U.S. Chemical Safety and Hazard Investigation Board

Tesoro Martinez Refinery

Process Safety Culture Case Study
Martinez, California

February 12, 2014 and March 10, 2014 Sulfuric Acid Release Incidents

No. 2014-02-I-CA

Investigation Summary:

A strong process safety culture is necessary to help prevent process safety incidents and worker injuries. The CSB investigated two sulfuric acid releases that occurred at the Tesoro Martinez refinery in Martinez, California. The investigation found that a weak process safety culture created conditions conducive to the recurrence of sulfuric acid incidents that caused worker injuries over several years.

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Executive Summary

The US Chemical Safety Board (CSB) investigated two process safety incidents at the Tesoro Martinez refinery in Martinez, California that involved sulfuric acid injuries to workers. On February 12, 2014, a mechanical integrity failure released sulfuric acid in the alkylation unit, which burned two Tesoro Martinez refinery employees. Approximately 84,000 pounds of sulfuric acid were released during the incident. On March 10, 2014, sulfuric acid sprayed and burned two contract workers while they removed piping in the same alkylation unit. The CSB found that this second incident shared similar causation with a 1999 incident at the same refinery, then called the Avon refinery, owned by the Tosco Corporation, that resulted in four fatalities. Similarities between the two incidents suggest that the Tesoro Martinez refinery did not effectively continue to implement or communicate important safety lessons from the 1999 Tosco incident.

The following case study highlights the details of the incidents and their technical and organizational causes. This case study also examines process safety culture ("safety culture") weaknesses through the evaluation of the Tesoro Martinez refinery's previous sulfuric acid incidents, worker statements, gaps in safety standards, deviations from established procedures and practices, and past efforts to assess and strengthen site safety culture. The CSB urges all refineries to review the key findings and conclusions for application to their own facilities, and to evaluate their safety culture, process safety management systems, and corporate safety oversight for potential improvements.

Although primary safety responsibility rests with the companies who own and operate facilities in high hazard industries, regulators are well positioned and empowered to help direct positive change in matters concerning safety. In addition, regulators can be more effective through robust preventive inspections and audits to encourage industry to adopt safer practices and to reduce risks to as low as reasonably practicable, or ALARP. Thus, with the goal of preventing future incidents, the report concludes by reinforcing the need to strengthen the regulatory oversight of petroleum refineries in the state of California.

Key Findings

The CSB's investigation of the February and March 2014 sulfuric acid incidents identified key findings related to safety culture, process safety indicators, and the continued need for a proactive regulator to conduct preventive inspections.

Safety Culture

A strong safety culture is necessary to help prevent process safety incidents, including worker injuries from sulfuric acid releases. The safety culture at the Tesoro Martinez refinery created conditions conducive to the occurrence and recurrence of process safety incidents that caused worker injuries at the refinery over several years. The February and March 2014 incidents are part of a lengthy pattern of sulfuric acid release-related injuries workers suffered at the facility since 2010, with many commonalities that suggest the refinery is not effectively implementing safety lessons from accidents. They are also illustrative of safety culture issues within the Tesoro Martinez refinery, such as:

- Minimization of the seriousness of the February 12, 2014 process safety incident involving chemical burns to workers and a loss of primary containment;
- Routine alkylation unit worker exposure to hazardous vapors, acids, and caustic;
- Taking inherently safer acid sample systems out of service;
- Reliance on inadequate temporary alkylation unit equipment or other workarounds;
- Failure to provide alkylation unit workers with necessary and functional personal protective equipment (PPE);
- Establishment of site-specific safety policies that were less protective than corporate standards and established industry good practice;
- Permit readiness program deficiencies resulting in perceived pressure on alkylation unit workers to expedite work;
- Failure to take corrective actions to address findings from refinery safety culture assessments;
- Ineffective incorporation and communication of lessons learned from previous safety incidents;
- Withdrawal from safety programs that workers believed were effective;
- Reports of pressure on alkylation unit workers to reduce cost by running at lower acid concentrations, but without adequate technical controls and infrastructure needed to operate safely at the desired conditions;
- Staffing resource limitations due to numerous worker injuries and workforce reductions; and
- Reports of increased management pressure on alkylation unit workers to expedite training and qualifications in order to fill gaps in staffing.

Regulator Inspections and the use of Indicators

An effective, proactive regulator can play a positive role in preventing process safety incidents in addition to a company's prioritization and implementation of safe practices and procedures.
Robust, preventive inspections by the regulator are necessary to identify opportunities to implement good practices, use the hierarchy of controls, and reduce risk to as low as reasonably practicable (ALARP) among other critical tasks. Such inspections could have identified the weaknesses of the sampling stations at the Tesoro Martinez refinery and safer sampling approaches used at other California refineries. In addition, preventive inspections could have identified the weak equipment and pipe opening practices at the Tesoro Martinez refinery. The collection and assessment of a company's leading and lagging process safety indicators can measure operational performance and promote ongoing safety improvement, leading to the potential for enhanced accident prevention efforts. Prior sulfuric acid exposure incidents at the Tesoro Martinez refinery could have properly been considered leading indicators of an impending serious chemical accident and then triggered preventive inspections and review of the refinery's safety systems and equipment.

1.0 Background Information

The US Chemical Safety Board (CSB) investigated two separate sulfuric acid release incidents that occurred in February and March 2014 in the alkylation unit of the Tesoro Martinez refinery in Martinez, California.[1] The incidents caused acid burn injuries to four workers and two of these workers each missed over 150 days of work. The February incident also caused a significant release of approximately 84,000 pounds of sulfuric acid from a 100,000-gallon vessel containing sulfuric acid and hydrocarbons.[2] Figure 1 below shows the location of the incidents within the refinery.

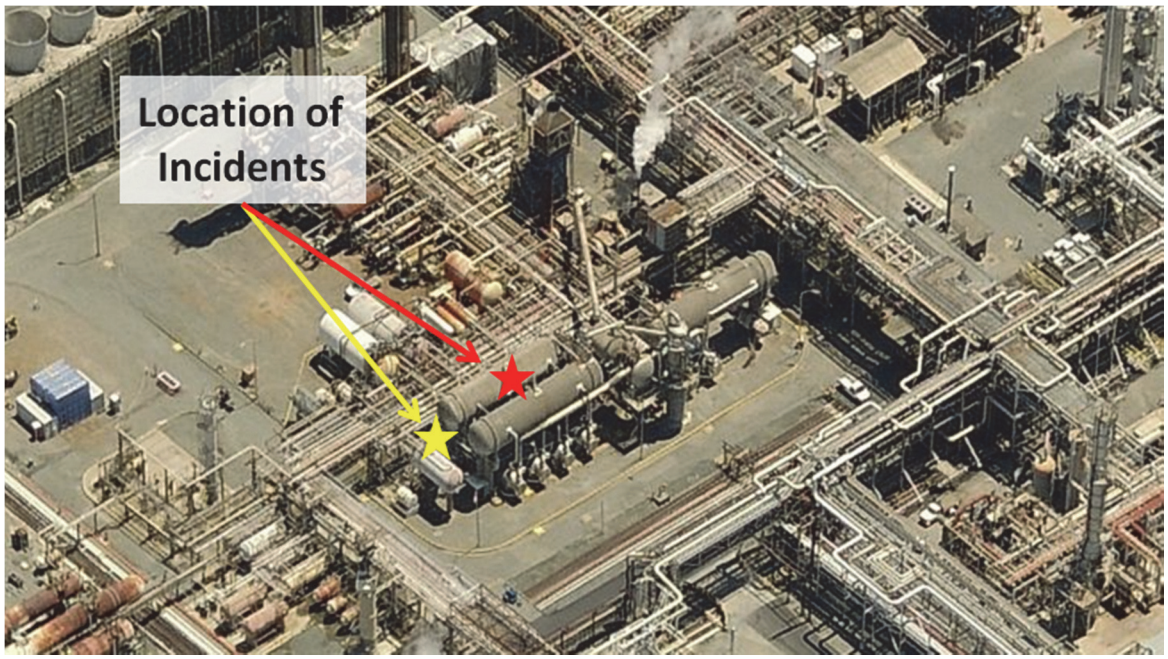

Figure 1. Overhead photo of the Tesoro Martinez refinery Alkylation Unit showing the approximate location of the February 12, 2014 (yellow star) and March 10, 2014 (red star) incidents. Credit Bing Maps.

[1] At the time of these incidents, the CSB was completing its investigation of the multi-fatality Tesoro Anacortes refinery investigation that uncovered numerous safety culture deficiencies, and was assessing the regulatory oversight of petroleum refineries in California through its investigation of the Chevron Richmond refinery (accessed June 20, 2016).

[2] Tesoro records indicate that the incident resulted in the release of 84,346 pounds of sulfuric acid and 26 pounds of sulfur dioxide.

1.1 Refinery History

Tesoro Corporation began in 1968 as a petroleum exploration and production company. In 1969, Tesoro began operating its first refinery near Kenai, Alaska. A Fortune 100 company, Tesoro now operates six refineries in the western United States. These refineries have a combined production capacity of approximately 850,000 barrels per day (bpd).[3]

The Martinez refinery has been in operation for more than 80 years. Its main products are motor fuels such as gasoline and diesel. Tosco Corporation operated the refinery (known then as Avon) from 1976-2000, when Tosco sold the refinery to Ultramar Diamond Shamrock which then renamed the Avon refinery the Golden Eagle refinery. Ultramar Diamond Shamrock then sold the refinery to Valero in 2002, and in rapid succession, Tesoro acquired the Golden Eagle refinery from Valero in 2002. In 2013, Tesoro renamed this facility the "Tesoro Martinez Refinery."

1.2 Alkylation and the Role of Sulfuric Acid

The alkylation process takes place in the alkylation unit of a refinery and occurs when isobutane combines with light olefins[4] in the presence of a strong acid catalyst[5] such as sulfuric acid. Tesoro describes alkylation as one of the most important processes in a modern refinery because it increases gasoline production by combining low value hydrocarbons such as propane and butane to produce a premium gasoline blend stock. The result is high-octane premium gasoline blending component, also known as high-octane alkylate.

The alkylation unit's spent sulfuric acid is highly corrosive, reactive, and can be flammable.[6] In the event of contact, sulfuric acid can cause severe skin burns, serious eye damage, and respiratory irritation. To ensure the alkylation unit is operating within its safe operating limit the sulfuric acid concentration (strength) must be controlled, which requires frequent sampling and testing.[7]

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[3] *See* http://tsocorp.com/about-tesoro/locations/ and http://tsocorp.com/about-tesoro/company-history/ (accessed June 14, 2016).

[4] Olefins, also known as "alkenes," are hydrocarbons that contain a carbon-carbon double bond.

[5] A catalyst allows a chemical reaction to take place, but is not consumed by the desired reaction.

[6] The spent sulfuric acid within the refinery alkylation unit is primarily sulfuric acid but may also contain hydrocarbons, because of chemical processing operations such as intense mixing in the reactor during the alkylation process.

[7] Undesired reactions consume the sulfuric acid in the alkylation process. As a result, the acid concentration (strength) is reduced from the fresh acid concentration (approximately 98.5 weight percent) to the final "spent" acid concentration (approximately 90 weight percent). If the acid is not maintained within safe operating limits, then the reactor could suffer an acid runaway. Section 5.2 describes this further.

2.0 Introduction

2.1 The Cultural Approach to Safety

The CSB identified numerous process safety management system deficiencies in its investigation of the February and March 2014 sulfuric acid incidents at the Tesoro Martinez refinery that were causal to the incidents. This report discusses those in detail throughout the technical and organizational analysis sections, but ultimately seeks to frame many of the issues in terms of process safety culture ("safety culture") at the refinery. As industrial safety and accident analysis expert Andrew Hopkins states in his book *Safety, Culture and Risk*, the safety culture perspective "does not replace the system perspective, it augments it. No one is saying, 'ignore systems, all we need to do is get the culture right'; on the contrary, the right culture is necessary to make safety systems work."[8] Andrew Hopkins continues by noting that there is more attention paid to safety culture today partly because of the "recognition of the limitations of safety management systems as a means of achieving safety."[9] The CSB stated in its BP Texas City investigation report that experts such as Hopkins and James Reason have indicated that "safety culture, risk awareness, and effective organizational safety practices found in high reliability organizations (HROs)[10] are closely related, in that '[a]ll refer to the aspects of organizational culture that are conducive to safety.'"[11] The CSB added that these experts have noted, "safety management systems are necessary for prevention, but that much more is needed to prevent major accidents. Effective organizational practices, such as encouraging that incidents be reported and allocating adequate resources for safe operation, are required to make safety systems work successfully."[12] As such, while the report discusses many of the issues in terms of safety culture, the reader should note and seek to learn from the many systemic issues discussed, as those are imperative to worker safety.

As discussed in the CSB's Tesoro Anacortes refinery investigation report, Andrew Hopkins describes safety culture as "the way we do things around here."[13] Others simply describe safety culture as "how the

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

[9] *Ibid* at p 3.

