A Call to Action: Understanding the Key Driver for Continual Process Safety Performance Improvement

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Abstract

A well-established design concept for management systems is the continual improvement life cycle involving the steps: Plan-Do-Check-Act (PDCA). Similar to standards for managing quality, environment, occupational health and safety, and security, design models for effective process safety management (PSM) systems also utilize the PDCA cycle.

The activities within each element of an integrated PSM system include the identification of deficiencies and closure of these gaps in order to improve overall system performance in reducing and/or controlling process safety risks. Root cause analysis is a valuable learning tool for sustained improvement. Without gaining a deep understanding of the cause(s) for why a deficiency exists or why an incident occurred, there can be no meaningful corrective or preventive action for improvement. Instead, only a correction as a short-term "quick fix" is possible, which results in a higher likelihood (and hence risk) that the same or similar deficiency (or incident) will be repeated. As a result, some improvement opportunities can be missed and many others only offer partial (or at best temporary) solutions to identified deficiencies within the PSM system itself or in the engineered process system to which PSM is being applied to reduce and/or control risks.

Yet successfully executing the "Plan", "Do", and "Check" steps for the identification and analysis of the causes of deficiencies, but failing during the "Act" step to properly implement and close out action items (from e.g., process hazard analyses, equipment inspections and tests, incident investigations, compliance audits, etc.) on time or, even worse, failure to close them at all, defeats the whole purpose. Besides lost opportunities for risk reduction, open actions can result in legal "smoking guns", as well-intended but unfulfilled actions that could be viewed as willful inactions.

1. Introduction

A well-established design concept for management systems is the continual improvement life cycle involving the steps: Plan-Do-Check-Act (PDCA). Similar to standards for managing quality, environment, occupational health and safety, and security [2,9,11,12], design models for effective process safety management (PSM) systems also utilize the PDCA cycle [13,14].

At a higher level, the PSM system elements address all four of the PDCA steps:

- **Plan** – Process Safety Information, Process Hazard Analysis (PHA), Operating Procedures, Operator Training, and Contractors address planning activities.
- **Do –** Employee Participation, Management of Change, and Emergency Planning/Response address operational activities.
- **Check –** Pre-Startup Safety Review, Mechanical Integrity, Incident Investigation, and Compliance Audits address verification activities.
- **Act –** Most of the PSM elements address activities or systems for managing actions.

In a well-design PSM system, each PSM element represents an individual management process which is aimed at contributing to an integrated, comprehensive, and risk-based approach for controlling risks and improving process safety performance. At a lower level, the PDCA life cycle model for each of these management processes assures a robust treatment of the process resources and activities required to achieve effective results for continual improvement.

Any deficiencies within the design or the implementation of these management processes will have a cumulative degrading effect on the results. For example, if one does not even plan to manage at the “Plan” step, there is no hope of ever reaching the actions needed for improvement. Similarly, planned activities that are poorly executed at the “Do” step will not achieve the desired results. Further, without proper monitoring and measuring at the “Check” step to verify whether results have actually been achieved, the likelihood of identifying system deficiencies is reduced. And finally, failure to effectively act on the findings or recommended actions in the “Act” step results in missed opportunities for continual improvement.

Yet successfully executing the “Plan”, “Do”, and “Check” steps for the identification and analysis of the causes of deficiencies, but failing during the “Act” step to properly implement and close out action items (from e.g., process hazard analyses, equipment inspections and tests, incident investigations, compliance audits, etc.) on time or, even worse, failure to close them at all, defeats the whole purpose. Besides lost opportunities for risk reduction, open actions can result in legal “smoking guns”, as well-intended, but unfulfilled actions that could be viewed as willful inactions.

Thus, managing process safety performance for continual risk reduction and/or risk control requires robust management processes that are effectively managed throughout the PDCA life cycle of key entities. These entities include critical inputs, resources, activities, and outputs for the overall PSM system, as well as the engineered process system for which the risks are being managed. For example, processes for managing leadership and employee participation are key inputs aimed at engaging and involving the entire workforce. Managing personnel and contractor competence, information quality, and asset integrity are all aimed at providing quality human, informational, and physical resources, respectively, which are needed to design, construct, operate, and maintain the engineered process system. Processes for managing the hazards and risks before an incident, managing emergencies during an incident, and managing lessons learned after an incident, are the three critically opportune times for reducing and/or controlling process safety risks. Finally, processes for managing plans (policies, programs, procedures), managing changes (organizational, procedural, technical), managing performance (conformance, compliance, results) and managing actions (corrections, corrective actions, preventive actions), are each aimed at the critical outputs of the risk-based process safety management system processes for Plan, Do, Check, and Act.

This paper stresses the integration of the "Check" and "Act" steps for several of the PSM elements and their management processes. Specifically, verification results of the "Check" steps for each of the management processes includes, for example, employee survey results, equipment tests and inspections, PHA findings, emergency response drill evaluation findings, incident investigation findings, audit findings, etc. Root cause analysis is a valuable learning tool for sustained improvement. Without gaining a deep understanding of the cause(s) for why a deficiency exists or why an incident occurred, there can be no meaningful corrective or preventive action for improvement. Instead, only a correction as a short-term "quick fix" is possible, which results in a higher likelihood (hence risk) that the same or similar deficiency (or incident) will be repeated.

Further, the action results of the "Act" step include the resolution and treatment of the recommended actions to correct deficiencies, address the findings, or improve other processes that could impact process safety performance. In order to achieve effective and lasting results from the action system, it is crucial to understand the differences between: (1) correction to eliminate deficiencies; (2) corrective action to eliminate the cause of an identified deficiency in order to prevent recurrence; and (3) preventive action to eliminate the cause of potential deficiencies in order to prevent future occurrences.

Ten real-life examples will be presented to demonstrate several elements of a PSM system where improperly managed deficiencies and actions have led to actual process safety incidents. Further, these examples will show how human factors are most often the prevalent root cause(s). That is, human errors or decisions causing deficiencies associated with designing and/or implementing either the management system or the engineered process system, if not properly identified and eliminated, represent a potential multi-fold increase in the risk of process safety incidents. This paper will draw upon the authors' extensive experience in conducting PSM system audits, incident investigations, and process hazard analyses, as well as expertise in designing robust systems for managing process safety, including corrective and preventive actions.

