Protecting Workers from Chemical Catastrophes: California's 2017 Process Safety Management Regulations for Petroleum Refineries.

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Photo courtesy U.S. Chemical Safety Board. Richmond, Chevron. August 6, 2012

Abstract

On August 6, 2012 a pipe failure in the Chevron Richmond, California oil refinery crude unit led to a large fire that endangered the lives of 19 workers and caused over 15,000 area residents to seek medical attention. In the wake of the incident, the U.S. Chemical Safety Board (CSB) and Governor Jerry Brown's Interagency Working Group on Refinery Safety called for substantial revisions to the

Process Safety Management (PSM) regulations governing the state's 14 oil refineries. The California Department of Industrial Relations (DIR) subsequently launched a three-year stakeholder process and promulgated a new, 24-part PSM regulation, *Process Safety Management for Petroleum Refineries, General Industry Safety Orders §5189.1*.[1] California adopted the new PSM regulation on October 1, 2017.[2]

The ~10,000-word new PSM regulation makes substantial changes to the 12 original PSM elements and adds nine new elements in the areas of damage mechanism reviews; hierarchy of controls analysis and inherent safety measures; safeguard protection analysis; process safety culture assessments; employee participation in PSM decision-making; root cause analysis for major incidents and near-misses; use of PSM indicators; mechanisms to improve accountability and transparency in PSM decision-making; integration of human factors; management of organizational change; and others. The new regulation draws heavily from the recommendations of the CSB, from the report of the Governor's Interagency Working Group on Refinery Safety, and from the Center for Chemical Process Safety (CCPS) publications, *Guidelines for Risk Based Process Safety* (2007) and *Inherently Safety Chemical Processes: A Life Cycle Approach (2009)*. The California Division of Occupational Safety and Health (Cal/OSHA) began enforcing the regulation on October 1, 2017 through increases in its PSM compliance staff that are funded by an annual refinery industry fee.

A RAND analysis of California's PSM regulation concluded that the combined compliance costs for the state's refineries would range between $20 and $184 million per year, with a point estimate of $58 million per year, spread across 14 refineries. When passed on to consumers, RAND reported that this figure would equate to a price increase of $0.004 per gallon of gasoline sold in the state. Based on the historical record in California, RAND found that each major refinery incident avoided would save a refinery about $220 million, not accounting for costs associated with worker fatalities and injuries or damage to surrounding communities. RAND concluded that the proposed regulatory requirements would substantially lower the risk of death among refinery workers and contractor workers, compared to the existing PSM standard.

California's new regulation represents the latest and most sweeping regulatory reform initiated by a U.S. government entity in response to a major process incident. In January 2018, the State of Washington released a revision to its own PSM regulation that closely reflects California's language. California's 2017 PSM regulation will likely influence the national discussion on the role of regulatory policy in preventing major process incidents.

Background

Immediately following an August 6, 2012 pipe failure and fire at the Richmond, Chevron refinery, California Governor Jerry Brown convened an Interagency Refinery Safety Working Group, made up of representatives from 13 state, Federal and local agencies.[3] The final report of the Working Group,

[1] The California EPA developed a counterpart regulation under Program 4 of the state's Accidental Release Program

[2] The new regulation does not apply to California's chemical facilities, which will continue to operate under the original PSM regulation that was adopted in California in 1992.

[3] Interagency Working Group on Refinery Safety members represented the Department of Industrial Relations (DIR), CalOSHA, Cal/EPA Secretary's Office, Air Resources Board (ARB), Governor's Office of Emergency Services (OES), Department of Toxic Substances Control (DTSC), State Water Resources Control Board (SWRCB), California Energy Commission (CEC), California Technology Agency (CTA), Department of Finance (DOF), Department of Public Health (DPH), Office of the State Fire Marshal (OSFM), U.S. EPA and Contra Costa County Health Services Agency.

issued in February 2014, concluded that "improving refinery safety is a goal strongly shared by government, industry, workers, and communities," and it called for changes in three areas to meet this objective:[4]