[10] The CSB BP Texas City investigation report describes HROs as "organizations from higher risk sectors such as nuclear power plants, air traffic control, or nuclear aircraft carriers that have developed characteristics such as preoccupation with failure, reluctance to simplify, and mindfulness to operations, which enables them to more successfully manage unexpected events and suffer fewer incidents." CSB Investigation Report. *Refinery Explosion and Fire.* BP Texas City. March 2007; p 139. http://www.csb.gov/assets/1/19/CSBFinalReportBP.pdf (accessed June 20, 2016).

[11] *Ibid.*

[12] *Ibid.*

[13] CSB Investigation Report. *Catastrophic Rupture of Heat Exchanger.* Tesoro Anacortes Refinery. May 2014; p 73. http://www.csb.gov/assets/1/7/Tesoro_Anacortes_2014-May-01.pdf (accessed June 14, 2016). Citing Hopkins, Andrew. *Safety, Culture and Risk; The Organisational Causes of Disaster.* Sydney, New South Wales: CCH Australia Limited. 2005; p 7. And Center for Chemical Process Safety (CCPS), Guidelines for Risk Based Process Safety. 2007; p 40. More recently, the CSB identified that the original source of the phrase "the way we do things around here" may come from Marvin Bower's 1966 book, *The Will to Manage*. Bower, Marvin, 1966. *The Will to Manage: Corporate Success through Programmed Management.* McGraw-Hill Book Company,

organization behaves when no one is watching."[14] The CSB found that specific safety culture weaknesses at the Tesoro Martinez refinery, demonstrated by a history of alkylation unit sulfuric acid incidents, the minimization of the seriousness of process safety incidents, failure to learn from past incidents at the refinery and implement important safety lessons, taking safer sulfuric acid sampling equipment out of service, weak management commitment to robust practices and procedures, and tolerance of worker exposure to unsafe conditions, were causal to both the February and March 2014 sulfuric acid incidents.

2.2 Relevant Accident History at the Refinery

Two previous major process safety incidents at the Martinez refinery in 1997 and 1999 resulted in federal investigations.

On January 21, 1997, an explosion and fire occurred at the Hydrocracker Unit of the Martinez refinery (then owned by the Tosco Avon refinery). This incident resulted in one fatality, 46 worker injuries, and a community shelter-in-place.[15] The EPA and OSHA both investigated this incident. The EPA found in its investigation, among other things, issues surrounding safety culture, including insufficient conditions to support and encourage employees to operate reactors in a safe manner, and inadequate supervision, which both contributed to the incident.[16]

On February 23, 1999, four workers were fatally injured and one critically injured when a fire occurred in the crude unit at the Avon refinery. Workers were attempting to replace piping attached to a 150-foot tall fractionator tower while the process unit remained in operation. Refinery management failed to formulate a plan to control the known hazards of cutting into piping containing flammable naphtha liquid. During removal of the piping, naphtha released onto the adjacent hot fractionator and ignited. The flames engulfed the five workers. As this report will discuss, although ownership at the refinery changed, some of the unsafe work practices previously identified at the site continued.

Tesoro tolerated numerous sulfuric acid worker injuries during the five-year period of 2010 to 2014. These incidents provide evidence of deficiencies in the refinery's organizational policies and practices governing safe work. The fact that these incidents continued for an extended period demonstrates a culture that does not effectively prioritize worker safety. The CSB found many commonalities that are illustrative of larger safety culture issues and which suggest the refinery is not effectively implementing safety lessons from accidents.

1966. http://www.mckinsey.com/global-themes/leadership/company-philosophy-the-way-we-do-things-around-here (accessed June 6, 2016).

[14] American Institute of Chemical Engineers (AIChE), *Safety Culture: What is at Stake*? http://www.aiche.org/ccps/topics/elements-process-safety/commitment-process-safety/process-safety-culture/building-safety-culture-tool-kit/what-is-at-stake (accessed June 14, 2016).

[15] EPA. *Chemical Accident Investigation Report; Tosco Avon Refinery, Martinez, California.* November 1998; p vi. http://nepis.epa.gov/Exe/ZyPDF.cgi/10003A2E.PDF?Dockey=10003A2E.PDF (accessed June14, 2016).

[16] *Ibid* at viii.

For example, the CSB identified a history of recent sulfuric acid worker injuries listed below:

1. In June 2010, a contract worker received a chemical burn from a sulfuric acid release during nonroutine maintenance[17] to remove a piping component connected to an alkylation reactor. Tesoro's investigation identified the cause of this incident to be improper personal protective equipment (PPE) due to a belief that sulfuric acid was not present at the time. Similar to the March 10, 2014 incident this piping should not have contained sulfuric acid; instead, it is intended to provide butane to the mechanical seal for one of the alkylation reactor agitators.

2. In August 2010, a sulfuric acid leak burned a Tesoro employee when it released from a piping component located above where the employee was working on an adjacent non-acid piping system.

3. In October 2010, sulfuric acid burned a contract worker assisting with nonroutine maintenance to isolate a process vessel when it released from the acid-containing equipment.

4. In January 2012, a Tesoro worker was injured and transported to the hospital following an acid release incident from a failed temporary pump. The permanently installed pump in this service was not operable. Rather than repairing the permanent pump, Tesoro opted to install a temporary pump that was not compatible with sulfuric acid as a work-around. According to its incident investigation records, Tesoro installed this temporary pump without a Management of Change (MOC)[18] and the pump failed because it was not suitable for sulfuric acid service.

5. Later in January 2012, a sulfuric acid release burned two contract workers during nonroutine maintenance while isolating a process vessel in preparation for a larger maintenance activity.

6. In February 2012, sulfuric acid burned a contract worker during nonroutine maintenance to replace a valve.

7. In August 2012, sulfuric acid burned a Tesoro employee when it drained from a hose that was disconnected above the location where he was working.

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[17] Nonroutine maintenance refers generically to activities that do not happen frequently and where a procedure does not address the required actions.

[18] Under OSHA's Process Safety Management (PSM) Standard, proposed changes to a process must be analyzed to determine their technical basis, required authorizations, and impact on health and safety. 29 C.F.R. § 1910.119(l) (2012). The EPA's Risk Management Plan (RMP) Rule also requires Management of Change under 40 C.F.R. § 68.175(i).

8. Later in August 2012, almost eight months after the January 2012 chemical burn injury from the temporary pump (incident No. 4 above), the hose to the temporary pump failed because it was also not suitable for sulfuric acid service. This incident injured two Tesoro workers. One worker received chemical burns to the face from sulfuric acid and the second worker injured his knee when he slipped on the sprayed acid. The temporary hose remained in service for nearly eight months and was determined after the incident to be incompatible with sulfuric acid.[19]

9. Also in August 2012, sulfuric acid sprayed a Tesoro employee while working to mitigate a piping leak to one of the alkylation unit reactors.

10. In September 2012, sulfuric acid injured a contract worker when it sprayed from tubing to one of the alkylation reactors during a nonroutine maintenance activity needed to prepare the reactor for maintenance.

11. In January 2013, sulfuric acid burned a contract worker while disconnecting a hose that Tesoro records indicate had not been in sulfuric acid service; unknown to the worker, acid had entered into the hose from an unanticipated source.

12. In May 2013, sulfuric acid sprayed a Tesoro employee while working on instrumentation connected to an alkylation reactor. A leaking valve had pressured the system with hydrocarbon and sulfuric acid.

13. In November 2013, sulfuric acid sprayed a Tesoro employee while preparing sulfuric acid piping for maintenance following a mechanical integrity failure.

[19] Tesoro could have identified and controlled this hazard by performing a MOC or by more thoroughly investigating the January 2012 incident (incident 4 above).

3.0 February 12, 2014 Incident

3.1 Incident Description

On February 12, 2014, two employees at the Tesoro Martinez refinery in Martinez, California, suffered first and second degree chemical burns while working to put a sulfuric acid sampling system[20] in the refinery's alkylation unit back in service following nonroutine maintenance. As will be further discussed below, concentrated sulfuric acid sprayed two workers following a mechanical integrity failure of a ¾-inch tubing connector adjacent to the acid sampling station.

The incident occurred when the operators opened a valve (Figure 2) to return an acid sampling system back to service (Figure 3). Shortly after fully opening this valve, the tubing directly downstream of the valve came apart at the connector, spraying the two operators with acid. The operators immediately went to a nearby safety shower. Until responders were able to isolate the system, acid continued to spray out of the failed tubing for over two hours from a nearly 100,000-gallon acid settler[21] that was operating below 100 pounds per square inch gauge (psig) and near the ambient temperature of approximately 50 degrees Fahrenheit (ºF). This resulted in the release of approximately 84,000 pounds of sulfuric acid.

At the time of the incident, the two employees were wearing the personal protective equipment (PPE) required by company policy to put the sample system back in service – hard hat, safety shoes, goggles, flame retardant jacket and coveralls, and gloves. This PPE was, however, insufficient to protect against an acid spray injury. Emergency responders transferred the workers by helicopter and ambulance to the UC Davis Regional Burn Center for evaluation and treatment of their sulfuric acid burn injuries. Neither employee returned to work for over 150 days.[22] Despite the serious nature of the employee injuries and quantity of hazardous chemicals released from the loss of containment,[23] Tesoro challenged the CSB's

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[20] A sampling station is industry terminology for the tubing, valves, and other equipment used to obtain a sample of process fluid needed for analysis. This sampling station design at Tesoro Martinez allowed for collection of two samples: one for immediate density analysis by the operator and a second for laboratory analysis to determine the weight percent acid.

[21] In brief, the acid settler receives sulfuric acid and hydrocarbon from alkylation reactors. The settler operates full of liquid and provides a low velocity area in order to allow the hydrocarbon and sulfuric acid to separate into separate liquid layers. Liquid enters the settler as an emulsion that gradually separates into a top layer that contains mostly hydrocarbon and a bottom layer that primarily consists of sulfuric acid.

[22] One worker returned to work on July 15, 2014 (153 days) and the second worker returned to work on August 4, 2014 (173 days).

[23] The American Petroleum Institute (API) applies a "Tier" approach to classify the significance of a process safety event, ranging in decreasing severity from Tier 1 through Tier 4. Tier 1 represents "loss of primary containment" incidents with the "greatest consequence." The February 12, 2014 incident is a Tier 1 process safety event. The incident resulted in "days away from work" injuries for two workers and released approximately 84,000 pounds of concentrated sulfuric acid, 34,195 pounds per hour for 148 minutes. API. *Recommended Practice 754: Process Safety Performance Indicators for the Refining and Petrochemical Industries.* April 2010; pp 8-9.

authority to investigate the incident and failed to preserve key evidence.[24] Tesoro corporate officials characterized the incident as a minor personal safety event rather than a process safety incident.[25, 26]

Based on information – including alkylation unit worker testimony – that the unit was not safe, the California Division of Occupational Safety and Health (Cal/OSHA) required the process to remain shut down from February 18, 2014 until February 28, 2014, when Tesoro completed abatement of the items identified in the order to prohibit use.[27] The Cal/OSHA Process Safety Management (PSM) Unit investigated the incident and issued citations totaling $51,450.[28] The citations were later reduced to three general and one serious, for a total penalty of $43,400.

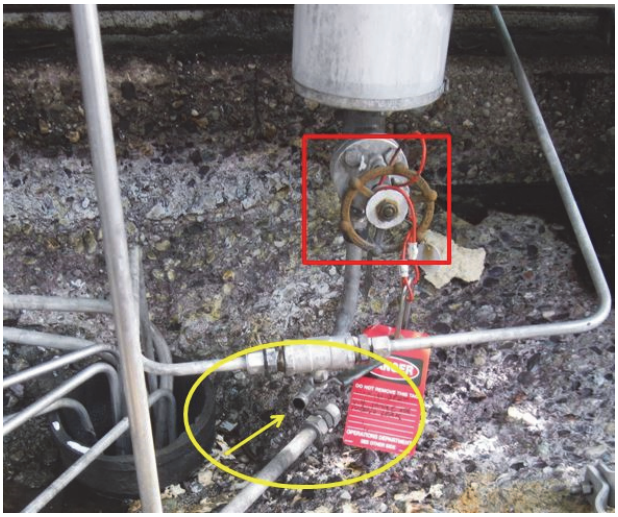

Figure 2. Photo showing the tubing that separated (yellow oval) after the valve (red square) was opened in order to return the sample system back to service following maintenance. Two workers were injured from this acid release incident on February 12, 2014. This loss of containment from the open-ended tubing released 84,000 pounds of sulfuric acid.

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[24] Tesoro did not obtain a sample of the sulfuric acid in the settler as requested by the CSB following the February 12, 2014 incident. The CSB was interested in this sample because investigators learned during the investigation that the physical characteristics of the released acid appeared unusual to witnesses. In addition, Tesoro replaced the agitator coupling for the alkylation reactor Tesoro workers quickly shut down prior to the February 12, 2014 acid release without providing CSB investigators the opportunity to inspect and document its condition. Tesoro workers described an unusual "grinding noise" from this adjacent reactor just prior to the acid release.

[25] The CSB investigation report on the 2005 BP Texas City refinery incident emphasized the distinction between personal safety and process safety. Personal safety is commonly described as slips, trips, and fall type incidents. Process safety addresses the control and prevention of fires, explosions, and accidental uncontrolled releases of hazardous substances. Process safety can be further simplified as the management systems that ensure that hazardous chemicals stay inside the pipes and equipment. *See* http://www.csb.gov/bp-america-refinery-explosion/ (accessed June 14, 2016).