2. Repeat Performance – The Need for Action

Changes, both planned (e.g., design changes, operational improvements) and unplanned (e.g., equipment deficiencies, human error) create a continual challenge to the management of process safety risks. If not properly managed, these changes can lead to deficiencies within the PSM system as well as the engineered process system. Identifying system deficiencies, including the causes of process safety incidents, is the first step in treating them. If not properly managed through actions, these deficiencies can repeat themselves or manifest as a systemic problem for similar situations.

2.1 System Deficiencies – The Opportunity for Improvement

Existing deficiencies with any system, whether a management system or the engineered process system, create process safety risks associated with ineffective risk controls required to prevent or mitigate process hazards. Each management process that employs a PDCA model presents opportunities to identify system deficiencies in the "Check" step, while certain processes (e.g., Process Hazard Analysis, Incident Investigation, and Compliance Audits) are actually intended as verification processes and therefore generate findings of deficiencies. Example deficiencies derived from verification activities for typical PSM system elements are shown in Table 1.

Table 1: Example PSM Deficiencies

PSM Element	Verification Activities	Example Deficiencies
Employee Participation	Culture survey	Inadequate communications
Process Safety Information	Design reviews P&ID walk-downs	Inaccurate piping & instrument diagrams (P&IDs), missing data
Process Hazard Analysis	Evaluation of process hazards and safeguards	Inadequate safeguards, incomplete design basis, design deficiencies
Operating Procedures	Periodic review for currency and accuracy	Outdated operating procedures
Operator Training	Testing / re-testing, on-the-job evaluation	Inadequately trained operators
Contractors	Pre-job and periodic evaluation of performance	Unqualified contractors or contractors not performing to expectations
Pre-startup Safety Review (PSSR)	Safety review of design, operating procedures, training, etc.	Construction and equipment not in accordance with design specifications
Mechanical Integrity	Equipment tests and inspections	Equipment deficiencies outside of acceptable limits
Management of Change	Technical review for proposed change	Impact of change on safety and health not assessed or not acceptable
Incident Investigation	Causal factor analysis and root cause analysis	Various management system deficiencies as findings
Emergency Planning / Response	Post-drill or post-incident response evaluation	Inadequate planning, lack of resources, inadequate emergency equipment
Compliance Audits	Interviews, records reviews, physical inspections/observations	Various management system deficiencies as findings

Note: **Bolded** PSM elements above require an action system per the OSHA PSM Standard [17].

Effective PSM systems that rigorously identify system deficiencies present opportunities for reducing and/or controlling risks at three stages of the incident life cycle [13,14]:

- ***Before* an incident** – Prevention through design and operational discipline in order to identify, avoid, eliminate, or minimize risks to prevent occurrence (e.g., Process Hazard Analysis, Compliance Audits, and most other PSM elements);
- ***During* an incident** – Emergency response in order to prepare for and respond to an incident in order to mitigate consequences during occurrences (e.g. Emergency Planning and Response); and
- ***After* an incident –** Incident investigation with root cause analysis and lessons learned in order to prevent recurrence (e.g., Incident Investigation).

However, missed opportunities for actions to improve risk reduction and/or risk control can occur at each step of the PDCA improvement life cycle for any of the management system processes:

- **Plan** – No plan or other mechanism to identify deficiencies; i.e., you didn't look for possible problems or opportunities for improvement.
- **Do –** Deficiencies not adequately identified; i.e., you didn't find existing problems.
- **Check** – Identified deficiency not adequately analyzed; i.e., you didn't determine root causes and settled for only corrections, instead of corrective and/or preventive actions.
- **Act –** Actions not adequately developed; i.e., you didn't develop proper solutions (poorly worded, wrong solutions) or any at all (ruled out based on risk, time, cost, etc.).

2.2 Correction, Corrective & Preventive Action – The Drivers for Improvement

Effectively integrating identified deficiencies with actions in a formal system allows us to gain the most out of managing the opportunities for improvement. For each of the management processes for the PSM system elements, the aim is to take the appropriate actions on a continual basis to improve the quality of the PSM system and its effectiveness in reducing and/or controlling process safety risks. The design intents of each PSM system element support the overall performance improvement objective of the PSM system, as shown in Table 2.

Table 2: Example PSM Action Objectives

PSM Element	Performance Objectives to Reduce/Control Risks
Employee Participation	To improve participation and ownership
Process Safety Information	To improve information quality
Process Hazard Analysis	To improve the process design & safeguard effectiveness
Operating Procedures	To improve operational control
Operator and Maintenance Training	To improve competence and performance
Contractors	To improve qualifications and performance
Safe Work Practices (Hot Work Permit)	To improve control of work
Pre-startup Safety Review	To improve the adequacy of PSM elements before startup
Mechanical Integrity	To improve the asset integrity
Management of Change	To improve the control of changes
Incident Investigation	To improve the system and prevent incident recurrence
Emergency Planning & Response	To improve response capability and mitigate consequences
Compliance Audits	To improve the effectiveness of the PSM system

In the context of management, actions are things we as humans do with intent. We often use the term "action plan" to define what and how we will carry out an action. For people to effectively carry out actions, management needs to define who (person responsible), what (the task), when (the schedule), where (the application), why (the intent or objective), and how (the method).

Types of Actions with Examples

Both industry and regulators use terms for "actions" that appear to be synonymous. To many, the terms *recommendation*, *resolution*, *action*, *correction*, *corrective action*, and *preventive action* all refer to the same thing: to fix a deficiency or address a finding or nonconformity. In fact, there are significant differences in these terms and their understanding can offer a better path toward performance improvement.

First, *recommendation* typically refers to a recommended action to address a finding, or deficiency.