1) Emergency Response and Preparedness
2) Safety and Prevention of Hazardous Events
3) Community Education and Alerts

Changes to the state's Process Safety Management (PSM) regulation appear in Section Two of the report, *Safety and Prevention of Hazardous Events*. The report recommended that the following revisions to California's PSM regulation "be required as soon as possible:"[5]

1) Implement inherently safer systems to the greatest extent feasible;
2) Perform periodic safety culture assessments;
3) Incorporate damage mechanism hazard reviews into process hazard analyses;
4) Conduct root cause analyses after significant accidents or releases;
5) Account for human factors and organizational changes; and
6) Use structured methods, such as layer of protection analysis, to ensure adequate safeguards in process hazard analyses.

The U.S. Chemical Safety Board (CSB) also called attention to long-standing weaknesses in the state's PSM regulation and recommended that both the regulation and the state's enforcement program be strengthened.[6] The CSB concluded, for example, that had the existing California PSM regulations required refiners to perform rigorous damage mechanism reviews (DMRs), the problem of sulfidation corrosion in the crude unit would likely have been identified and mitigated well before the catastrophic pipe failure in August 2012. Similarly, the CSB reported that there were no requirements of refiners to analyze the effectiveness of process hazard analysis (PHA) safeguards or to deploy inherently safer technologies, using a hierarchy of controls.

In developing its PSM regulation, DIR conducted extensive outreach to industry and refinery workers. During 2014, DIR convened or participated in 26 meetings or hearings pertaining to process safety at oil refineries. At each of these meetings, DIR presented the findings and recommendations of the Governor's report and CSB; described DIR's proposed revisions to the refinery PSM regulation; and listened to and recorded the views of meeting participants. DIR convened a technical PSM Advisory Committee, made up of representatives of labor and industry. All Advisory Committee meetings were open to the public, who were invited to present their views before the Committee and DIR staff.

Regulatory Overview

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[4] Governor Edmund G. Brown (February 2014). *Improving Public and Worker Safety at Oil Refineries: Report of the Interagency Working Group on Refinery Safety.* (Available: http://www.dir.ca.gov/dosh/interagency-refinery-task-force.html) Accessed March 22, 2017. pp. 24-33.

[5] Governor Edmund G. Brown (February 2014) *op cit.* p. 21

[6] U.S. Chemical Safety and Hazard Investigation Board (October 2014). *Regulatory Report. Chevron Richmond Refinery Pipe Rupture and Fire.* Report No. 2012-03-I-CA. (Available: http://www.csb.gov/file.aspx?DocumentId=661) Accessed February 2018. pp. 96-98

The Department of Industrial Relations (DIR) translated the recommendations of the Governor's report, the CSB, and Advisory Committee into a revised, 24-part PSM regulation for the state's 14 oil refineries, known as *Process Safety Management for Petroleum Refineries, General Industry Safety Orders (GISO)* §*5189.1*. The Occupational Safety and Health Standards Board held a public hearing on the proposed regulation on September 15, 2016; approved a revised version by unanimous vote on May 18, 2017; and adopted the regulation into force on October 1, 2017. [7]

The California PSM regulation represents the nation's first comprehensive rule pertaining to process safety. It requires refineries to take an integrated, structured approach to anticipating, analyzing and mitigating the hazards that underpin process incidents. In broad terms, it is intended to shift process safety management from focusing on controlling and responding to risks, to preventing risks from arising in the first place. In the same way, the regulation shifts the focus of the Cal/OSHA program from responding to emergencies and complaints toward working with—and requiring—refiners to build a comprehensive PSM program: one that continuously identifies and mitigates process safety hazards by deploying the most effective and enduring solutions at the earliest possible point.

The Cal/OSHA program is meeting this objective with a larger and better-trained staff of PSM compliance officers, using funds generated from an oil industry fee. Most of Cal/OSHA's new PSM personnel are educated in engineering and other technical fields, and they all receive hundreds of hours of PSM training before conducting an inspection. In previous years, a single Cal/OSHA compliance officer might assess a single element of a refiner's PSM program each year; under the new regulation, Cal/OSHA is coordinating its inspections with county compliance officers and U.S. EPA, such that an inspection is now able to address multiple elements of PSM over a period of many weeks.