[26] The 100,000-gallon acid settler contains a flammable hydrocarbon liquid layer above the sulfuric acid layer. Had the sulfuric acid drained out, the flammable hydrocarbon layer on top of the acid would have followed, likely resulting in an escalation of the incident with the potential for an explosion and fire.

[27] Issuing an Order to Prohibit Use is an enforcement action that Cal/OSHA infrequently implements.

[28] Cal/OSHA citations included mechanical integrity related to the sample station tubing, PPE required for sampling, and process hazard analysis (PHA) deficiencies related to sampling. Cal/OSHA ultimately withdrew the PHA and mechanical integrity citations.

Figure 3. Photo showing the sulfuric acid sampling station at the Tesoro Martinez refinery. The photo on the left shows the sample station just after the February 12, 2014 incident and the photo on the right shows the sample station after repairs were made and the alkylation unit was again operating. Workers informed the CSB that the concrete containment area, clearly visible in the photos above, had badly deteriorated from routine exposure to sulfuric acid.

3.2 Technical Analysis

The sample system involved in the February 12, 2014 incident was out of service for maintenance beginning November 26, 2013 due to leaking tubing and an improperly manufactured sample container. Despite the sample system being out of service, the alkylation unit continued to operate as usual. Tesoro technical personnel stated to the CSB that this sample station was not essential to daily operation of the alkylation unit. The alkylation unit technology licensor, however, recommends sampling this acid once per day to verify instrumentation and controls are functioning properly. Tesoro performed maintenance on the sample system on February 10 and 11, 2014, which included replacing the container. Due to maintenance program deficiencies including gaps in planning, documentation, and communication, Tesoro did not effectively repair or leak-test the tubing prior to placing it back in service. The Tesoro Martinez refinery did not require workers to leak-test tubing of this type following repairs.

In an agreement among the CSB, Cal/OSHA, and Tesoro, the CSB commissioned Anamet, Inc., a materials engineering and laboratory testing company, to conduct testing on the failed tubing (Figure 4). The CSB released a technical evaluation report detailing the testing results and conclusions on August 15,

2014.[29] The report concluded that the sulfuric acid release on February 12, 2014 resulted from the failure of a ¾-inch diameter stainless steel tubing connector that came apart due to insufficient tightening between a tube and a compression joint at the sulfuric acid sampling station.

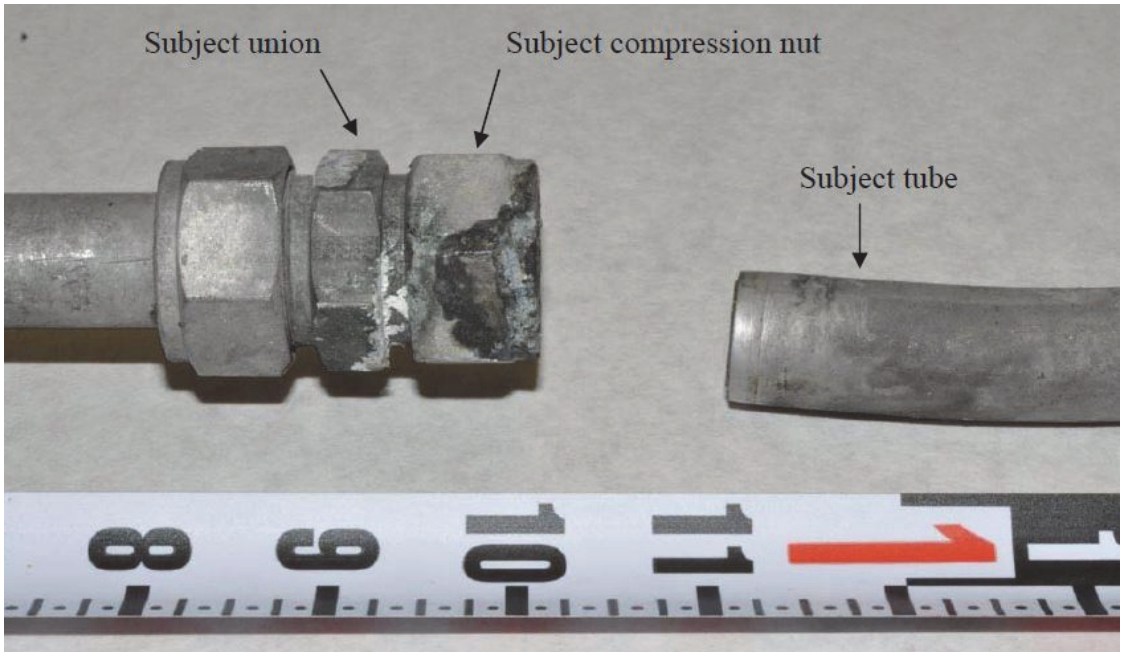

Figure 4. Photo of the tubing connection that failed and resulted in the February 12, 2014 incident. This photo is from the CSB's technical evaluation report that determined the compression joint was insufficiently tightened.

Following the February 12, 2014 incident, maintenance workers also found an inadequately tightened compression fitting for an adjacent sample station. This tubing connector did not fail during start-up like the other connector, however, because the tubing was wedged against a concrete wall, holding it in place.

[29] Anamet, Inc. Examination of a 0.75-Inch Diameter Stainless Steel Tube Compression Joint Involved in the Tesoro Martinez Acid Spill that Burned Two Workers on February 12, 2014. *See* http://www.csb.gov/assets/1/7/Tesoro_Martinez_Metallurgical_Report.pdf. (accessed June 14, 2016). Figure 11 of this metallurgical report shows a sectioned example of a properly installed compression fitting.

3.3 Analysis of Sulfuric Acid Sampling System Design

As the CSB discussed in many of its investigation reports, the effective implementation of inherently safer design[30] and the hierarchy of controls[31] are key to reducing risks and preventing major accidents. In January 2010, the Tesoro Martinez refinery made a substantial financial investment in what the refinery asserted was a more robust, "inherently safer" sampling system, which the refinery then failed to make operable and took out of service.[32] On February 12, 2014, workers were putting the older, poorly designed system back into service when the incident occurred. The CSB notes that although the February 12, 2014 incident did not occur during acid sampling, differences in Tesoro Martinez operations and maintenance work practices meant that the workers would have leak-tested the piping and flanges in the sample system that was taken out of service, but not the tubing and fittings in the old system being brought back into service. The Tesoro Martinez refinery management therefore continued to rely on the older sampling system that they acknowledged presented a greater risk to workers.

To learn how other companies that operate refineries with sulfuric acid alkylation units controlled hazards from acid sampling, the CSB requested and received cooperation from two local refineries – Company X and Company Y. The CSB's review of these companies' sample systems revealed superior sampling equipment through more effective application of the hierarchy of controls. Both companies' sample systems emphasized engineering controls (such as more robust piping) in addition to administrative controls (such as PPE).

3.3.1 Tesoro Martinez Refinery Sample Systems

Sulfuric acid sampling systems at the Tesoro Martinez refinery routinely exposed operators to avoidable risks. Even when conducted as Tesoro intended, the sampling process generated a hazardous white vapor cloud likely consisting of acid gas and hydrocarbon vapor when the material drained from the acid settler to the process chemical sewer. This poses an obvious respiratory hazard to operators engaged in

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[30] The Center for Chemical Process Safety (CCPS) defines inherently safer design as the process of identifying and implementing safety in a specific context that is permanent and inseparable from the process. Center for Chemical Process Safety (CCPS). *Inherently Safer Chemical Processes – A Life Cycle Approach.* 2009; Section 2.2. In the book *Guidelines for Engineering Design for Process Safety,* the CCPS states "inherently safer design solutions eliminate or mitigate the hazard by using materials and process conditions that are less hazardous." Center for Chemical Process Safety (CCPS). *Guidelines for Engineering Design for Process Safety*, 2nd ed., 2012.

[31] The hierarchy of controls is a concept that refers to the ranking of the safety potential of various strategies for hazard management from most to least effective. Even if a greater risk-reduction action, such as minimizing hazardous chemicals, is used, it is still important to maintain other, lower level, administrative controls, such as wearing adequate personal protective equipment (PPE). This way even if one risk reduction system fails others are in place to prevent or minimize the incident's impact. Prevention and mitigation strategies represent the safeguards designed to eliminate, prevent, reduce, or mitigate a scenario; they are also referred to as barriers, layers of protection, lines of defense, or control measures. CSB Investigation Report. *Catastrophic Rupture of Heat Exchanger*. Tesoro Anacortes Refinery. May 2014; pp 34-35. http://www.csb.gov/assets/1/7/Tesoro_Anacortes_2014-May-01.pdf (accessed June 20, 2016).

[32] The CSB notes this is not the only example of the Tesoro Martinez refinery postponing efforts to correct problems with more robust equipment. Examples include the permanent pump identified in the January and August 2012 incidents summarized above in the Introduction.

sampling. Additionally, due to the dangers this sampling station presented, the Tesoro Martinez refinery's acid sampling procedure required operators to evacuate nearby workers from the area prior to initiating the sampling procedure. Rather than reengineering the process to eliminate the vapor cloud, Tesoro placed burlap bags around the process sewer drain opening to attempt to reduce the size of the vapor cloud generated by the sampling process (Figure 5).

Figure 5. The photo on the left shows a burlap bag covering the process sewer drain at one of the Tesoro Martinez refinery sulfuric acid sample stations. The photo on the right shows the white vapor cloud released from the process sewer drain when Tesoro operators conduct the procedure to sample the sulfuric acid.

Although the Tesoro Martinez refinery's acid sampling procedure warns that "acid fumes are harmful if inhaled" and that "extreme caution must be used to prevent irritation and/or injury from acid fumes," the procedure did not recommend or require any respiratory protection to be worn (Figure 6). Tesoro operators informed the CSB that during acid sampling, their personal gas monitors routinely alarmed, indicating the presence of harmful sulfur dioxide gas.[33] Furthermore, Tesoro operators informed the CSB that despite the fact that Tesoro Martinez required four items of PPE, the workers only wore the goggles and chemical gloves. The workers did not use the acid suit jacket required by the procedure because Tesoro stopped carrying this item in its PPE inventory. Operators also explained that because the face shield attachment interfered with how the goggles attached to the operators' hard hats, they never wore the shields.

[33] Tesoro records state that sulfur dioxide is a colorless, corrosive, toxic gas with an irritating pungent odor that can be perceived as "burnt matches." Cal/OSHA defines the Short Term Exposure Limit (STEL) as a 15-minute time-weighted average exposure, which is not to be exceeded at any time during a workday even if the 8-hour time-weighted average is below the PEL. *See* https://www.dir.ca.gov/title8/5155.html (accessed June 14, 2016). Cal/OSHA has set the STEL for sulfur dioxide as five parts of gas or vapor per million parts of air by volume at 25 °C and 760mm Hg pressure. *See* https://www.dir.ca.gov/title8/5155table_ac1.html (accessed June 14, 2016). Sulfur dioxide is a toxic gas that is immediately dangerous to life and health at a concentration of 100 parts per million. *See* http://nj.gov/health/eoh/rtkweb/documents/fs/1759.pdf (accessed June 14, 2016).

PERSONAL PROTECTIVE EQUIPMENT	Standard P.P.E. is required (refer to R&SI 11-1). Additional P.P.E. requirements: Personal Protective Equipment is required during sampling: Face shield Goggles Chemical gloves Acid suit jacket Operator must know the location of the closest safety shower at all times.

Figure 6. Excerpt of Tesoro's sulfuric acid sampling procedure detailing the personal protective equipment (PPE) requirements. Tesoro workers informed the CSB that of the four items of PPE required by Tesoro, only goggles and chemical gloves were actually worn.

After the February 12, 2014 incident, Tesoro upgraded the PPE requirements during acid sampling to include a full acid suit and air-purifying respirator (Figure 7).

Figure 7. Photos of an operator at the Tesoro Martinez refinery taking a sulfuric acid sample. These photos were taken following the February 12, 2014 incident with the new PPE requirements in place. Tesoro's sulfuric acid sampling system requires two separate one-hour waiting periods to allow hydrocarbons to vent to the atmosphere. In addition to potential liquid acid exposure, the sampling process exposes the operator to hydrocarbon vapor, and sulfuric acid vapor. Following the incident, Tesoro upgraded the PPE requirements to include a full-face respirator and a full-body acid suit.