Next, a common misunderstanding is with the term *resolution* (of recommendations from PHAs, incident investigations, etc.) as used by the OSHA PSM Standard. Resolution does not mean to close the action, but instead refers to a decision by management to either adopt the recommendations or to decline to do so. Since the promulgation of the PSM Standard in the early 1990s, OSHA has clarified their intent within their Compliance Directive for PSM, as follows:

> "OSHA considers an employer to have 'resolved' the team's findings and recommendations when the employer either has adopted the recommendations, or has justifiably declined to do so. Where a recommendation is rejected, the employer must communicate this to the team, and expeditiously resolve any subsequent recommendations of the team. An employer can justifiably decline to adopt a recommendation where the employer can document, in writing and based upon adequate evidence, that one or more of the following conditions is true:
>
> 1. The analysis upon which the recommendation is based contains material factual errors;
> 2. The recommendation is not necessary to protect the health and safety of the employer's own employees, or the employees of contractors;
> 3. An alternative measure would provide a sufficient level of protection; or
> 4. The recommendation is infeasible." [18]

Such a clarification, originally provided as direction to OSHA Inspectors, also provides industry with a better understanding of the steps to resolve, then take, appropriate action.

Finally, there are three different types of *action* intended to address an identified deficiency, each with a specific purpose. As a minimum action, we generally make a *correction* to eliminate an identified deficiency. However, *corrective and preventive actions,* both of which address the root causes of deficiencies, offer longer-lasting and farther-reaching solutions, respectively. These three types of actions are commonly used in international standards for quality, environment, occupational health and safety, and security management systems [2,9,11,12].

For consistency, the following definitions based on quality management terms from ISO 9000:2015 are used throughout this paper [19]:

- **Nonconformity –** Non-fulfilment of a requirement. Note, the term "deficiency" is a type of nonconformity.
- **Correction –** Action to eliminate a detected nonconformity (or deficiency).
- **Corrective action –** Action to eliminate the cause of a nonconformity (or deficiency) in order to prevent recurrence.
- **Preventive action –** Action to eliminate the cause of a potential nonconformity (or deficiency) or other undesirable potential situation in order to prevent occurrence.

The important distinction here is that a correction only addresses eliminating the immediate deficiency, whereas a corrective action goes further to eliminate the cause(s) of that deficiency in order to prevent recurrence. Even more importantly, a preventive action extends the corrective action to other potential deficiencies, perhaps in other management system elements, other equipment or process units, or even other facilities.

The risk reduction opportunity of actions is increased dramatically by extending a correction to a corrective action, and adding preventive actions, to address the elimination of causes of deficiencies. Thus, lessons learned from eliminating causes can reap a larger return on investment. To illustrate this concept with a simple example, consider the possible actions and improvement opportunities for the following hazard scenario:

During a walkthrough inspection of a manufacturing plant, lubrication oil was observed on the floor next to operating machinery.

Possible actions to treat this hazardous condition are postulated in Table 3:

Table 3: Actions to Treat an Oil Spill

Action Type	Possible Action	Benefit
Correction	Eliminate the detected deficiency by cleaning up the oil spilled on the floor.	Prevents someone from slipping on the spilt oil (in the short term).
Corrective Action	Eliminate the cause of the detected deficiency by replacing a defective hose to prevent recurrence of a spill.	Prevents someone from slipping on the spilt oil (in the long term) and reduces repeated cleanup efforts.
Preventive Action	Eliminate the cause of a potential deficiency by replacing similarly defective hoses on other machinery at this and other plants to prevent occurrence before they leak.	Prevents several people from possibly slipping on spilt oil at several locations and eliminates future cleanup efforts.

The important implication here is that many process safety incidents occur as a result of ignoring corrections or not properly implementing the corrections. Further, other incidents have occurred despite correcting the deficiencies, by not analyzing and eliminating the causes of the deficiencies that could have prevented their recurrence. Of even more significance, some incidents could have had a more profound effect on the prevention of similar incidents within the industry had published recommendations been more effectively shared and more rigorously applied as preventive actions.

The “Check” steps for PSM system elements should aim to identify the system deficiencies and to analyze their causes so that the appropriate actions can be developed and taken to correct the deficiencies and eliminate their causes. Thus, actions should be aimed at answering both “what exists/happened” and “why it exists/happened”.

Causes can be analyzed through a simple or formal root cause analysis process, depending on the complexity of the deficiency. Causal factor analysis and root cause analysis are quite common in incident investigations to determine the causes of process safety incidents [4,7]. Similarly, failure analysis and trending is often used for engineered process systems to determine the root causes of process equipment deficiencies to assure mechanical integrity [5,7].

While inspections, tests, and other verification methods may be used to identify engineered process system deficiencies, auditing techniques are aimed at identifying the systemic causes of management system deficiencies, such as a weak safety culture and other organizational and human factors [3]. But without the proper analysis of the causes of such deficiencies, the actions which are generated tend to address only corrections and not corrective and preventive actions.

To further illustrate the points discussed above, three example process safety incidents with tragic outcomes from published investigations are summarized in Table 4 for the cases of (1) no corrections, (2) no corrective actions, and (3) no preventive actions, covering three different life cycle phases for the engineered process system: design, operation, and maintenance.

Table 4: Example Incidents Involving Failure to Carry Out Three Types of Actions

Actions Not Taken	Incident Summary	Deficiencies and Impacts
Corrections (deficiencies not identified)	• D.D. Williamson & Co. (DDW) facility in Louisville, Kentucky. • Caramel Coloring Feed Tank Overpressure and Explosion, 2003 • Life cycle phase – Design CSB Investigation Report No. 2003-11-I-KY [28]	• Deficient Management Process – Hazard Evaluation System (i.e., Process Hazard Analysis) • 1 fatality, community evacuation, and shelter-in-place
Corrective Actions (corrections made, but causes of deficiencies not identified)	• Giant Industries’ Ciniza refinery in Jamestown, New Mexico. • Hydrofluoric Acid Alkylation Unit Pump Fire and Explosion, 2004 • Life cycle phase – Maintenance CSB Case Study Report No. 2004-08-I-NM [26]	• Deficient Management Process – Mechanical Integrity program • 6 employee injuries
Preventive Actions (potential deficiencies not identified for previous incidents)	• First Chemical Corporation (FCC) facility in Pascagoula, Mississippi • Mononitrotoluene (MNT) Distillation Column Runaway Reaction, Explosion and Fire, 2002 • Life cycle phase – Operations CSB Investigation Report No. 2003-01-I-MS [29]	• Deficient Management Process – Incident Investigation program • 3 employee injuries, offsite consequences

Example Incident #1 – No Corrections

Lesson to be Learned – *Without a verification process to identify design deficiencies and evaluate the associated process hazards, corrections to reduce risks cannot be made.*