The regulation applies a mix of prescriptive and performance-based approaches, which reflects a best-practice approach to process safety engineering and management. DIR Advisory Committee representatives pointed out that this approach is appropriate in a refinery setting, where thousands of potential risks must be identified, evaluated, prioritized and mitigated by applying engineering and management judgment.

Because judgment is improved by involving the expertise of front-line workers (as listed within CCPS's four pillars of process safety, below), the regulation includes a suite of new provisions that provide for employee participation in a refiners PSM program. As noted by the CCPS in 2007:

> *Workers are potentially the most knowledgeable people with respect to the day-to-day details of operating the process and maintaining the equipment and facilities*.[8]

The Initial Statement of Reasons for the California PSM regulation makes a similar finding in presenting the rationale for new employee participation authorities in the regulation:

> *Effective employee participation is necessary to ensure process safety in all refinery operations because employees are often the first to become aware of process safety hazards. Employees have direct experience with the routine operation or maintenance of a process. In some cases, operators and maintenance personnel may be the sole source*

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[7] See the full text of the regulation at: http://www.dir.ca.gov/OSHSB/documents/Process-Safety-Management-for-Petroleum-Refineries-apprvdtxt.pdf. A description of the purpose and necessity for each PSM element is provided in DIR's *Initial Statement of Reasons*: http://www.dir.ca.gov/OSHSB/documents/Process-Safety-Management-for-Petroleum-Refineriess-ISOR.pdf.

[8] Center for Chemical Process Safety (CCPS) (2007). *Guidelines for Risk Based Process Safety*. American Institute of Chemical Engineers (AIChE). Wiley: New Jersey. p. 124.

of information obtained through their work experiences, and are therefore a valuable source of information. Effectively integrating employee expertise into the refinery's PSM program is critical to ensure—and continually improve—process safety.

In addition to explicitly providing for the right of refinery employees to participate "throughout all phases" of PSM decision-making, the new PSM regulation gives the collective bargaining agent the authority to select its representative(s) who participate in the PSM program and in PSM teams. These teams are required by the regulation as part of conducting a process hazard analysis (PHA), damage mechanism review (DMR), hierarchy of hazard controls analysis (HCA), management of change (MOC), management of organizational change (MOOC), process safety culture assessment (PSCA), incident investigation, safeguard protection analysis (SPA) and pre-start-up safety review (PSSR). The regulation includes additional measures to improve transparency and accountability in process safety decision-making.

Altogether, California's approach is expected to lead to continuing improvement in process safety throughout the state's refinery sector, albeit with a learning curve that could prove to be steep for some of the state's refiners. While it is intended primarily to protect the safety of refinery workers and neighboring communities, the risk reductions achieved by the regulation also aim to help ensure the operational integrity and continuity of this important industrial sector in California, which relies on its domestic refining capacity to meet the great majority of the state's demand for processed fuels.

A more robust Process Hazard Analysis

The new PSM regulation contains nine new elements (subsections k, l, r-x) and retains 15 existing elements that have been substantially revised (Table 1).

Table 1. Twenty-four elements of California's PSM regulation. Subsections K, l and r-x are new in 2017.[9]

[9] Table 1 applies to the full text of the regulation posted by the California Occupational Safety and Health Standards Board: http://www.dir.ca.gov/OSHSB/documents/Process-Safety-Management-for-Petroleum-Refineries-apprvdtxt.pdf.

Each of the PSM elements functions as part of an integrated engineering and management system, which is intended to drive continual improvement, investment and innovation in process safety. The Process Hazard Analysis (PHA), which existed in the original PSM regulation, remains at the heart of the new regulation, but it now incorporates a more robust body of technical information, including the results of damage mechanism reviews (DMRs); findings from similar processes across the refinery sector; human factors; aspects of organizational changes; and others (see Figure 1).