In its 2009 process hazard analysis (PHA), Tesoro evaluated the hazards of sampling sulfuric acid. Tesoro's PHA documentation indicates that the PHA Team identified the sampling hazard to have a potential severity of a lost workday injury, which they anticipated to be likely to occur within 20 years. Tesoro's PHA risk matrix identifies this combination of severity and frequency to be "low risk." The PHA team listed PPE as the only safeguard necessary to mitigate the worker injury hazard despite the fact that not all of the PPE required by the procedure was available. In addition, workers could not use some of the required PPE due to the incompatibility of the face shield, hard hat, and goggles. In its 2013 PHA, Tesoro did not specifically evaluate the hazards of the sulfuric acid sample stations. Instead, a human factors checklist was used to cover the sample systems. The checklist questions did not evaluate sampling system hazards and were limited to evaluating issues involving accessibility, such as the proximity to safety showers, eyewash stations, and transport of samples from elevated locations. Therefore, they were unlikely to trigger an effective evaluation of the sulfuric acid sampling system hazards. In addition, the report from Contra Costa County's inspection following the February 12, 2014 incident concluded that neither the 2009 nor the 2012 alkylation unit PHAs adequately evaluated the hazards associated with the acid sample stations.[34]

Tesoro approved a project to install new closed loop sample systems in June 2009 (Figure 8). Tesoro designed these systems to be a significant upgrade to the existing sample stations, with the goal of minimizing operator exposure to the sulfuric acid when sampling, among other important reasons. Tesoro stated this new design was inherently safer than the existing sample system. Tesoro's design improvement records show:

> "Closed loop sampler design is inherently safe and will protect Operators against exposure to strong sulfuric acid when sampling."
>
> "New closed loop sampler is simple to use and involves the use of only two valves each time a sample is taken. The isolation valve is spring loaded and must be held open to take a sample; thus, insures [sic] against the sampler being left open and accidentally spilling sulfuric acid or venting nitrogen to the atmosphere."

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[34] Contra Costa County conducted an inspection of the alkylation unit at the Tesoro Martinez refinery following the February and March 2014 incidents. CCHMP issued a report *Compliance with California Accidental Release Prevention (CalARP) & Contra Costa County Industrial Safety Ordinance (ISO) Programs: Alkylation Unit Inspection Report: Trade Secret Version* on November 10, 2015. The 145-page report identified 50 regulatory concerns and developed 70 improvement suggestions to Tesoro. The 120 regulatory and improvement items identified by the Contra Costa County inspection report covered a broad range of process safety management categories, including: operating procedures; mechanical integrity; management of change; incident investigation; process safety information; process hazard analysis; human factors applications; safe work; management of organizational change; miscellaneous; and management systems. CalARP is an acronym for the California Accidental Release Program. *See* http://www.caloes.ca.gov/FireRescueSite/Documents/CalARP%20Regulations%2001012015.pdf (accessed June 14, 2016).

> "The samplers will be located at waist level or slightly higher so that the Operators won't have to bend or stretch to take a sample."

Figure 8. Photo showing one of the upgraded sample stations that Tesoro installed to reduce operator exposure to acid during sampling. Tesoro never resolved the reliability issues with these sample stations and the sample stations were taken out of service. As a result, they were not in use at the time of the February 12, 2014 incident.

In addition to the safety improvements, the justification Tesoro stated for these upgraded sample systems included ensuring compliance with environmental regulations and a significant annual cost savings of approximately $300,000. Despite the significant cost to purchase and install the improved sample systems, Tesoro records show the new equipment would have a two-year payback time. Tesoro based the quick return on this investment on the company's expectation that these new sample systems would allow the operations staff to further lower the spent sulfuric acid concentration. Due to reliability problems with these upgraded sample systems, however, Tesoro ceased efforts to make them functional and took them out of service.[35] These problems included plugging, foaming of the collected sample, and problems with the nitrogen purge supply. According to Tesoro employee statements made to the CSB, Tesoro Martinez laid off the contract engineer responsible for identifying and correcting the sample system reliability problems.

Consequently, Tesoro relied on the old sample systems, the use of which resulted in the February 2014 sulfuric acid release incident that injured two workers. Ultimately, Tesoro continued to rely on PPE as the control method, which is a less effective method than engineering controls on the hierarchy of controls. As Tesoro did not provide appropriate PPE and compliance with PPE expectations were not reinforced, inadequate controls were in place to protect workers from the sulfuric acid hazards.

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[35] As of May 2016, the more robust sample systems were still not in service; however, Tesoro stated to the CSB that they are actively working with the supplier to address reliability and safety concerns.

3.3.2 Tesoro Los Angeles Refinery Sample Systems

Tesoro records indicate that the Martinez refinery's sulfuric acid alkylation unit acid sampling system has more potential for operator exposure to acid than those in use at the other Tesoro refinery in California, Tesoro's Los Angeles refinery, which uses an enclosure around the sampling system to protect operators from potential acid spray (Figure 9).

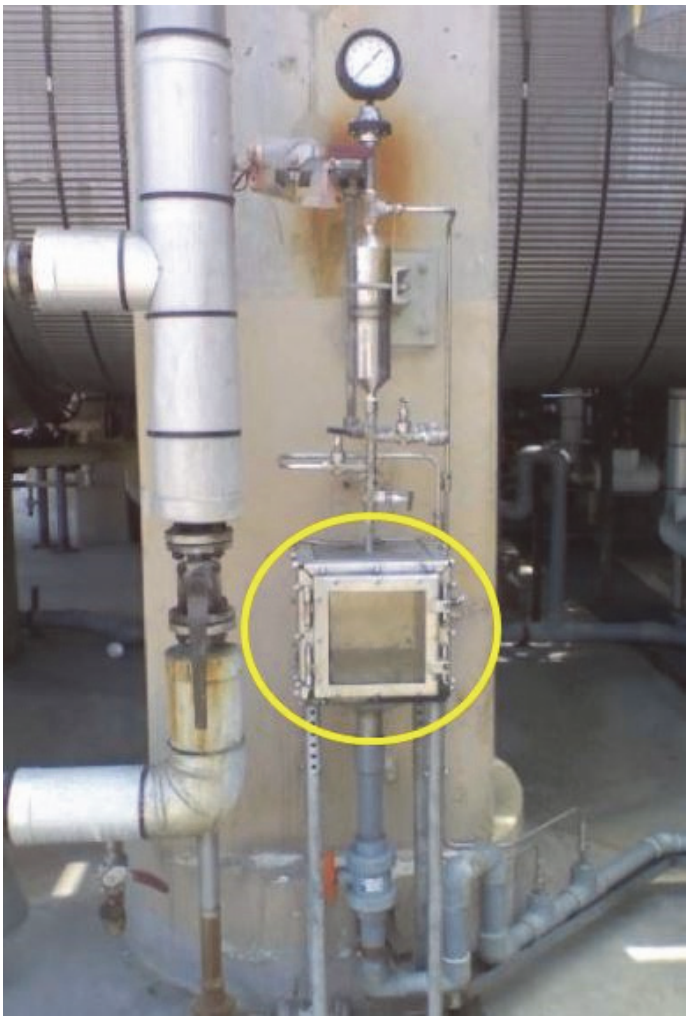

Figure 9. Photo of the sulfuric acid sample station at the Tesoro Los Angeles refinery. This sample system includes an enclosure at the sample point to protect operators from potential acid spray.

3.3.3 Company X Refinery Sample Systems

Company X refinery's sulfuric acid alkylation unit acid sampling equipment (Figure 10) is similar to the inherently safer system that Tesoro installed but took out of service. Company X initiated efforts to upgrade its alkylation unit sample stations in 2012. The design justification for the upgrade includes improved design that would be safer because it would minimize the potential for worker exposure to sulfuric acid. Company X also uses a more robust piping material due to the "extremely high" corrosivity of the sulfuric acid. Company X installed these sample systems in 2013 and the CSB learned that although these systems had some initial reliability problems similar to those Tesoro Martinez experienced, Company X successfully transitioned to its more robust sample systems.

Figure 10. Photo of the sulfuric acid sample station at the Company X refinery. The photo on the left shows a typical sample station used by Company X workers to obtain sulfuric acid samples. The photo on the top right shows a typical sample bottle and the photo on the bottom right shows the sample bottle installed to obtain a sample.

3.3.4 Company Y Refinery Sample Systems

Acid sampling equipment within the sulfuric acid alkylation unit at the Company Y refinery is also more robust than the system at Tesoro Martinez involved in the February 12, 2014 incident.[36] Company Y's acid sampling equipment consists primarily of piping with only a short section of tubing used to collect the acid sample (Figure 11). The sampling equipment (piping, valves, and tubing) used by Company Y is better designed and maintained than the equipment at the Tesoro Martinez refinery (left photo in Figure 3).

Figure 11. Photo of the sulfuric acid sample station at the Company Y refinery. The photo shows a typical sulfuric acid sampling station at the refinery. The yellow circle identifies the location where the operator obtains the acid sample.

[36] Required sampling PPE at the Company Y refinery includes goggles, face shield, rubber gloves, and a rubber apron.

3.4 Organizational Analysis

The Tesoro Martinez refinery's practices of taking more robust equipment out of service, tolerating unnecessary worker exposure during sampling, and failing to ensure effective PPE all point to weaknesses in the refinery's alkylation unit safety culture.

3.4.1 Equipment Testing and Postponing Upgrades

Tesoro requires workers to leak-test instrument tubing after installation and prior to initial operation, but there is no requirement to leak-test process tubing, such as the sample system tubing, after making modifications or repairs. In addition, piping and larger equipment would be leak-tested before putting them into service after maintenance repair work, but tubing such as that used for the acid sampling systems was not leak-tested. Workers at the site recognized the discrepancy but were not sure why Tesoro differentiated tubing this way. When asked why process tubing was not leak-tested prior to putting equipment back in service following nonroutine maintenance, such as repairs conducted the day before the February 2014 incident, one worker stated, "I'm not sure why. We just don't."

As previously described, Tesoro installed, but later ceased efforts to implement a more robust sulfuric acid sampling system. Taking the sample systems out of service that Tesoro had installed to protect workers and continuing to rely on the old sample systems that posed unnecessary risks to operators in terms of acid exposure further demonstrates a weak commitment to safety.

This type of decision-making also continued a trend of postponing completion of important equipment upgrades at the Tesoro Martinez refinery that led to subsequent worker injuries from sulfuric acid releases. For example, two additional acid release incidents that occurred in January and August 2012 (listed as incidents 4 and 8 in the Introduction) both occurred as the result of ceasing efforts to repair permanent equipment. Instead, Tesoro installed temporary equipment that was not compatible with sulfuric acid. In January 2012, a temporary pump failed and injured one worker. But Tesoro's investigation of the January 2012 incident did not trigger a thorough hazard review of the temporary equipment and a temporary hose that was not compatible with sulfuric acid remained in service, but then subsequently failed in August 2012, injuring two more workers.

3.4.2 PPE Unavailability and Insufficiency

As noted above, Tesoro Martinez operators informed the CSB that Tesoro failed to make important PPE, the acid suit jacket, required by refinery sulfuric acid sampling procedures available for operators to use. When confronting a particular safety issue, a company with a robust safety culture would use a hazard analysis to identify appropriate controls to minimize and mitigate the effects of those hazards. A culture that fosters safety should ensure that controls such as procedures reflect actual practices and address problems with PPE so that workers have the equipment they need, and that all PPE is functional. The required PPE was either not available, or did not fit correctly, and therefore Tesoro workers did not wear it. Tesoro alkylation unit operators stated that of the four items of PPE required by Tesoro, they only wore the goggles and chemical gloves. The workers stated that they did not use the acid suit jacket

required by the sampling procedure because Tesoro stopped carrying this item in its PPE inventory several years before the February 2014 incident. In addition, operators did not wear the required face shield because it interfered with how the goggles attached to the operators' hard hats. As a result, operators stated that they never wore the face shields.

Some worker comments from a 2013 Tesoro Martinez refinery safety culture survey (discussed in more detail in Section 5.1) also reflect PPE availability problems at the refinery. Workers provided the following verbatim comments in the 2013 safety culture survey:

> "Selection & availability & maintenance of necessary PPE has slipped to unacceptable conditions. This needs to be addressed & fixed."
>
> "PPE is out of stock or tough to get at the unit most times."
>
> "We no longer keep an adequate amount of PPE on hand."

3.4.3 Production vs. Safety

In Tesoro's 2013 safety culture assessment, some worker comments identified other weaknesses as well – weak safety values and a weak commitment to process safety. Tesoro Martinez alkylation unit workers informed the CSB that they believed the culture at the refinery favored production over safety, and management and workers alike were often hesitant to initiate a shutdown. A Tesoro operator told the CSB that during the February 12, 2014 incident, he had to use his stop work authority to promptly shut down the unit and disregard perceived management pressure to keep the unit operating during the 84,000-pound sulfuric acid release.[37] The operator knew that if the acid drained out, the flammable hydrocarbon layer on top of the acid would follow, likely resulting in an escalation of the incident with the potential for an explosion and fire. Some alkylation unit workers informed the CSB, however, that not all workers would exercise their stop work authority due to a history of perceived retaliation at the facility for exercising stop work authority.

3.4.4 Caustic Sampling Issues

Tesoro Martinez alkylation unit operators informed the CSB that the sodium hydroxide solution ("caustic") sampling systems were even more hazardous than the sulfuric acid sampling systems. One employee explained that industrial hygienists and other safety staff accompanied him on a tour in order to observe employees taking a sample of caustic, which they witnessed periodically splattering from pockets of butane. This required the relocation of staff from the adjacent areas and temporary work stoppage until sampling ended. Another alkylation unit operator corroborated this, explaining the various Tesoro personnel who he brought to the area to show "how the caustic blows back" when operators take caustic samples. He stated that the "battle" over caustic spray incidents had been going on for "years and years" without the refinery resolving the issue. The employee explained:

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[37] Tesoro records indicate unit shutdown was initiated 16 minutes after the sulfuric acid release began.

> "You crack it open a little bit and it just spits out. And you have to hide yourself behind piping to shield yourself from anything. It's like one of the only defenses that you have."