The CSB found:

> "D. D. Williamson did not have effective programs in place to determine if equipment and processes met basic process and plant engineering requirements.
>
> - There was *no program to evaluate* [emphasis added] necessary layers of protection on the spray dryer feed tanks. Likewise, there was no recognition of the need to provide process control and alarm instrumentation on the two feed tanks.
> - The feed tanks were installed for use in the spray dryer process *without a review* [emphasis added] of their design versus system requirements.
> - Safety valves on the spray dryer feed tanks had been removed to transport the tanks to Louisville and were never reinstalled. There was *no* evidence that DDW conducted an *engineering evaluation* [emphasis added] to determine the hazards of this change." [28]

The CSB concluded:

> "D. D. Williamson did *not have adequate hazard analysis systems* [emphasis added] to identify feed tank hazards, nor did it effectively use contractors and consultants to evaluate and respond to associated risks.
>
> - Neither DDW nor its contractors and consultants recognized the need for overpressure protection for the two feed tanks used in the spray dryer process." [28]

Example Incident #2 – No Corrective Actions

Lesson to be Learned – *Unless the causes of deficiencies are identified and eliminated, these same deficiencies can recur and corrections to the same problem may be repeated multiple times, thus increasing the risk that their potential consequences will be realized in future incidents.*

The CSB found:

> "A review of repair work prior to the incident revealed a history of repeated pump failures. The primary, electric, and steam-driven spare isostripper recirculation pumps had 23 work orders submitted for repair of seal-related problems or pump seizures in the one-year period prior to the incident" [26].

The CSB concluded:

> "Giant's mechanical integrity program did not effectively prevent these repeated failures of the pump seals… Giant's approach to these frequent pump seal problems was an example of breakdown maintenance. In other words, pump failures were addressed when the equipment finally broke down, instead of identifying causes of breakdowns and preventing them before they occurred again" [26].

Example Incident #3 – No Preventive Actions

Lesson to be Learned – *When instances of deficiency identification and the actions for their solution are treated in isolation and not shared, valuable lessons learned cannot be effectively applied to other potential deficiencies to prevent similar incidents.*

The CSB noted from *Essential Practices for Managing Chemical Reactivity Hazards* by CCPS: "Multiple facilities in an organization may have similar chemical reactivity hazards . . . or use similar technology to control the associated hazards. If so, it may be more efficient for a corporate office or personnel to assume responsibility for some improvement activities… This can also facilitate communication of incidents and best practices between facilities" [29].

The CSB revealed the following root cause:

> "The FCC Pascagoula facility did not have an adequate system for evaluating the hazards of processing mononitrotoluene (MNT) in its continuous process and *did not apply lessons learned from hazard analyses conducted on similar processes in the plant* [emphasis added] … The facility became aware of the hazards of allowing MNT to be exposed to elevated temperatures for an extended time during a batch project in 1996, but the lessons learned (including operating considerations and the addition of safety interlocks) were not applied to the existing MNT columns… there was *no system to apply evaluation results* [emphasis added] from the batch process to continuous processing equipment" [29].

The CSB also found:

> "FCC experienced an explosion and fire in a batch process under development for a third party in 1986… The incident involved a runaway reaction and overpressurization of equipment in a column that had no provisions to mitigate a thermal runaway… One of the recommendations was to perform hazard analyses of existing processes. FCC *did not apply lessons learned from this event* [emphasis added] to the MNT distillation system. OSHA made the following determinations: The PHA was deficient because it did not identify 'any previous incident which had a likely potential for catastrophic consequences'" [29].

Action Systems

A means for effectively managing corrections, corrective actions, and preventive actions is an action system, often narrowly referred to as a corrective action system. Requirements for these systems have been defined by international standards and guidelines for quality, environment, occupational health and safety, and security management systems, as well as by regulations [2,9,11,12].

Good practice beyond the minimum stated compliance requirements would be to incorporate these features into a common action system and apply them to all PSM system processes requiring the management of actions throughout their life cycle.

Table 5 shows "what good looks like" for an action system using a PDCA model, with references to explicit requirements in the OSHA PSM Standard [17] for certain aspects of such a system. An interesting observation from Table 5 is how the wording of the requirements for similar action systems can vary, even from the same source.

Table 5: Action System Model

Step	Task	Example OSHA PSM Requirements [17]
Plan	• Address findings (deficiencies) and recommendations. • Resolve findings (deficiencies, contributing factors) and recommendations; document resolution. • Determine causes of deficiencies. • Document actions (corrections, corrective and preventive actions) to be taken. • Assign responsibilities for actions. • Develop written schedule to complete actions.	**Process Hazard Analysis** – "The employer shall establish a system to promptly address the team's findings and recommendations; assure that the recommendations are resolved in a timely manner and that the resolution is documented; document what actions are to be taken; develop a written schedule of when these actions are to be completed." **Incident Investigation** – "The employer shall establish a system to promptly address and resolve the incident report findings (i.e., factors that contributed to the incident) and recommendations. Resolutions and corrective actions shall be documented." **Compliance Audits** – "The employer shall promptly determine and document an appropriate response to each of the findings of the compliance audit."
Do	• Complete actions (correct deficiencies, eliminate causes of deficiencies). • Communicate actions and lessons learned to those affected.	**Process Hazard Analysis** – "Complete actions as soon as possible; communicate the actions to operating, maintenance and other employees whose work assignments are in the process and who may be affected by the recommendations or actions." **Incident Investigation** – "The report shall be reviewed with all affected personnel whose job tasks are relevant to the incident findings including contract employees where applicable."
Check	• Monitor timeliness of closeouts. • Review actions taken. • Review effectiveness of actions. • Monitor trends for common deficiencies.	
Act	• Follow up on overdue actions. • Document closeout.	**Compliance Audits** – "Document that deficiencies have been corrected."

Properly designed and implemented action systems, whether manual or electronic, would incorporate a robust process for managing the aforementioned life cycle of actions. The next section addresses examples of process safety incidents that have occurred as a result of inadequately designed or ineffectively implemented PSM system management processes, including the action system.

3. Example Process Safety Incidents – Lessons to be Learned

Industry is replete with examples of process safety incident investigation reports and case histories from which we can learn lessons and apply to the improvement of PSM systems [8,15,16,19,20].

