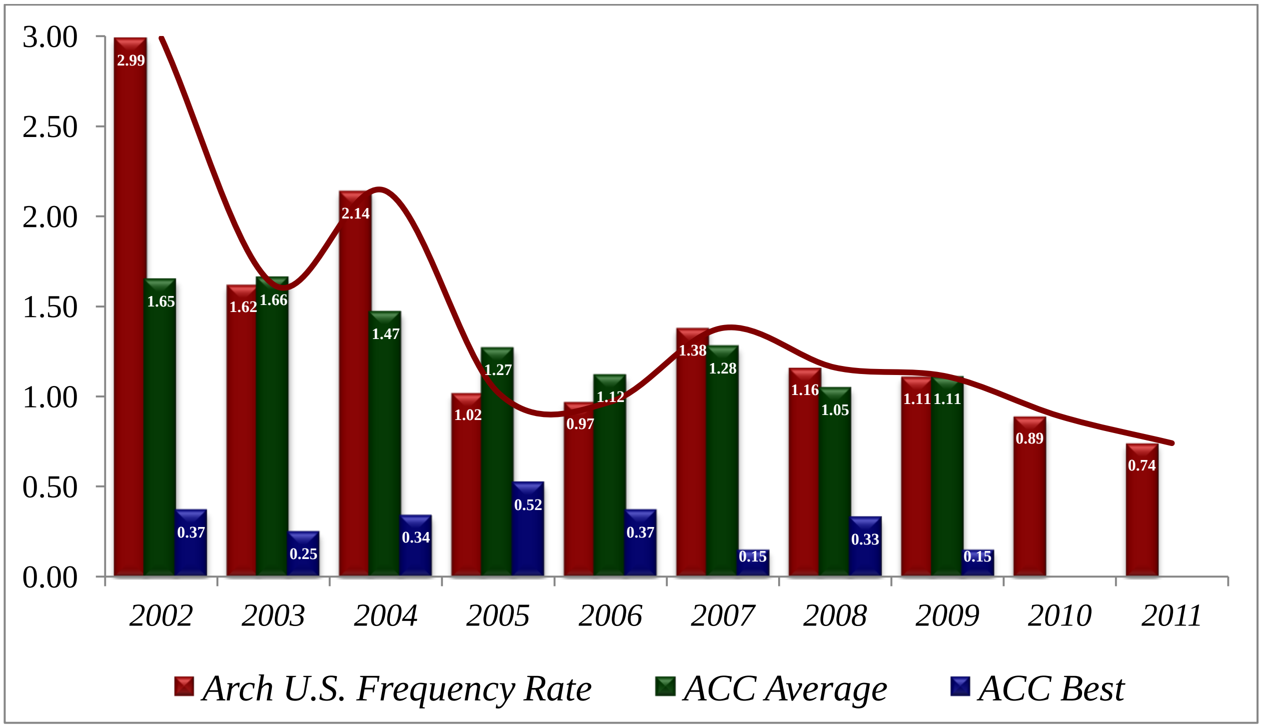


Table 5 summarizes the results of this case study.

Table 5 – Summary of ARCH Safety Culture Improvement Results

- 2 billion sales, 3000+ employees, 40+ facilities, global company
- Responsible Care, "Goal is Zero", some leading metrics, quarterly CEO/staff management review
- 4th-quartile employee safety rate had recently stagnated/spiked due to "untrendy causes"
- ABSG performed a global safety performance assurance review/culture evaluation
- Company implemented a corporate, plant, work group, and personnel culture strengthening program over a year
- Began monitoring safety culture monthly using event root cause/ cultural cause mapping to adjust/focus culture strengthening
- Resumed their drive to zero for personnel/process safety metrics
  - multiple years without process safety or environmental incidents
  - zero contractor injuries
  - 50% reduction in combined injury rate

The **Process Safety Performance Management** approach described in this paper, addressing both technical and cultural causal factors and improvement actions and on-going monitoring, led to a significant and sustained improvement in performance for Arch Chemicals.

Conclusions

Companies that want to improve in process safety must do effective root cause analysis and corrective/preventive actions for incidents and related process safety performance situations. In order to pursue continuous improvement in process safety, that is not enough – a company must develop, use, and act upon effective leading indicators. To have sustainable, continuous improvement, there is no alternative to reducing/eliminating at-risk human behaviors and improve safety culture. Table 6 lists some aspects of "good" process safety companies.

Table 6 - Characteristics of Good Process Safety Companies

- Not blind or arrogant – willing to look into the mirror
- Safe questioning/learning environment
- Proper safety ownership and leadership
- Effective, fit-for-purpose management systems
- Disciplined in execution - low/decreasing backlogs
- Effective action - prevention, not just correction
- Action at multiple levels of the pyramid
- Builds better ownership and fosters a better culture
- Learns lessons cheaply taught from all sources - avoids repeat teaching
- Pursues effective continuous improvement – seeks out better practices
- High quality incident investigations
- Proper process safety metrics and discerning audits
- Effective management review

For companies that want to be better than "good" – to pursue zero – they've got to change the ways they are doing some things that served them to get to where they are at today, but may not be good enough to move toward zero. A Process safety equivalent to "drive to zero" should address the goals in Table 7.

Table 7 - A Vision for "Perfect Process Safety"

- A culture based on proper ownership of HSE
- Risk-informed sensitivity that guides everything
- Effective, fit-for-purpose management systems
- PS practices embraced and followed with good operational discipline at ALL levels
- Learning from ALL sources – internal, external and outside industry group
- Well-formed/visible performance pyramid; metrics at every level to drive behaviors
- Goals and actual performance that improves

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