In addition, Contra Costa County's report, detailing the results from its inspection conducted after the February 12, 2014 acid release incident, stated that Tesoro's 2012 PHA identified the hazards caustic sampling presented to workers, but did not ensure the hazard would be corrected. The PHA stated, "[p]otential personnel exposure concerns to caustic and butane during sampling due to sample point not being a closed system. Operations experience suggests that foaming and HC [hydrocarbon] flashing causes caustic to spray out of the sample point increasing personnel exposure risk." The county's report also noted that no PHA recommendations were made as the "[t]eam noted that plans exist to upgrade the sampling systems." Upgrades to the caustic sampling systems did not occur, however, until after the February 12, 2014 sulfuric acid release incident that injured two workers.

An alkylation unit employee also reported that personal gas monitors for sulfur dioxide "always go off" (alarm) during caustic sampling. Alkylation unit operators reported numerous incidents involving workers being sprayed during caustic sampling, but also stated that there is underreporting of the incidents despite the widespread number of occurrences. CSB investigators learned from alkylation unit workers that these caustic spray incidents result in workers using the safety showers, but the workers "don't want to report it" as a caustic spray incident, so they will say that they are "washing their hands" instead of washing the caustic off of their faces.

> "You know you're not washing your hands. You don't wash your hands out there. Okay. But if they're getting it off their face, and they don't want to report it, you know, just like I said, in fear of Tesoro."

Finally, following the February 12, 2014 incident, workers informed Cal/OSHA safety engineers about their safety concerns with the alkylation unit caustic sampling systems. Cal/OSHA referenced these sample systems in its order to prohibit use. With respect to the caustic sampling systems, the Cal/OSHA order stated:

> Operators state they are afraid to take caustic samples. The lines [piping] they use to get the Caustic samples always plug up on them and they have to hit the pipes with something to free the plug. They use a 1½-inch pipe with a cup on the end of it to grab the sample so they are very close to the caustic when they try to clear the line from the plugging. They also get bubbles of butane in the stream of caustic which causes the caustic to splatter out at them.

Following Cal/OSHA's enforcement efforts, Tesoro modified all of the caustic sampling stations to minimize worker exposure to caustic prior to resuming production at the alkylation unit. Furthermore, since Tesoro Martinez had no procedure to take caustic samples, Tesoro developed one and trained workers on it, in order to improve safety when sampling caustic. Tesoro Martinez also increased the PPE requirements during caustic sampling to include an acid suit and an air-purifying respirator.

4.0 March 10, 2014 Incident

4.1 Incident Description

On March 10, 2014, sulfuric acid sprayed two contract workers while they conducted planned nonroutine maintenance work to remove approximately 40 feet of 1-inch piping in the same alkylation unit. The sulfuric acid sprayed the two workers when they cut into the piping using a portable band saw (Figure 12, Figure 13, and Figure 14). The piping was not adequately drained of process chemicals and remained under pressure despite Tesoro issuing a hot work permit to cut and remove a portion of the piping. This piping normally carries butane[38] liquid to the mechanical seal[39] of the alkylation reactor agitator (mixer), but at times has had sulfuric acid in it when the alkylation reactor pressure exceeds the butane supply pressure.

Although the maintenance workers were wearing protective suits while performing the work as a precaution for potential residual sulfuric acid, the acid still burned them. The hood of one worker's acid suit caught on scaffolding as he evacuated from the temporary work platform, exposing his head and neck to the spraying acid. Acid drained onto the second worker's neck and burned him while removing his PPE during decontamination in the safety shower. An ambulance transported both workers to a local hospital for evaluation and treatment of their first and second-degree chemical burn injuries. The Cal/OSHA PSM Unit investigated the incident and issued citations totaling $13,500 to the contractor and $45,970 to Tesoro.[40]

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[38] Although this utility system was commonly referred to as butane, Tesoro engineering documents indicate it is a hydrocarbon mixture that operates at approximately 150 pounds per square inch gauge (psig) and 20 °F and consists of approximately 79 weight percent (%) isobutane, 16% butane, and 5% other hydrocarbons.

[39] Mechanical seals are used to keep the contents of rotating equipment such as pumps and compressors from escaping. They do this by sealing the shaft that protrudes from the casing.

[40] Citations issued to the contractor included issues surrounding the proper use of PPE. Citations issued to Tesoro included missing pressure gauge in field that was shown on piping and instrument diagram, safe lockout and tagout, failure to confirm depressuring of line, and lack of safety procedures. The citations to Tesoro were later reduced to one general and one serious citation.

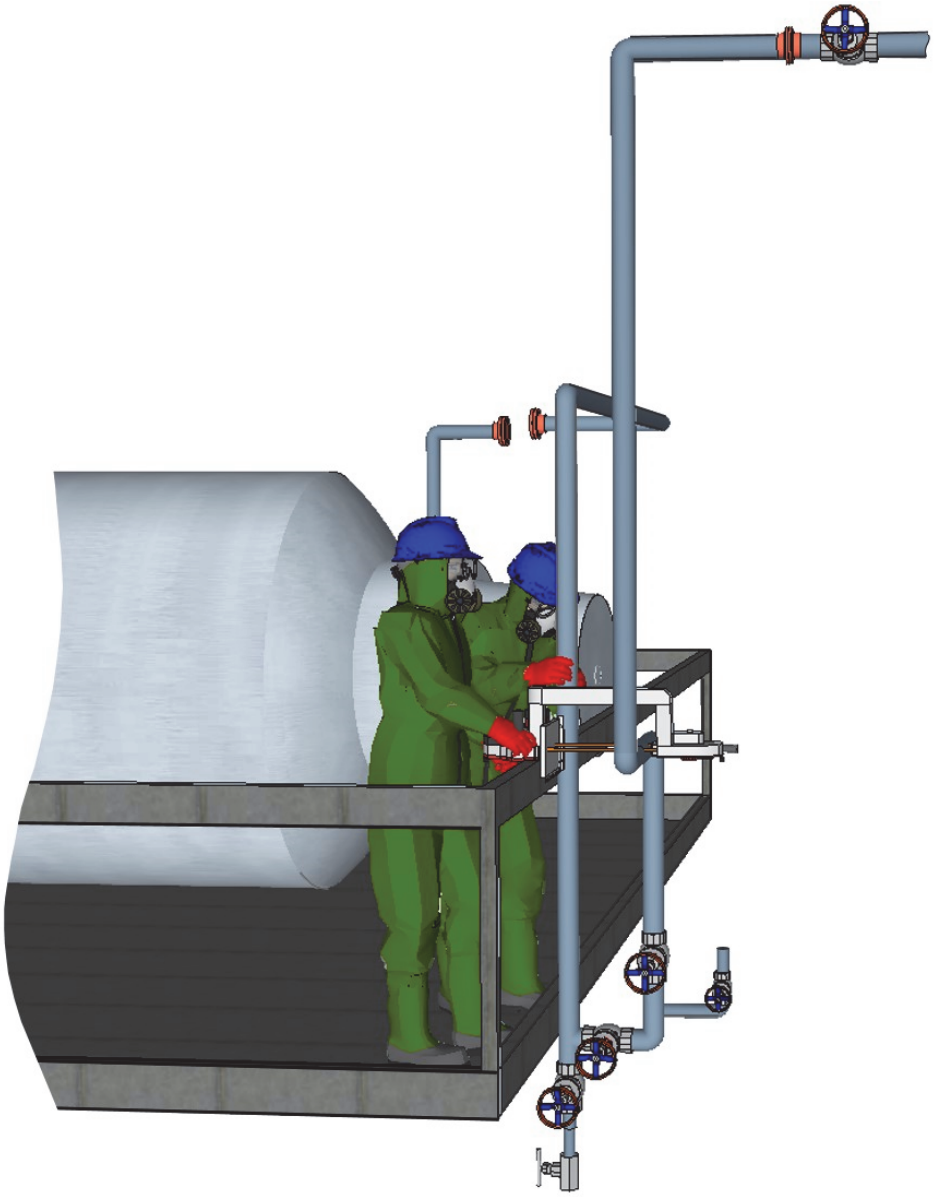

Figure 12. CSB depiction of the workers cutting the 1-inch butane piping just prior to the sulfuric acid spray incident on March 10, 2014.

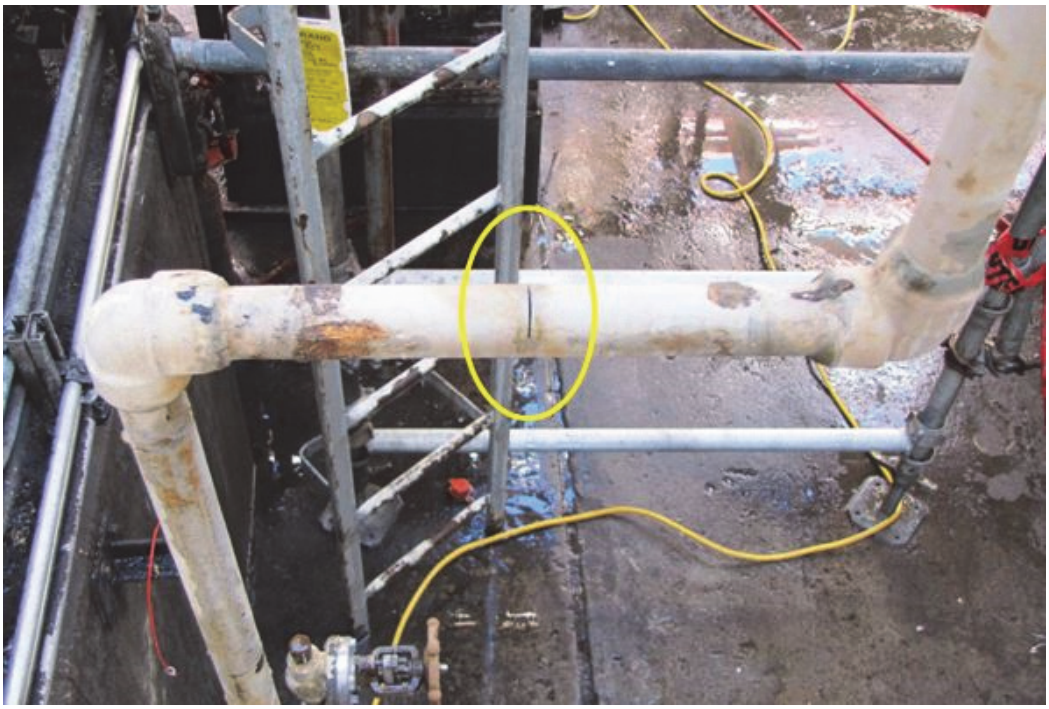

Figure 13. Photo of piping involved with the March 10, 2014 incident. The yellow oval shows the cut the workers made using a band saw that resulted in the acid release. Figure 14 also shows the location of this piping.

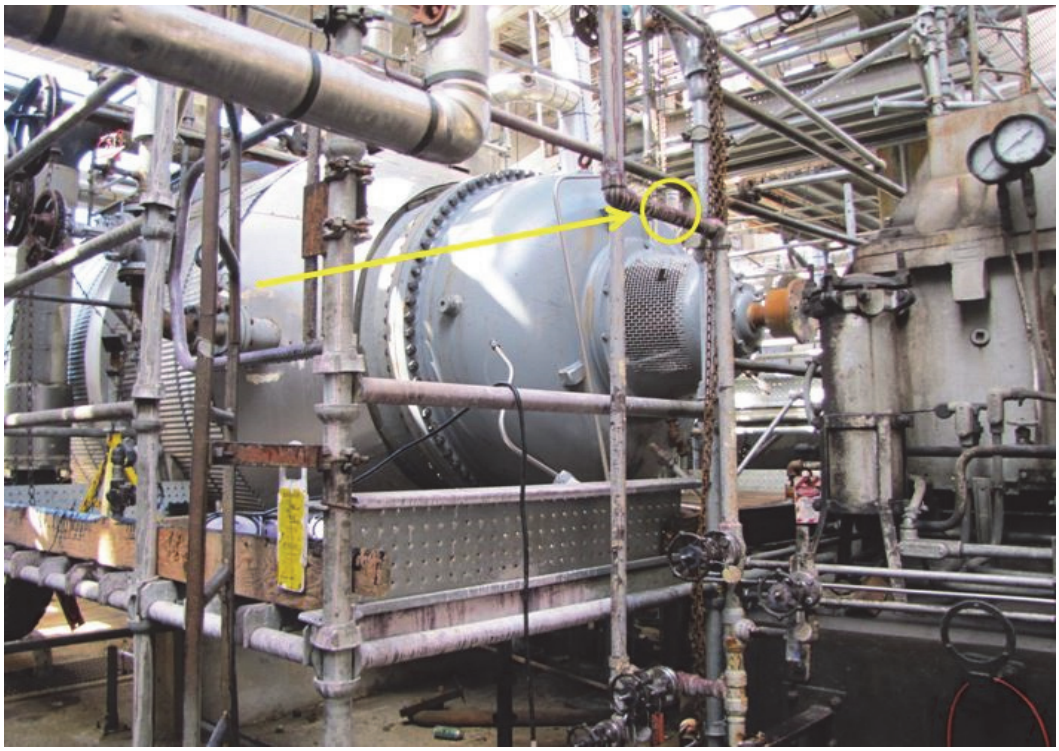

Figure 14. Photo of location of the March 10, 2014 incident. As depicted in Figure 12, two workers were located on this temporary scaffold platform and were cutting the piping (yellow circle) with a portable band saw.