The PHA team is charged with generating recommendations for corrective actions, which then trigger implementation requirements and timelines in the regulation. An exception to this procedure occurs if the team identifies a process scenario or condition that could lead to a "major incident." This finding triggers a hierarchy of hazard controls analysis (HCA) and safeguard protection analysis (SPA), each of which link to the regulation's implementation requirements. Importantly, the new regulation defines a "major incident" as "any event involving fire, explosion or release of a substance which has the potential to result in death or serious physical harm."

Serious physical harm is defined, in turn, by California Labor Code Section 6432(e) as "*any injury or illness, specific or cumulative, occurring in the place of employment or in connection with any employment, that results in any of the following: inpatient hospitalization for purposes other than medical observation; the loss of any member of the body; any serious degree of permanent disfigurement; and impairment sufficient to cause a part of the body or the function of an organ to*

become permanently and significantly reduced in efficiency on or off the job, including, but not limited to, depending on the severity, second-degree or worse burns, crushing injuries including internal injuries even though skin surface may be intact, respiratory illnesses, or broken bones."

It is readily apparent that preventing an incident that has the "potential" to result in "serious physical harm" requires a higher degree of vigilance and earlier action compared to "preventing or minimizing the consequences of catastrophic releases," a phrase used in the 1992 version of the PSM regulation. The California PSM regulation thereby lowers the threshold for corrective actions; this introduces a more conservative, or protective, process safety performance standard compared to the existing PSM regulation.

Other PSM elements that might be incorporated into or otherwise affected by the PHA include mechanical integrity; process safety information; operating procedures; safety culture assessments; training; contractors; and others.

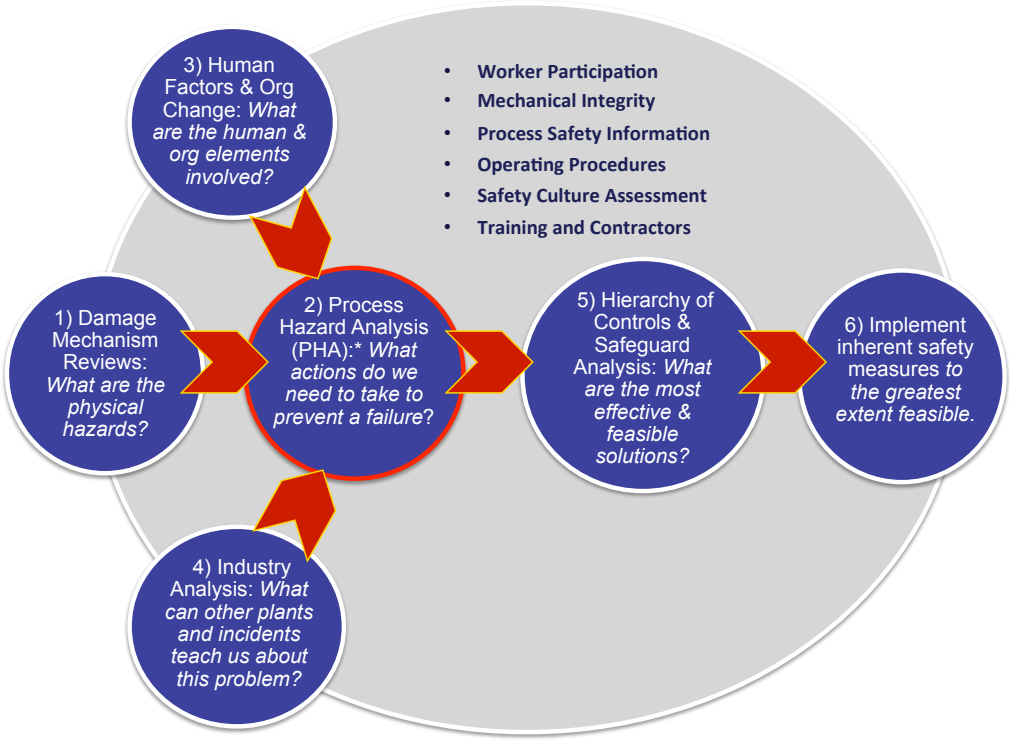

Figure 1. Logic model of the California PSM regulation. The PHA remains the heart of the PSM program, but it incorporates a more robust body of technical and organizational information, and it triggers explicit implementation requirements. If a PHA team identifies a process scenario or condition with the potential for a major incident, a hierarchy of hazard controls analysis (HCA) and safeguard protection analysis (SPA) are required, each of which trigger their own implementation requirements. Each of the bulleted elements may be integrated into or affected by the PHA. Several PSM elements are not included in the model.