Ten real-life examples are presented in this section to demonstrate several elements of a PSM system where improperly managing deficiencies and actions have led to actual process safety incidents. These examples show a wide range of issues related to deficiencies within both the PSM system and the engineered process system for a cross-section of industries, types of hazards, and geographic regions.

These examples also demonstrate how human factors are often the prevalent root cause(s) [6]. That is, human errors or decisions causing deficiencies associated with designing and/or implementing either the management system or the engineered process system, if not properly identified and eliminated, represent a potential multi-fold increase in the risk of process safety incidents. Organizational and human factors contributing to incidents beyond human errors and poor decisions may include a lack of commitment and recognition of the value of safety, an inadequate safety culture, misperceptions of risk, a higher appetite for risk taking, and simply poor leadership and management of the business.

For each of the PSM system elements and corresponding example process safety incidents presented in Table 6, a synopsis from the respective incident investigations reports by the U.S. Chemical Safety and Hazard Investigation Board (CSB) is presented in the following sub-sections.

These briefs synopses demonstrate how PSM system deficiencies within PSM system elements (individually or in combination) contributed to the ultimate failure of management to take appropriate action(s) that could have prevented such incidents.

From the example incidents selected, we see that there are different ways to break the PDCA continual improvement life cycle in such a way that actions were not able to be taken (see Table 7). Such gaps prevent achieving the goal of continually improving process safety performance.

For instance, some incidents involved missing or ineffectively implemented policies and programs that would have required in the “Plan” step the need for identifying deficiencies, and therefore prevented any progress in the subsequent “Do”, “Check”, and “Act” steps.

Next, some incidents which may have had successful planning also inadequately identified deficiencies in the “Do” step, which did not allow for meaningful causes to be determined in the subsequent “Check” step.

Further, other incidents included no root causes or improperly determined causes of the identified deficiencies in the “Check” step, which did not allow for suitable actions to be proposed for the “Act” step.

Finally, one incident demonstrated that despite apparent success in the “Plan”, “Do”, and “Check” steps, ineffectively managed action within the action system prevented improvement and actually contributed to the incident.

Table 6: Example Incidents from Ineffective Management of Deficiencies & Actions

PSM Element	Incident Reference	Location, Impacts & Process Deficiencies
Example Incident 1: Employee Participation	Refinery Crude Unit Pipe Rupture and Fire, 2012, CSB Investigation Report No. 2012-03-I-CA [27]	• Refinery in Richmond, California. • 6 minor employee injuries. • Stop Work Authority program; Safety Culture Assessment process.
Example Incident 2: Process Hazard Analysis	Refinery Propane Deasphalting Unit Fire, 2007, CSB Investigation Report No. 2007-05-I-TX [30]	• Refinery in Sunray, Texas. • 3 employee injuries; 1 contractor injury. • Process Hazard Analysis program.
Example Incident 3: Operating Procedures	Refinery Isomerization Unit Overfill, Fire and Explosion, 2005, CSB Investigation Report No. 2005-04-I-TX [31]	• Refinery in Texas City, Texas. • 15 contractor fatalities; 180 employee and contractor injuries. • Operating Procedures process; Management of Change (MOC) process; Pre-Startup Safety Review (PSSR) process.
Example Incident 4: Operator Training	Ink Dust Collection System Explosion and Flash Fire, 2012, CSB Case Study No. 2013-01-I-NJ [24]	• Manufacturing facility in East Rutherford, New Jersey. • 7 employee injuries. • Operator Training Program.
Example Incident 5: Contractors & Hot Work Permit	Oilfield Production Tank Explosion, 2006, CSB Investigation Report No. 2006-07-I-MS [23]	• Oilfield in Raleigh, Mississippi. • 3 contractor fatalities; 1 serious contractor injury. • Contractor Safety Program; Hot Work Program.
Example Incident 6: Mechanical Integrity	Refinery Sulfuric Acid Storage Tank Explosion, 2001, CSB Investigation Report No. 2001-05-I-DE [32]	• Refinery in Delaware City, Delaware. • 1 employee fatality; 8 employee injuries. • Mechanical Integrity management system.
Example Incident 7: Management of Change (MOC) & Pre-Startup Safety Review (PSSR)	Peroxide/Alcohol Piping Explosion and Flash Fire, 2004, CSB Safety Bulletin No. 2004-03-B [21]	• Petrochemical facility in Port Neches, Texas. • 2 serious employee injuries. • Management of Change process; Pre-Startup Safety Review process.
Example Incident 8: Incident Investigation	Thermal Decomposition in Polymer Catch Tank, 2001, CSB Investigation Report No. 2001-03-I-GA [33]	• Plastics plant in Augusta, Georgia. • 3 employee fatalities. • Incident Investigation system.
Example Incident 9: Emergency Planning / Response	Mixing Tank Heptane Vapor Cloud Explosion, 2006, CSB Case Study No. 2006-08-I-IL [25]	• Concrete chemicals facility in Bellwood, Illinois. • 1 contractor fatality; 1 serious employee injury; 1 minor employee injury. • Emergency Planning & Response process.
Example Incident 10: Compliance Audits	Vinyl Chloride Tank Welding Flammable Vapor Explosion, 2010, CSB Case Study No. 2011-01-I-NY [22]	• Chemical plant in Buffalo, New York. • 1 contractor fatality; 1 serious contractor injury. • Compliance Audit process.

Table 7: Summary of PSM System Deficiencies for Ten Example Incidents

PSM Element	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Example Incident 1: Employee Participation	✓	✓	✓	✗
Example Incident 2: Process Hazard Analysis	✓	✓	✗	✗
Example Incident 3: Operating Procedures	✓	✓	✗	✗
Example Incident 4: Operator Training	✓	✗	✗	✗
Example Incident 5: Contractors & Hot Work Permit	✗	✗	✗	✗
Example Incident 6: Mechanical Integrity	✓	✓	✗	✗
Example Incident 7: Management of Change & PSSR	✓	✗	✗	✗
Example Incident 8: Incident Investigation	✓	✓	✗	✗
Example Incident 9: Emergency Planning / Response	✗	✗	✗	✗
Example Incident 10: Compliance Audits	✓	✗	✗	✗

Note: ✓ indicates a successful PDCA step; ✗ indicates an unsuccessful step.