4.2 Technical Analysis

The Tesoro Martinez refinery's alkylation unit contains several reactors. To perform maintenance, Tesoro periodically shuts down each reactor while the other reactors continue to operate. As a result, refinery management regularly relies upon a single valve to isolate the butane piping. This design is the least effective approach to ensure the isolation of hazardous material and did not follow Tesoro corporate and industry standards. As a result, Tesoro's isolation system design contributed to the March 10, 2014 incident.

At the time of the March 10, 2014 incident, other alkylation reactor agitator systems were operating with liquid butane flowing from a process pump to agitators for these reactor systems. Contrary to corporate requirements, the refinery used a single isolation valve to prevent liquid butane from flowing into the piping system workers were preparing to cut. Tesoro isolated the butane piping involved in the March 2014 incident with a single valve and placed it out of service in December 2013. It is likely that a slow leak through the single isolation valve gradually increased the pressure in the butane piping up to 150 psig between December 2013 and March 2014. Pressure from this butane caused the sulfuric acid to spray out of the piping when workers cut into it. The CSB learned from alkylation unit workers that Tesoro commonly used single valve isolation rather than blinding and flushing the piping before conducting hot work that involved what met the refinery's definition of "low energy" tools.[41]

Figure 15 below defines Tesoro Martinez terminology used in its policies pertaining to controlling hazardous energy for maintenance operations. Fully draining, eliminating internal pressure, and removing hazardous material through flushing or other means should have enabled the workers to verify the piping was safe to allow for the cutting and pipe removal – especially if the cutting occurred in a timely manner, immediately following the flushing. The pipe cutting on March 10, 2014, however, had a three-month delay from when the piping was drained until the cutting was performed.

[41] The permit stated that this work involved "low energy" tools. The permit defines "low energy tools" to include electric tools, battery powered tools, jackhammers, abrasive blasting, vacuum truck operation, motorized equipment, and refueling. The permit defines "high energy tools" to include welding, cutting, pre/post weld heat-treating, other open flame, abrasive blasting on the roof of a cone roof tank, grinding, powder-actuated tools, and welding on in-service/unclean piping and/or equipment.

Hot Work - Any work that may be a source of ignition, including open flames, cutting and welding, sparking of electrical equipment, grinding, buffing, drilling, chipping, sawing, or other similar operations that create hot metal sparks or hot surfaces from friction or impact.

Isolation - The process by which a pipe, line, duct or confined space is removed from service and completely protected against the release of energy and material into the space by such means as: blanking or blinding; misaligning or removing sections of lines, pipes, or ducts; a double block and bleed system; lockout or tagout of all sources of energy; or blocking or disconnecting all mechanical linkages.

Blinding - The absolute closure of a pipe, line or duct by the fastening of a solid plate (i.e., a spectacle blind or skillet blind) that completely covers the bore and that is capable of withstanding the maximum expected pressure of the pipe, line or duct with no leakage beyond the plate.

Double block and bleed - the closure of a line, duct, or pipe by closing and locking or tagging two in-line valves and by opening and tagging a drain or vent valve in the line between the two closed valves.

Figure 15. Tesoro definitions relevant to controlling hazardous energy prior to performing a maintenance operation such as cutting the butane piping for removal. A Tesoro corporate standard is the source for the hot work definition. All other definitions are from Tesoro Martinez refinery procedures.

A Tesoro alkylation unit operator stated to the CSB that on the day of the incident he understood (correctly) that the "line had already been opened once before." In addition, the system was blinded on one end and locked closed on the other, giving him no reason to believe the pipe was not already empty and safe for workers to cut and remove. Regardless, prior to issuing the hot work permit for the job, the operator opened a drain valve associated with the piping system and he observed what appeared to be a "wisp" of butane vapor come out of the valve. The operator then used his gas meter to perform an atmospheric check for additional hydrocarbon flow from the drain valve, and found none. The operator explained: "So to me that meant that the line, in my mind, was cleared because I didn't have a pressure gauge on that line to determine if there was in fact any pressure on there." The contract workers who were present to cut and remove the piping also both knew the pipe was worked on before, had already been disconnected from the alkylation reactor with a blind flange installed, and saw that the drain valve was opened with no hydrocarbons detected on the operator's gas meter. These factors reinforced to them the appearance of a safe condition for performing the work. After the incident, however, it was determined that the drain piping was internally plugged, preventing flow through the open drain valves, and as a result it provided the operator and contract workers with a false sense of security that the piping had been depressurized and drained of its contents (Figure 16).

Figure 16. Photo of drain piping and valves. Evaluation of this equipment after the incident identified plugging in these piping components that prevented liquid from freely draining through the open valves.

4.3 Organizational Analysis

4.3.1 Pressure to Expedite Maintenance Work

To understand the March 10, 2014 incident it is also necessary to consider the broader cultural aspects of conducting maintenance and operations activities at the Tesoro Martinez refinery. Tesoro alkylation unit operators consistently described a difficult work environment where management criticized and even investigated workers for purportedly holding up maintenance work, and workers perceived intense pressure to avoid delaying maintenance work. Tesoro supervisors conducted routine investigations to determine why jobs took longer for the operators to prepare than the supervisors initially believed they should have taken. This caused alkylation unit workers to feel pressure to expedite work and take no additional precautions beyond the normal steps required to ensure work was safely prepared for maintenance. When asked why operators might not take the time to perform extra steps that could be prudent in order to ensure a system was effectively drained (such as, in this case, rodding out a valve or pressuring with nitrogen to verify that the system is ready and safe for maintenance), one operator stated that such actions would be "frowned upon by management." He also noted that he would be "questioned

by management" as to why he was taking those potentially unnecessary additional precautions. Thus, the organizational goals and practices, directed and supported by management, created a culture at the alkylation unit that tended to discourage the performance of extra work unless there was a clear indication of a dangerous condition.

As a result, the operator and contractors did not take any extra steps to ascertain whether the piping was properly drained and depressurized. All available evidence suggested that the pipe was properly drained and depressurized. Combined with the fact that the pressure indicator on this piping system was not available to alert the workers to hazardous conditions (because the pressure indicator had been previously removed and replaced with a plug as shown in Figure 17), the operator had no indication of the dangerous condition – that a pressurized inventory of concentrated (94 weight percent) sulfuric acid remained in the piping.[42]

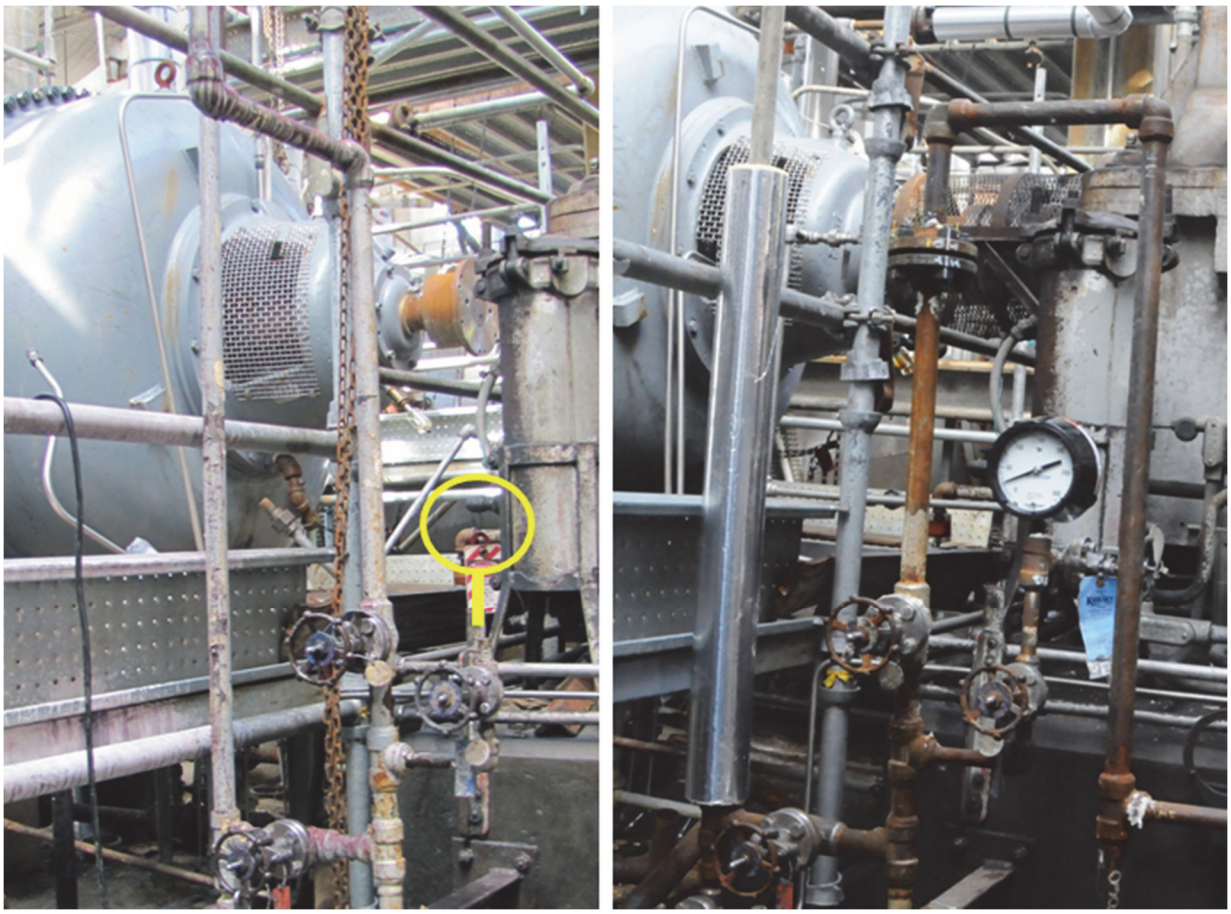

Figure 17. Photo of piping involved with the March 10, 2014 incident (left photo). The photo on the right shows the piping after repairs were made and the pressure indicator was reinstalled. Note the yellow circle in the photo on the left that shows the location where a pressure indicator was supposed to be located, but had been removed. Had this pressure indicator been available it could have alerted workers that dangerous pressure remained in the piping system.

[42] The CSB was unable to determine why the pressure indicator had been removed and replaced with a plug.

4.3.2 Blinding and Isolation Requirements

Safety culture is a key factor in major accident prevention and, as the CSB noted in the Macondo investigation report, "is expressed not only in the stated goals, policies, procedures, and practices that a company formally adopts to enhance process safety, but also in the actual commitment by leaders, management, and the workforce to meet those corporate requirements. This commitment impacts 'how the organization behaves when no one is watching' and influences decisions by personnel at all levels of the organization."[43] As will be discussed below, Tesoro showed a lack of commitment to ensuring that refinery-specific policies and work practices met good process safety practices, standards, and corporate requirements.

4.3.2.1 Blinding Requirements

In December 2013, workers disconnected the butane piping involved in the incident from the alkylation reactor, and then installed a blind flange on the reactor side in accordance with Tesoro standards and good industry practice, as shown in Figure 18. On the butane supply side, however, Tesoro relied on a single isolation valve, rather than disconnecting and/or blinding, contrary to corporate standards. The CSB learned that this was a common practice at the Tesoro Martinez refinery's alkylation unit during hot work that involved "low energy" tools that met the site's concept of "low risk." The Tesoro Martinez policy defines "high risk" work as jobs that involve working on high-pressure systems, high hydrogen sulfide, sulfur dioxide, ammonia, and process streams above the auto ignition temperature. The policy provided no actual definition of "low risk." The workers commonly understood that "low risk" applied to anything not defined as "high risk." The workers considered the task performed on March 10, 2014, to be "low risk" work with a "low energy" cutting tool.

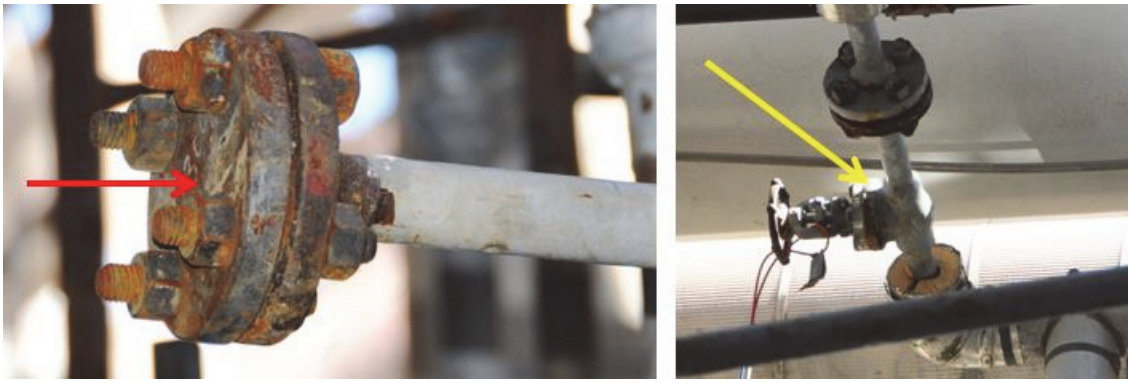

Figure 18. Photo of piping isolation at time of March 10, 2014 incident. The photo on the left shows the piping isolation on the reactor side. A blind flange (red arrow) was installed in December 2013 when the piping was disconnected from the alkylation reactor. The photo on the right (yellow arrow) shows the single valve used to isolate butane from the piping workers were cutting.