Drawing on Best Practices

In addition to relying on the recommendations of the CSB and Governor's Interagency Working Group, California's PSM regulation draws heavily from the Center for Chemical Process Safety (CCPS) *Guidelines for Risk Based Process Safety (2007)* which "reflects fifteen years of PSM implementation experience and well-established best practices from a variety of industries." [(10)] The CCPS *Guidelines* categorize the elements of an effective PSM program into the following four pillars of process safety: (1) commit to process safety; (2) understand hazards and risk; (3) manage risk; (4) learn from experience (Table 2). The CCPS developed these areas of practice based on evidence that incident investigations in high hazard process industries "continue to identify inadequate management system performance as a key contributor to the incident," and that "audits reveal a history of repeat findings" that "indicate chronic problems whose symptoms are fixed again and again without effectively addressing the technical and cultural root causes."[(11)]

Table 2. Each element of the California PSM regulation supports one of the four pillars of risk-based process safety identified by the Center for Chemical Process Safety (2007).

Commit to Process Safety	**Understand Hazards and Risk**
(a) Scope and Purpose (b) Application (q) Employee Participation (r) Process Safety Culture Assessment (v) Process Safety Management Program	(c) Definitions (d) Process Safety Information (e) Process Hazard Analysis (k) Damage Mechanism Review (s) Human Factors
Manage Risk	**Learn from Experience**
(f) Operating Procedures (g) Training (h) Contractors (i) Pre Start-Up Safety Review (j) Mechanical Integrity (l) Hierarchy of Hazard Controls Analysis (m) Hot Work (n) Management of Change (p) Emergency Planning and Response (t) Management of Organizational Change (x) Implementation	(o) Incident Investigation – Root Cause Analysis (u) Compliance Audits (w) Division Access to Documents and Information

While each element of the California PSM regulation can be grouped within these pillars of process safety, the regulation also updates this framework by including the "hierarchy of hazard controls" and "inherent safety," as recommended by the CCPS in *Inherently Safety Chemical Processes: A Life Cycle Approach (2009)*. This text compiles more than a decade of industry experience in the area of inherent safety (Table 2).[(12)]

Consistent with this approach, the hierarchy of hazard controls analysis (HCA) is a foundation of California's PSM regulation, alongside the PHA. The HCA, combined with the regulation's

[10] Center for Chemical Process Safety (CCPS) (2007). *Guidelines for Risk Based Process Safety*. American Institute of Chemical Engineers (AIChE). Wiley: New Jersey. p. l.
[11] Center for Chemical Process Safety (CCPS) (2007) *Risk-Based Process Safety.* The RBPS Subcommittee consists of members from Chevron Energy Technology Company, 3M Company, Celanese Chemical, The Lubrizol Corporation, Air Products and Chemicals, Inc., Rohm and Haas Company, DuPont, Eastman Chemical Company, Shell Chemical Company, Bayer Material Science BP, Eli Lilly and Company, BP, Monsanto Company, Olin Corporation, INEOS Olefins and Polymers USA, Rhodia, Inc. p. 1.
[12] Center for Chemical Process Safety (CCPS) (2007) *op cit.*

implementation provisions, requires a refiner to identify, analyze and implement the most effective and feasible solutions to serious hazards identified in the PHA. The HCA requires the refinery to assess potential solutions to these hazards by applying the hierarchy of controls, beginning with inherent safety measures, followed by passive safeguards, active safeguards, and procedural protections (Figure 2).