3.1 Example Incident 1 – Employee Participation

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Refinery Crude Unit Pipe Rupture and Fire, 2012, CSB Investigation Report No. 2012-03-I-CA [27]	✓	✓	✓	✗

Lesson to be Learned – A Stop Work Authority (SWA) program at the Chevron Refinery in Richmond, California was in place and periodic safety culture assessments required by the local regulations provided a means of verification to identify deficiencies (findings), develop an improvement plan with a list of actions and milestones, and provide a rationale for prioritizing actions and their justification [27]. *However, actions were not effectively taken to improve identified weaknesses in the SWA program and therefore contributed to the incident in 2012.*

Finding – The CSB concluded:

> "In the years leading to the August 6, 2012, incident, the Chevron Richmond Refinery identified weaknesses in its Stop Work Authority program due to employee hesitation to use Stop Work Authority when witnessing an unsafe act. However, the regulator did not require the Chevron Richmond Refinery to take quality, constructive steps to improve these areas." [27]

Human Factors Issue – The CSB noted:

> "No one formally invoked their Stop Work Authority. In addition, Chevron safety culture surveys indicate that between 2008 and 2010, personnel had become less willing to use their Stop Work Authority. Regardless of how a Stop Work program is portrayed, there are a number of reasons why such a program may fail related to the 'human factors' issue of decision-making; these reasons include belief that the Stop Work decision should be made by someone else higher in the organizational hierarchy, reluctance to speak up and delay work progress, and fear of reprisal for stopping the job." [27]

3.2 Example Incident 2 – Process Hazard Analysis

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Refinery Propane Deasphalting Unit Fire, 2007, CSB Investigation Report No. 2007-05-I-TX [30]	✓	✓	✗	✗

Lesson to be Learned – A Process Hazard Analysis (PHA) program at the Valero McKee Refinery in Sunray, Texas was in place and periodic PHA revalidations should have provided a means of verification to identify safeguard deficiencies, generate and resolve recommendations, and follow up on their implementation [30]. *However, a recommended action for installing remotely-operated shut-off valves (ROSOVs) made during the initial PHA eleven years prior was never implemented, was subsequently inaccurately closed out as "complete", and was not discovered during a 5-year PHA revalidation.*

Finding – The CSB concluded:

> "The McKee Refinery did not apply Valero's mandatory *Emergency Isolation Valve* procedure when evaluating risks in the PDA unit to ensure that the large quantities of flammable materials in the unit could be rapidly isolated in an emergency" [30].

Human Factors Issue – In addition to the abovementioned action being incorrectly closed out as being complete as a result of human error, the verification processes failed on multiple occasions from an organizational perspective to detect this critical error.

3.3 Example Incident 3 – Operating Procedures

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Refinery Isomerization Unit Overfill, Fire and Explosion, 2005, CSB Investigation Report No. 2005-04-I-TX [31]	✓	✓	✗	✗

Lesson to be Learned – A management process for developing and implementing written Operating Procedures was in place at the BP Texas City Refinery, with the intent to provide clear instructions for safely conducting activities involved in each covered process (as required by the OSHA PSM Standard) [31]. Furthermore, BP guidelines requiring that procedures be reviewed as often as necessary and certified annually as being current and accurate, including changes managed under the MOC policy, as well as PSSR reviews, should have provided a means of verification to assure that they reflected current operating practices (as required by the OSHA PSM Standard) [31]. *However, the operating procedures did not reflect actual practice, were not corrected over time, were not reviewed for changes as required before multiple start-ups, and were routinely deviated from during operations.*

Finding – The CSB found in the two previous PSM audits prior to the incident (another verification means for identifying management system deficiencies), that:

> "a number of operating procedures were not current and did not accurately reflect practices on particular units" and that "process safety action item resolution was still a problem for the refinery (20 percent of open action items were overdue), and that changes were still being made before MOC sign-offs and action items had been resolved" [31].

Human Factors Issue – The CSB noted:

> “Addressed here are the human factors that explain why feed was added to the tower for three hours without liquid being removed. While recognizing that human errors were made in the raffinate startup, this investigation goes beyond individual failures to gain a deeper understanding of why the incident occurred, which is more useful in major accident prevention… The broader aspects of this investigation revealed serious management safety system deficiencies that allowed the operators and supervisors to fail. The following underlying latent conditions contributed to the unsafe start up:
>
> - A work environment that encouraged operations personnel to deviate from procedure.
> - Lack of a BP policy or emphasis on effective communication for shift change and hazardous operations (such as unit startup).
> - Ineffective supervisory oversight and technical assistance during unit startup.
> - Insufficient staffing to handle board operator workload during the high-risk time of unit startup.
> - Lack of a human fatigue-prevention policy.
> - Inadequate operator training for abnormal and startup conditions.
> - Failure to establish effective safe operating limits.” [31]

3.4 Example Incident 4 – Operator Training

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Ink Dust Collection System Explosion and Flash Fire, 2012, CSB Case Study No. 2013-01-I-NJ [24]	✓	✗	✗	✗

Lesson to be Learned – Although combustible dust is not covered under the OSHA PSM Standard and at the time OSHA had not promulgated a combustible dust standard, certain management system processes were in place at the U.S. Ink/Sun Chemical black ink manufacturing facility in East Rutherford, New Jersey, including operator training and related verification processes for managing risks, including PHA and MOC [24]. *However, these processes were not effectively implemented to prevent injuries from an ink dust explosion and flash fire in a new dust collection.*

Finding – Further, a Capital Appropriations/Asset Request (CAR) process was in place, but the CSB found:

> “In the CAR environmental health and safety section, a checkbox indicating the need for a process hazard analysis (PHA) or management of change (MOC) was not checked, indicating that neither a PHA nor a MOC was necessary for the dust collection system” [24]. This precluded an important means for verifying that procedures and training were in place, based on an understanding of the combustible dust hazards.

Human Factors Issue – The CSB found that:

> "The lack of adequate oversight by Sun Chemical Corporation management personnel in the planning, design, installation, and commissioning of the dust collection system likely contributed to the October 9, 2012, incident. The CSB identified significant management issues, including inadequate project oversight, ineffective employee training on the dust collection mechanism, and failure to develop and implement corrective actions from a previous incident" [24].