[43] *See* page 235 of the CSB Macondo investigation report, Volume 3, available at http://www.csb.gov/assets/1/19/Macondo_Vol3_Final_20160527.pdf (accessed June 13, 2016).

Tesoro's corporate standards, however, were more protective than the site policy and required the Tesoro Martinez refinery to isolate the butane line using a blind rather than a single isolation valve. Blinding is a more robust isolation approach that should have prevented butane from pressuring up the line. According to Tesoro's corporate engineering standard for metallic piping systems, isolation using a single valve is not permitted. The corporate standard requires a more robust isolation approach, such as blinding or a double block and bleed, in situations where "positive isolation is required." In addition, another Tesoro corporate standard that governs blinding and isolation only allows single valve isolation for piping that contains low-risk material, such as air or water.

The United Kingdom safety regulator, the Health and Safety Executive (HSE), uses the hierarchy of controls to explain the mechanical security provided by various types of isolation methods.[44] According to HSE, when using valves, the isolation reliability of a double block and bleed is greatest while that for a single valve is least.[45] Furthermore, HSE states that companies should not use a single valve for isolation when working on a live plant containing hazardous substances.[46]

In addition, the American Petroleum Institute (API) industry standard that addresses safe hot work practices provides the following guidance:

> An important precaution before welding or cutting piping is to properly isolate the piping (e.g., blinding, disconnecting, or double blocking and bleeding). The type of isolation used will depend on the contents, pressure, or piping configuration. A single valve may be used, depending on conditions and if isolation is not required (e.g., welding on inert gas piping, water lines). However, if the work falls under certain regulatory standards (such as OSHA confined space or Lockout/Tagout standards) *a single closed valve is not likely to be an acceptable means of isolation*. (Emphasis added) [47]

Despite the corporate and industry requirements and strong guidance, the Tesoro Martinez site policy allows the refinery to use single valve isolation for short duration "high risk" work that, as noted above, excludes some types of hot work on piping and equipment containing hazardous material. Further, although the Martinez policy acknowledges, "blinding is the best method of isolating piping system and equipment for cold work" (work performed via a hot work permit with low energy tools), the Tesoro Martinez policy nevertheless permitted the work to be performed using a single isolation valve – a much less effective approach. The Tesoro Martinez refinery policy states:

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[44] Health and Safety Executive (HSE). *The Safe Isolation of Plant and Equipment,* HSG253, pg. 25, 2006. http://www.hse.gov.uk/pubns/priced/hsg253.pdf (June 14, 2016).

[45] HSE defines a double block and bleed as isolation method consisting of an arrangement of two block valves with a bleed valve located in between. *Ibid* at p 79.

[46] HSE also defines a bleed valve as a valve that is used for draining liquids or venting gas from a pressurized system. *Ibid* at p 27.

[47] API Recommended Practice (RP) 2009. Safe Welding, Cutting, and Hot Work Practices in the Petroleum and Petrochemical Industries. 7th Ed., Section 14.2, February 2002.

> Blinding is the best method of isolating piping system and equipment for cold work. However, in many instances the low risk involved in doing a task does not justify installing blinds. In such cases a double block and bleed shall be used if it is available. If a double block and bleed is not available then single block valves may be used.

Rather than limiting single valve isolation to low-risk situations involving air or water consistent with the corporate standard, the Martinez refinery policy greatly expanded upon the situations allowing single isolation valves. Consequently, this exposed workers to higher risks than allowed by the corporate and industry standards.

4.3.2.2 Requirements for Removing Pressure, Flushing, and Draining

Although routinely not performed, the Tesoro Martinez refinery policy on blinding and isolation requirements does require flushing the piping prior to performing hot work on systems, such as the butane piping being cut on March 10, 2014.

> Extreme caution must be taken to insure that all hydrocarbons have been eliminated (i.e., steaming, purging, or water filling the equipment).

The refinery management's allowance of the improper use of a single isolation valve, however, prevented the workers from flushing the piping prior to performing hot work. As seen in Figure 19 below, Tesoro's corporate blinding policy provides for a piping design that includes an additional valve that would allow flushing with water, whereas the single isolation valve does not.

When workers went to the job site to cut and remove the butane piping, they did not know the drain piping was internally plugged, preventing the residual sulfuric acid inside the pipe from draining through the open valves. Had workers flushed the piping, it is likely that they would have identified the plugged drain valve when they attempted to drain the water. In addition, the workers believed the pipe had been drained and depressurized. Visually observing that the valves were open, seeing no flow from the open drain piping, and having no hydrocarbons detected on the operator's gas meter during an atmospheric check, provided a false sense of security that the piping was safe to cut.

In addition to flushing the butane piping system, both the Tesoro Martinez refinery policy and the Tesoro corporate standard required the system to be drained and internal pressure removed before cutting and removing the line:

> "Prior to opening lines or equipment: Gases, oils or chemicals must be drained, washed, and steamed or purged as applicable."
>
> "When using vents or bleeders, pressure shall be relieved by opening high-point vents or bleeders and ensuring that vents and bleeders are not plugged. This can be accomplished by using the appropriate tools for clearing out lines and/or installing a pressure gauge."

> "Pressure shall be reduced to atmospheric or as near atmospheric as is practical."

Due to the fact that the refinery policy allowed single isolation valves, and workers were unable to identify the plugged drain valve, the piping was not safe to cut at the time of the incident.

4.3.2.3 Isolation Improved after the Incident

Two days after the March 2014 incident, Tesoro modified the isolation for the liquid butane piping from using single valve isolation to blinding, a more robust isolation approach that followed the best practice methods detailed in refinery procedures, corporate standards, and industry standards (Figure 19). Had Tesoro followed its own standards and recommended practices during the initial December 2013 isolation of this butane piping system, the March 10, 2014 incident could have been prevented. Piping should have been flushed to remove the acid, drained to ensure no residual liquid, and blinded to eliminate the potential for a slow leaking valve to pressure the piping system.

Figure 19. Photo of post-incident isolation of liquid butane supply piping to alkylation reactor. This photo shows the same piping shown in the right photo of Figure 18. Two days after the March incident, Tesoro modified the liquid butane isolation to match the API recommend practice, Tesoro's corporate standards requirement, and Tesoro Martinez procedure recommendations by disconnecting and installing isolation flanges on each end of the isolated piping.

4.3.3 Lessons from Previous Incidents Not Learned

4.3.3.1 1999 Tosco Incident

On February 23, 1999, a fire at the Tosco Avon refinery (now the Tesoro Martinez refinery) fatally injured four workers during a nonroutine maintenance activity to replace piping that had not been effectively isolated and drained. While working to remove the piping, flammable hydrocarbon liquid released and ignited. As the CSB most recently discussed in the Tesoro Anacortes investigation report,[48] nonroutine work can be a highly hazardous activity, as seen in this case, because work was performed on equipment that contained hazardous process materials due to reliance on a single isolation valve. The Center for Chemical Process Safety (CCPS) has noted, "by its nature, nonroutine work carries with it the potential for unrecognized hazards that sometimes has led to a catastrophic incident."[49]

The CSB investigated the 1999 Tosco incident and issued a final investigation report in March 2001.[50] The CSB investigation found that on the day of the incident a Tosco work permit authorized maintenance workers to remove 100 feet of 6-inch piping that was not drained because drain lines were plugged and remained pressurized from the running process. When workers opened liquid-filled piping, flammable naphtha released onto a hot distillation column and ignited, quickly engulfing the equipment and the workers.

As detailed in the CSB Tosco investigation report, although Tosco procedures required piping to be drained, depressurized, and flushed prior to opening, this was not accomplished.[51] The CSB report noted the refinery had a historic practice of opening piping and equipment prior to draining and verifying removal of hazardous material.[52] In addition, the CSB found that Tosco's job planning procedures did not require a formal evaluation of the hazards associated with replacing the piping because Tosco classified it as low-risk maintenance and managers did not reevaluate the risks when workers alerted them about the fact that the line could not be drained and isolated. Thus, Tosco directed workers to conduct nonroutine maintenance to remove piping without proper assessment and control of hazards. Furthermore, the CSB found that Tosco supervisors were not involved in inspecting the job site or reviewing the work permit. The CSB investigation also noted the maintenance supervisor was the only management representative present during the nonroutine piping removal work. The CSB made a recommendation[53] that addressed

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[48] CSB Investigation Report. *Catastrophic Rupture of Heat Exchanger*. Tesoro Anacortes Refinery. *See* http://www.csb.gov/assets/1/7/Tesoro_Anacortes_2014-May-01.pdf (accessed June 14, 2016).

[49] Center for Chemical Process Safety (CCPS). *Guidelines for Auditing Process Safety Management Systems.* 2011; p 393.

[50] CSB Investigation Report. *Refinery Fire Incident*. Tosco Avon Refinery. http://www.csb.gov/assets/1/19/Tosco_Final_Report.pdf (accessed June 14, 2016).

[51] *Ibid.*

[52] *Ibid* at p 47.

[53] The CSB issued recommendation 1999-014-I-CA-2 to the Ultramar Diamond Shamrock Golden Eagle refinery (now Tesoro Martinez refinery) and the Board voted to designate it as "Closed – Acceptable Action" on July 5, 2005.

the importance of advanced planning and thorough hazard evaluations for the safe performance of hazardous nonroutine work.

The refinery developed and tracked corrective action items to address the CSB recommendation. Although these action items were closed in early 2002 when Valero still owned the refinery, Tesoro should have retained knowledge of these lessons. Managers who remained at the refinery under Tesoro ownership closed these action items. In addition, Tesoro's corrective action tracking system still maintains the refinery's documentation.

Despite the major multi-fatality accident at this facility in 1999, the CSB notes that Tesoro has not effectively learned the major process safety lessons to prevent future similar incidents at this refinery. Although the incidents are not identical, the CSB identified that several significant process safety management system weaknesses that led to the 1999 incident were also present in the March 10, 2014 incident, as listed below:

- Nonroutine maintenance was performed without the proper control of hazards;
- Piping was not effectively drained and isolation was not verified prior to performing nonroutine maintenance;
- The work was classified as low-risk, which resulted in less robust piping isolation practices such as relying on a single valve for isolation;
- Hot work permits authorized workers to remove piping that had not been effectively isolated and drained; and
- Supervisors were not involved in inspecting the job site or reviewing the work permit and the contract maintenance supervisor was the only management representative present during the inspection and review processes, as well as for the nonroutine piping removal work.

In addition, Tesoro's failure to learn the lessons of the 1999 incident at the refinery, under Tosco ownership, contributed to a weak safety culture that tolerated inadequate refinery policies, procedures, and work practices that led to the March 10, 2014 alkylation unit incident.

4.3.3.2 June 2010 Incident

In June 2010, a Tesoro Martinez contract worker received a chemical burn from a sulfuric acid release during nonroutine maintenance to remove a piping component connected to an alkylation reactor. Tesoro's investigation identified the cause of this incident to be insufficient PPE due to a belief that acid was not present in the piping. Despite the fact that this piping was intended to contain butane and not sulfuric acid, the acid found its way into the line and inadequate approaches were taken to clear the line of its hazardous contents. Similar to the March 10, 2014 incident this piping provided butane to the mechanical seal for one of the alkylation reactor agitators.

In relation to the June 2010 incident, a Tesoro investigation team proposed corrective actions, including the installation of check valves to prevent a reverse flow of sulfuric acid from the reactor into this butane piping, as well as a post-shutdown wash to ensure acid did not remain in the butane piping. Two months later a management review eliminated these action items from the corrective action plan because Tesoro management determined they were not causally related to the incident. The CSB notes that if Tesoro had implemented the investigation team's 2010 recommendations to provide reliable reverse flow protection and to perform a post-shutdown wash, the March 10, 2014 acid release incident could have been prevented. These proposed safeguards could have ensured that sulfuric acid would not be present in the butane piping.

5.0 Tesoro Martinez Refinery Safety Culture Analysis

5.1 Martinez Refinery Safety Culture Assessments

5.1.1 Introduction

The Martinez refinery has a 15-year history of safety culture evaluations beginning with a 1999 assessment following the multi-fatality accident that occurred when Tosco owned and operated the facility. A follow-up evaluation in 2001 showed significant improvement in the safety culture at the refinery. In 2007 Tesoro conducted a corporate-wide safety culture survey based on the approach used by the Baker Panel, an independent panel that was formed as a result of a CSB recommendation made during the agency's investigation of the 2005 BP Texas City refinery catastrophic accident.[54] Beginning in 2009, local process safety regulations required covered refineries including Martinez to perform safety culture assessments every five years.[55] The CSB investigation of the 2014 alkylation unit sulfuric acid releases and Tesoro's own 2013 safety culture assessment identified some similar safety culture weaknesses. In addition, following the March 2014 acid release incident that injured workers, the United Steelworkers Tesoro Council, which represents Tesoro workers throughout the US, issued a statement calling for safety culture improvements at all Tesoro facilities.[56] Despite performing these periodic safety culture assessments, significant safety culture weaknesses at the Tesoro Martinez refinery persist and these issues must be improved in order to prevent process safety incidents, such as the February and March 2014 sulfuric acid releases that injured four workers.