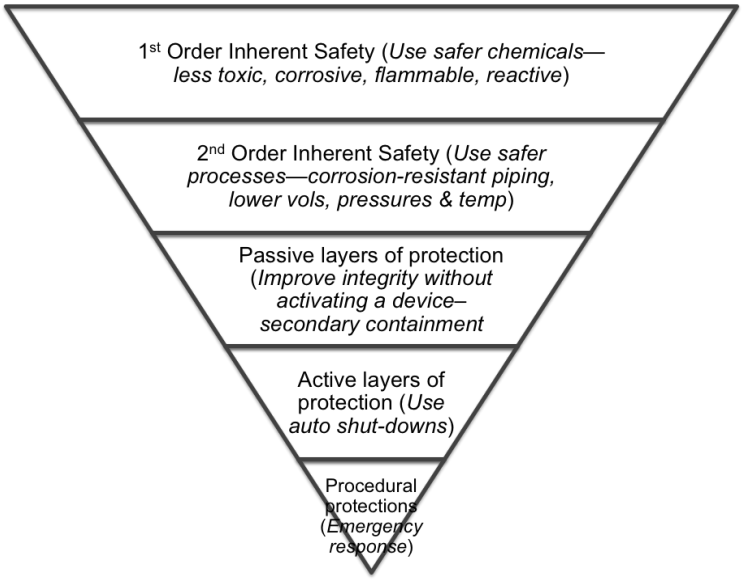

Figure 2. Framework of the California PSM Hierarchy of Hazard Controls Analysis (HCA).

For example, under the requirements of the HCA, an HCA team would need to address the risks posed by a hazardous chemical by assessing corrective actions in the following sequence and priority order:

1) First order inherent safety: Can the hazardous chemical be replaced with a safer alternative? Does the safer alternative introduce new risks at the plant or elsewhere up or down the supply chain? Can these risks be prevented or mitigated?

2) Second order inherent safety: Can the hazardous chemical be used in smaller quantities and/or under ambient temperatures and pressures?

3) Passive safeguards: Can the hazardous chemical be contained in piping and equipment that are more resistant to the corrosive effects of the chemical?

4) Active safeguards: Can devices be installed that automatically activate a device in the event of a failure, such as shutting off flow in a transfer line between a truck tank and refinery tank?

5) Procedural actions: Is it feasible for employees to activate a device, such as a valve or fire monitor, to mitigate a release of the chemical?

Under the HCA requirements, it would likely not be permissible for a refiner to rely primarily on chemical release alarms, for example, or on procedures activated by employees as the primary solution to process safety problems identified in the PHA. While the regulation might allow these approaches to *augment* inherent safety measures or passive safeguards, they would not—in and of themselves—constitute an acceptable, baseline approach to corrective actions taken by a refiner.

Responding to a Persistent Problem

ncidents in the refinery sector demonstrate that improvements in process safety continue to be needed. In 2014, the CSB concluded that there had been "a considerable problem with significant and deadly incidents at petroleum refineries over the last decade." In 2012 alone, the CSB tracked 125 significant process safety incidents at U.S. petroleum refineries, 17 (14%) of which took place in California.[13]An examination of reports submitted between 2007 and 2014 by petroleum refineries to the U.S. Department of Energy shows that the industry continues to experience serious process safety incidents on a regular basis.[14]

The federal regulations governing refineries have not been updated since the early 1990s, when the PSM regulations were first adopted in response to the 1984 industrial disaster in Bhopal, India, where a late-night leak of methyl isocyanate at the Union Carbide pesticide manufacturing plant killed thousands of people—most of whom were sleeping at the time. In the intervening 25 years, PSM expertise by leading companies has advanced significantly, but the PSM regulation has remained static.

In the wake of the April 17, 2013 West, Texas disaster, the Obama Administration issued Executive Order 13650 in an effort to update the nation's process safety regulations, as administered by federal OSHA, EPA and Homeland Security.[15] The Trump Administration subsequently delayed implementation of the updated EPA Risk Management Program (RMP) rules that resulted from this effort; there were no changes made to the federal OSHA PSM program.