3.5 Example Incident 5 – Contractors & Hot Work Permit

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Oilfield Production Tank Explosion, 2006, CSB Investigation Report No. 2006-07-I-MS [23]	✘	✘	✘	✘

Lesson to be Learned – Neither a Contractor Safety Program nor a Hot Work Program were in place by Partridge-Raleigh (oilfield owner) or Stringer's Oilfield Services (contractor) at an oilfield in Raleigh, Mississippi when an explosion incident occurred on June 5, 2006 as flammable vapor inside two tanks was ignited by welding activities on a nearby tank [23]. *Such programs could have provided for safe work practices and emergency procedures, as well as a means for verification of the welding task (e.g., hot work permit) and verification of contractor safety management (e.g., evaluating contractor safety performance when selecting contractors, informing contract employers of the known potential fire, explosion, or toxic release hazards related to the contractor's work, and periodically evaluating on-the-job performance).*

Finding – The CSB found [23]:

- Partridge-Raleigh and Stringer's did not use available industry guidelines for hot work safety such as that provided in NFPA 326 and API 2009.
- A flammable gas detector was not used prior to welding activities. "Instead, workers used an open flame, or tank 'flashing' to verify that flammable vapor was not present in the tank."
- Partridge-Raleigh did not have established safety requirements for personnel at the oilfield. Stringer's had not established a formal safety program for its employees, and Partridge-Raleigh did not require Stringer's to have one.
- "Stringer's and Partridge-Raleigh did not adhere to OSHA requirements and precautions for burning and welding. OSHA Standard 29 CFR 1910.252 contains requirements in a number of areas including the use of guards to confine heat, sparks and slag generated during welding; special precautions when welding in the presence of explosive atmospheres; and requirements for cleaning used drums, barrels, tanks or other containers prior to welding".

Human Factors Issue – Neither a Contractor Safety Program nor a Hot Work Program at the facility were found to be in place. Without a culture of safety and the organizational commitments by both parties to require the most basic safety programs and safe work practices, this incident was not able to be prevented.

3.6 Example Incident 6 – Mechanical Integrity

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Refinery Sulfuric Acid Storage Tank Explosion, 2001, CSB Investigation Report No. 2001-05-I-DE [32]	✓	✓	✗	✗

Lesson to be Learned – A Mechanical Integrity management system for the Motiva Enterprises Delaware City Refinery was in place and periodic inspections should have provided a means of verification to identify and correct equipment deficiencies that are outside acceptable limits in a safe and timely manner (as required by the OSHA PSM Standard) [32]. *However, this program was not effectively implemented to determine causes and to correct deficiencies before a process safety incident occurred on July 17, 2001.*

Finding – The CSB concluded as a root cause:

> "Motiva did not have an adequate mechanical integrity management system to prevent and address safety and environmental hazards from the deterioration of H_2SO_4 storage tanks.
> - The repeated recommendations of the tank inspectors that tank 393 be taken out of service 'as soon as possible' for an internal inspection were unheeded.
> - A leak in the shell of tank 393, observed in May 2001, was not repaired. Instead, the tank liquid level was lowered below the leak point and the tank remained in service.
> - Management failed to recognize the imminent hazard posed by the holes in tank 393 and did not promptly initiate repairs or take the tank out of service" [32].

The CSB also concluded as a contributing factor:

> "The Motiva refinery system for investigating Unsafe Condition Reports, informing workers about such reports, and tracking the satisfactory resolution of issues was inadequate.
> - In the 3 weeks between submittal of the Unsafe Condition Report on June 27 and the day of the incident, management did not correct the reported deficiencies or implement temporary safeguards" [32].

Human Factors Issue – The CSB noted a lack of management accountability:

> "The Motiva Enterprises LLC management oversight system failed to detect and hold Motiva refinery management accountable for deficiencies in the refinery's mechanical integrity, engineering management, and MOC systems" [32].

3.7 Example Incident 7 – Management of Change

Incident Reference	Plan	Do	Check	Act
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Peroxide/Alcohol Piping Explosion and Flash Fire, 2004, CSB Safety Bulletin No. 2004-03-B [21]	✓	✗	✗	✗

Lesson to be Learned – MOC and PSSR processes at the Huntsman Petrochemical Corporation facility in Port Neches, Texas, were in place and should have provided a means of verification to manage changes to assure that considerations for changes to process chemicals, piping, and procedures (including safe work practices such as opening process equipment or piping), as well as the impact on safety and health, are addressed prior to any change, and also to confirm that prior to start-up that safety procedures are accurate (as required by the OSHA PSM Standard) [21]. *However, these processes did not adequately address the deficiencies associated with safety effects of a procedural change from water flushing to nitrogen purging for removal of hazardous chemicals as a precursor step to steam purging, nor the identification of low-point traps from a previous piping change, by the time a flash fire incident occurred in January 2004 [21].*

Finding – The CSB found:

> "To reduce waste volume, Huntsman revised the procedures to substitute inert gas purging for water flushing. However, purging with inert gas or steam does not necessarily remove trapped liquid. The revised procedure:
> - Failed to address the importance of identifying low points in the piping.
> - Failed to require the use of low-point drains to remove trapped hazardous liquids" [21].

Human Factors Issue – Based on a lack of oversight for managing technical changes in existing processes, the CSB concluded:

> "A comprehensive review of the as-built drawings, combined with a walkdown of the entire peroxide/alcohol transfer pipe – if required in the management of change (MOC) process – would have likely identified the low-point trap" [21].

3.8 Example Incident 8 – Incident Investigation

Incident Reference	Plan	Do	Check	Act
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Thermal Decomposition in Polymer Catch Tank, 2001, CSB Investigation Report No. 2001-03-I-GA [33]	✓	✓	✗	✗

A site Incident Investigation system was in place at the BP Amoco Polymers, Inc. plant in Augusta, Georgia and should have provided a means of verification to thoroughly investigate and analyze process safety incidents and near misses by identifying and determining the contributing factors (as required by the OSHA PSM Standard) [33]. *However, the system did not adequately identify causes or related hazards for previous incidents by the time a process safety incident occurred on March 13, 2001. As a result, no effective measures had been developed to prevent recurrence of numerous fires or tank overfills and no review system was in place to detect trends.*

Finding – The CSB found:

> "Since 1993, there had been several near-miss incidents involving both the polymer catch tank and the waste plastic. Had these incidents been more thoroughly investigated, they could have provided insight into the hazards associated with the operation" [33].

The CSB also concluded as a root cause:

> "The Augusta site system for investigating incidents and near miss incidents did not adequately identify causes or related hazards. This information was needed to correct the design and operating deficiencies that led to the recurrence of incidents.
>
> - Sound technical theories were not developed to explain the spontaneous ignition of waste plastic or the phenomenon whereby lumps of waste plastic burst.
> - Incidents and near misses tended to be treated as isolated events. Management did not have a review system to detect trends and patterns among incidents.
> - The polymer catch tank had been overfilled and the vent lines plugged on other occasions. No effective measures were developed to prevent recurrence.
> - Fires occurred at the extruder on numerous occasions. No effective countermeasures were developed" [33].

Human Factors Issue – Based on weaknesses with management oversight of the incident investigation system, the CSB recommended:

> "Implement a program to conduct periodic management reviews of incidents and near-miss incidents. Look for trends and patterns among incidents. Address root causes and implement and track corrective measures" [33].

3.9 Example Incident 9 – Emergency Planning & Response

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Mixing Tank Heptane Vapor Cloud Explosion, 2006, CSB Case Study No. 2006-08-I-IL [25]	✘	✘	✘	✘

Lesson to be Learned – An Emergency Planning & Response management process at the Universal Form Clamp (UFC) facility in Bellwood, Illinois, was not in place. *However, had this process been in place, it would have provided employees a means for planning, training, and verification to prepare for emergencies such as the release of heptane vapor from a heated mixing tank which exploded on June 14, 2006 [25].*

Finding – The CSB found:

> "UFC had no emergency action plan, employees had not received any emergency action training or conducted an evacuation drill, and the facility was not equipped with an employee alarm system." The CSB also found: "…there was no procedure or system to initiate a facility-wide evacuation" [25].

Human Factors Issue – The CSB noted:

> "The Process Safety Management (PSM) standard provides a structured program for a systematic approach to chemical process safety and the prevention of catastrophic incidents… However, at the time of the incident, UFC had not implemented a program to comply with this standard" [25]. A lack of management commitment to comply with existing regulations resulted in a missed opportunity for the facility's employees to prepare for emergencies.

3.10 Example Incident 10 – Compliance Audits

Incident Reference	**Plan**	**Do**	**Check**	**Act**
	Policies/Programs developed?	Deficiencies identified?	Causes determined?	Actions taken?
Vinyl Chloride Tank Welding Flammable Vapor Explosion, 2010, CSB Case Study No. 2011-01-I-NY [22]	✓	✗	✗	✗

Lesson to be Learned – A Compliance Audit process was in place and used by DuPont corporate to conduct PSM audits in 2006 and 2009 at the DuPont facility in Buffalo, New York in order to evaluate compliance (as required by the OSHA PSM Standard), and should have provided an independent means of verification that the procedures and practices developed under the OSHA PSM Standard were adequate and being followed [22]. *However, the CSB concluded: "These latest audits carried out by DuPont at the DuPont Buffalo facility missed many deficiencies that became apparent as a result of the November 9, 2010 incident" [22].*

Finding – Specifically, the CSB noted:

> "In November 2006, DuPont corporate performed a PSM audit of the DuPont Buffalo facility. DuPont awarded DuPont Buffalo a score of 99% on this audit, the highest score the auditor team had ever awarded a facility. The audit commended the Buffalo facility on their operating procedures and safe work practices and made no recommendations to improve these programs. No recommendations were made for the Buffalo facility's MOC procedure for subtle changes, stating that 'all systems comply'. Another DuPont audit was carried out in October 2009. This document commended DuPont Buffalo's PHA process. It stated that the PHA's were 'very well managed and executed' and are of 'consistently high quality'" [22].

Human Factors Issue – An apparent discrepancy between corporate audit scores and actual facility PSM system compliance may have resulted in missed opportunities for process safety performance improvements.

4. Conclusions

In its independent safety review report of five BP refineries following the explosion at Texas City, Texas in 2005, the Baker Panel commented [1]:

> "BP had not instituted effective root cause analysis procedures to identify systemic causal factors that may contribute to future accidents. When true root or system causes are not identified, corrective actions may address immediate or superficial causes, but not the true root causes."
>
> "BP, however, has sometime failed to address promptly and track to completion process safety deficiencies identified during hazard assessments, audits, inspections, and incident investigations. The Panel's review, for example, found repeat audit findings at BP's U.S. refineries, suggesting that true root causes were not being identified and corrected."

Despite the significant progress for managing process safety within the chemical industry over the past 25 years, more recent experience of process safety incidents has shown us that there is much room for improvement and lessons still to be learned. This is especially true for: (1) how we can better identify deficiencies with both the PSM system and the engineered process system; (2) how we can better analyze the causes of these deficiencies; and (3) how we can better resolve and make commitments to rigorously carry out corrections, corrective actions, and preventive actions to closure, in order to reduce and/or control risks.

A call to action for leadership to drive such continual improvement of process safety performance includes the following challenges:

1. **Plan** – Instill a continual improvement culture of learning and commit the necessary resources to seek out deficiencies within both the engineered process system and each management process of the PSM system.
2. **Do** – Demonstrate leadership by proactively identifying deficiencies through the verification mechanisms designed within each element of the PSM system.
3. **Check –** Adopt and apply a rigorous, analytical approach to understanding the causes of both existing and potential deficiencies in order to generate effective actions.
4. **Act –** Implement a system to manage the life cycle of actions in order to correct identified deficiencies, eliminate the causes of existing deficiencies through corrective actions in order to prevent their recurrence, and eliminate the causes of potential deficiencies through preventive actions in order to prevent their occurrence in the future.

This paper has shown that we have at our disposal a multitude of lessons learned from industrial process safety incidents through published investigation reports and other sources. We also have at our fingertips industry-standard methods and technology to enable us to manage deficiencies through meaningful actions to continually reduce and control process safety risks.

Towards this end and with these means, we can live up to our policies to protect people's safety and health, the environment, and our communities.

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