RAND Economic Analysis

A RAND economic analysis of California's PSM revision at the time it was proposed concluded that implementing and maintaining compliance with the new regulation would cost the state's refiners between $20 and $184 million per year in total, with a point estimate of $58 million per year, spread across 14 refineries.[16] When passed on to consumers, RAND report that this would equate to a price increase of about $0.004 per gallon in California.[17]

RAND found that each major refinery incident avoided (as a result of improved PSM practices required by the new regulation) would be expected to save a refinery about $220 million, not including the potential costs associated with worker fatalities and injuries or damage to surrounding communities. RAND found that the improvements in process safety would also improve "system reliability, community relations, labor–management relations, and company reputation and public image."

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[13] U.S. Chemical Safety and Hazard Investigation Board (October 2014). *Regulatory Report: Chevron Richmond Refinery Pipe Rupture and Fire.* Report No. 2012-03-I-CA. p. 11.

[14] U.S. Department of Energy, Office of Electricity Delivery and Energy Relability. *Energy Assurance Daily*. [Available: http://www.oe.netl.doe.gov/ead.aspx] (Accessed March, 2017). (Note: For weekly summaries, go to *Download EADs* and scroll to *Petroleum*.)

[15] Executive Order 13650 (May 2014). Actions to Improve Chemical Facility Safety and Security—A Shared Commitment. Report for the President. DHS, USDA, DOJ, DOL, DOT, EPA. (Available: https://www.osha.gov/chemicalexecutiveorder/final_chemical_eo_status_report.pdf) Accessed Feb 2018.

[16] Gonzales D, Gulden T, Strong A, Hoyle W (2016). *Cost-Benefit Analysis of Proposed California Oil and Gas Regulations.* The RAND Corporation. Santa Monica, CA. (Available: http://www.rand.org/pubs/research_reports/RR1421.html) Accessed Feb 2018.

[17] Based on California's 2014 gasoline consumption rate of 14.5 billion gallons per year.

In RAND's analysis, the largest potential economic benefit of the PSM revision would be the improved reliability of the state's fuel supply. This is particularly relevant for California, which refines nearly all of its own fuels. RAND found, for example, that the California economy contracted by $6.9 billion in the first six months following the February 2015 explosion at the ExxonMobil refinery in Torrance, which destroyed the plant's electrostatic precipitator. During this period, Californians paid about $2.4 billion in the form of a $0.40 per gallon increase in gasoline prices.

Finally, RAND found that a refinery worker dies in many refinery incidents, and that in a few such incidents, multiple refinery workers die. The analysis concluded that California's PSM regulation would result in a substantially lower death rate among refinery workers compared to the existing PSM standard.

Emerging Issues

In early 2018, the regulation is in its early stages of implementation. There is evidence that some refiners are fully implementing the regulation; others may be resisting elements of the worker participation requirements. Cal/OSHA has opened PSM inspections at two refineries for complaints related to this element of the new regulation.

In addition to 14 refineries, there are about 1,600 chemical plants of various sizes in California. These chemical plants will continue to operate under the existing PSM regulation, California Code of Regulations (CCR) Title 8, *General Industry Safety Orders* (GISO) §5189. The Governor's Working Group on Refinery Safety identified several shortcomings with the existing PSM regulation, which has not been modified since its adoption in the early 1990s. The fact that the new PSM regulation applies to oil refineries but not chemical plants has resulted in a "two-tier" regulatory scheme in California, whereby refinery workers and communities now have greater regulatory protections compared to chemical plant workers and communities. This may need to be remedied in the future, at least for those chemical plants that present a substantial risk to worker and public safety, as reported through U.S. EPA's Risk Management Program (RMP) regulations.

Conclusion

California's new PSM regulation represents the latest and most sweeping regulatory reform initiated by a U.S. government entity in response to a major process incident. In January 2018, the State of Washington released a revision to its own PSM regulation that closely reflects California's language. California's 2017 PSM regulation will likely influence the national discussion on the role of regulatory policy in preventing major process incidents.