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[54] *See* http://www.csb.gov/assets/1/19/Baker_panel_report1.pdf (accessed June 14, 2016).

[55] Chapter 450-8 of the Industrial Safety Ordinance (ISO), as amended by Ordinance 2006-22. The amendment modified some sections and also included a new subdivision (h) that required the completion of a Safety Culture Assessment within one year after development of guidance (which was completed on November 10, 2009), and at least once every five years thereafter. *See* http://cchealth.org/hazmat/pdf/iso/introduction.pdf (accessed June 14, 2016).

[56] The council stated, "In light of the recent incidents at refineries owned by Tesoro, we the Tesoro Council, which represents workers at Tesoro facilities all across the United States, including refineries and pipelines, condemn Tesoro for its inadequate safety culture and call on Tesoro to improve safety at its facilities before even more catastrophic incidents occur which threaten workers, the community and property." *See* http://www.usw.org/news/pdfs/Statement-Tesoro-Council-on-Safety-3.15.14.pdf (accessed June 14, 2016).

5.1.2 Industrial Safety Ordinance Safety Culture Requirements

Contra Costa Health Services' Hazardous Materials Programs (CCHMP)[57] administers the Industrial Safety Ordinance ("ISO"), which covers seven facilities within Contra Costa County ("CCC") – including the Tesoro Martinez refinery.[58] The ISO requires, among other things, that covered facilities perform a safety culture assessment at least once every five years, and permits the CCHMP to audit the assessment and perform its own investigation following a major chemical accident or release[59] or the occurrence of any incident that could reasonably have led to a major chemical accident or release.[60] Following each assessment, the facility's management, along with its workforce, must develop a plan to act on the audit findings that includes, among other things, the reasoning behind rejecting any findings and prioritizing the action items.[61]

CCHMP provides additional guidance on the conduct of safety culture assessments in ISO Guidance Document F: *Safety Culture Assessments*. The guidance defines "safety culture" as:

> [A] measure of the importance that individuals and organizations exhibit towards working safely. It is the summation of attitudes and actions people do at 2 a.m. on a Sunday night when no one is watching. An organization can influence employees to embrace positive shared safety values with consistent policies and practices and by leading through example.[62]

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[57] Contra Costa County's Hazardous Materials program is responsible for responding to emergencies and monitoring hazardous materials in Contra Costa County (CCC). It is program's mission to safeguard the Contra Costa County ecosystem from the release of hazardous materials and other pollutants. For more information see http://cchealth.org/hazmat/ (accessed June 14, 2016).

[58] The ISO became effective January 15, 1999, and applies to petroleum refineries or chemical plants within Contra Costa County. The ISO was adopted to improve industrial safety by requiring more comprehensive coverage of the whole facility and providing more robust review, inspection, auditing, and safety requirements; requiring the development and implementation of a human factors program; and preventing and reducing the number, frequency, and severity of accidental releases in Contra Costa County.

[59] The ISO defines "Major chemical accident or release" as "an incident that meets the definition of a level 3 or level 2 incident in the community warning system incident level classification system defined in the hazardous materials incident notification policy, as determined by the department; or results in the release of a regulated substance and meets one or more of the following criteria: (1) Results in one or more fatalities; (2) Results in at least twenty-four hours of hospital treatment of each of at least three persons; (3) Causes on- and/or off-site property damage (including clean-up and restoration activities) initially estimated at five hundred thousand dollars or more. Onsite estimates shall be performed by the stationary source. Off-site estimates shall be performed by appropriate agencies and compiled by the department; (4) Results in a vapor cloud of flammables and/or combustibles that is more than five thousand pounds." County Ordinance Chapter 450-8.014(h). May 6, 2014.

[60] County Ordinance Chapter 450-8.016(h). *Safety Culture Assessment*. May 6, 2014. *See* http://cchealth.org/hazmat/pdf/iso/Chapter-450-8-RISK-MANAGEMENT.pdf (accessed June 14, 2016).

[61] ISO Guidance Document F: *Safety Culture Assessments*. June 15, 2011; p F-19. *See* http://cchealth.org/hazmat/pdf/iso/section_f.pdf (accessed June 14, 2016).

[62] *Ibid* at p *F-1*.

The guidance also elaborates on the importance of conducting safety culture assessments:

> A Safety Culture Assessment will enable a facility to understand where they are in terms of risk acceptance. Additional benefits of performing a Safety Culture Assessment include:
>
> - Identify positive as well as negative aspects of the onsite health and safety program
> - Assist in identifying opportunities for improving health and safety
> - Another tool to improve facility personnel's awareness and participation in health and safety
> - Identify perception gaps between managers, supervisors, and the workforce
> - Assist to demonstrate management's commitment to safety by performing the assessment and visibly addressing the results[63]

The ISO also provides guidance for evaluating management commitment and leadership, which includes determining how effectively management "sets expectations to shutdown unsafe equipment or activities" and evaluating how effectively management responds to safety concerns.[64] As discussed above, Tesoro alkylation unit workers told the CSB that Tesoro Martinez refinery management personnel pressured workers to delay the unit shutdown and were perceived to be unresponsive to workers' safety concerns regarding the sampling systems.

5.1.3 History of Safety Culture Assessments

Following the 1999 Tosco incident CCHMP contracted a third party auditor, Arthur D. Little, to conduct a safety evaluation at the Avon (now Tesoro Martinez) refinery in March 1999, as well as a follow-up evaluation in April 2001. The initial assessment evaluated the refinery's safety management systems, potential human factors issues, and safety culture, along with identifying potential deficiencies, and developing findings and recommendations.[65] The evaluation found that refinery safety performance focused primarily on the number of injuries;[66] that Tosco management lacked a commitment to safety;[67] and workers perceived that organizational changes over the last decade were made for economic reasons and had a detrimental effect on the refinery's safety culture.[68] The assessment also found that lessons learned and safety performance issues in general needed to be communicated more effectively and

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[63] *Ibid* at p F-1.
[64] *Ibid* at p F-17.
[65] Little, Arthur D. *Safety Evaluation of the Tosco Avon Refinery in Martinez, California; Final Report to the Contra Costa Health Services.* May 10, 1999; p ES-1.
[66] *Ibid* at p 7.
[67] *Ibid* at p 34.
[68] *Ibid* at p 34.

actively throughout the organization.[69] To improve safety culture the evaluation team recommended that Tosco, among other things, develop and distribute a safety and health newsletter that emphasized safety performance and lessons learned, and that the refinery should increase the staffing levels and visibility of the refinery's Health and Safety Department.[70]

Arthur D. Little conducted a follow-up assessment of the refinery in April 2001. Ultramar Inc.[71] ("Ultramar") purchased the refinery on September 1, 2000, and owned the refinery at the time of the 2001 evaluation. The goal of the assessment was to review progress made in implementing recommendations from the initial 1999 safety evaluation. The follow-up assessment team found that in the area of safety culture there was a "dramatic change in the attitudes and perceptions of the refinery workforce" since the original evaluation and described the difference as "like night and day."[72] The team found that results of incident and near miss investigations, general facility health and safety information, audits and process hazards analysis results, safety policies, and mission and vision statements were being communicated effectively and consistently.[73] Ultramar management personnel were found to be firmly committed to core safety values including the mission statement, and were recognized as role models for good safety management.[74] In addition, four positions were created in the Health and Safety Department and worker statements from CSB interviews showed they were a valuable addition.[75]

Tesoro acquired the Martinez refinery in 2002 and conducted its own safety culture surveys in 2007 and 2013. Following the Baker Panel approach, each survey administered 65 process safety specific questions grouped into six categories: process safety reporting; safety values/commitment to process safety; supervisory involvement and support; procedure and equipment; worker professionalism/empowerment; and process safety training.[76] The Baker Panel concluded that survey data (such as the data collected through Tesoro's surveys) does have limitations, stating that "[s]urvey data generally reflect impressions, beliefs, and opinions of the group being surveyed," and "[…] the [Baker] Panel does not construe survey responses as facts, but as data providing insights into perceptions of refinery personnel concerning process safety culture in their refineries."[77]

The Baker Panel believed that responses "to a survey relating to process safety, which involves potentially catastrophic accidents, should be viewed differently from workforce surveys generally."[78] The Baker Panel also concluded that: "Given the importance of process safety to the well-being of a refinery workforce and the community in which a refinery is located, the [Baker] Panel believes that it should use

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[69] *Ibid* at p 16.
[70] *Ibid* at pp 18 through 25.
[71] Ultramar Inc. is a wholly owned subsidiary of Ultramar Diamond Shamrock.
[72] Little, Arthur D. *Follow-up Safety Assessment of the Ultramar Golden Eagle Refinery in Martinez, California: Draft Report to Contra Costa Health Services.* May 21, 2001; p ES-3.
[73] *Ibid* at p 9.
[74] *Ibid* at p 14.
[75] *Ibid* at p 16.
[76] Baker III, James, A. et al. The Report of the BP U.S. Refineries Independent Safety Review Panel. January 2007; p 8. http://www.csb.gov/assets/1/19/Baker_panel_report1.pdf (accessed June 14, 2016).
[77] *Ibid* at p 9.
[78] *Ibid* at p 10.

more stringent criteria, or effectively "raise the bar," in its evaluation of the process safety culture survey data.[79] Rather than taking a view that any particular level of "positive response rates are acceptable, favorable, or 'good enough,' the [Baker] Panel believed it was important to view more critically departures from 100 percent positive response rates."[80]

Much of the information covered in the remainder of this report section (Section 5) describes negative results and worker comments to Tesoro's 2013 process safety culture survey that represent clear departures from 100 percent positive response rates. These negative results and comments presented also support worker statements made to the CSB following the 2014 sulfuric acid release incidents in the alkylation unit; however, it is important to acknowledge that Tesoro's safety culture surveys, which covered all workers at the refinery, also include many positive results and worker comments. Similar to the Baker Panel, the CSB "has focused necessarily on identified shortcomings" not "to present an unbalanced view of process safety culture" at the Tesoro Martinez refinery, "but rather to highlight areas for potential improvement."[81]

Tesoro's 2013 safety culture survey results, however, do indicate several areas of strength. For example, Tesoro outperformed the typical refining industry benchmarks to a statistically significant degree in the following areas where workers believed:

- Within their work group, process safety concerns are more important than achieving production goals;
- In areas of process safety, they can challenge decisions made by their supervisors without fear of a negative consequence; and
- That they knew how to access appropriate process safety resources if needed.

In addition, the Tesoro Martinez refinery exceeded or matched "best-in-class" refining industry benchmarks in two areas where workers believed:

- That their process safety training has provided them with the ability to recognize when a process should be shutdown, if safety critical process safety equipment fails or is not available; and
- That they felt responsible of identifying process safety concerns at the refinery.

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[79] *Ibid* at p 10.
[80] *Ibid* at p 10.
[81] *Ibid* at pp 10 and 11.

Examples of positive comments made by workers in Tesoro's 2013 process safety culture survey include:

> "I have worked in every refinery in the Bay area and I can truly say that I feel excited and glad on coming to work every day. At this refinery I get my safety concerns addressed and resolved and I am recognized for my hard work. Here I feel empowered and I can make a difference."
>
> "This company demonstrates a strong commitment to safety."
>
> "I have worked in all of the Bay Area refineries and here at GER [Golden Eagle Refinery] when it was Tosco. The safety culture here now has changed dramatically from the Tosco days and I believe now it is the best of all of the Bay Area refineries."
>
> "I can tell you that today in contrast to the Tosco days, we are doing very well concerning safety. Thank you!!"
>
> "I believe that the supervisors do a good job of walking the walk and talking the talk and get the people in their departments involved and onboard process safety."
>
> "Training around here is very high, this is one of the safest places I worked at."
>
> "Like to thank all the supervision from the top to the bottom. Everyone seems to be on the same page, it's a fun and safe place to work. Thank you."
>
> "Top of the industry standards at Golden Eagle. One of/if not the best place to work in all of the industry."

Following the February and March incidents, however, some alkylation unit workers stated to the CSB that they believed the alkylation unit to be the most difficult and dangerous unit to work in – a unit that employees feared and actively tried to transfer out of – and where many of the workers were assigned straight out of initial new-hire training. One worker in particular confirmed that "nobody" wants to work in the alky plant, though he himself wanted the job there to help "control the dangerous environment." Thus, some differentiation must be made between positive worker perception and opinion comments related to general safety issues and even noted improvements that might be relevant to the overall operation of the refinery, versus the situation within the alkylation unit, the hazards specific to operations within it, and the repeated sulfuric acid accidents and other safety issues that alkylation unit workers described to the CSB, which were the focus of the CSB's investigation.

Although considerable resources are typically needed to conduct a safety culture assessment, Tesoro did not follow through on its commitment to develop an action plan to strengthen areas of perceived weaknesses identified in the 2007 survey. The 2007 survey results showed that Tesoro management provided more favorable responses to questions in all six categories than all other types of workers at

Tesoro. Furthermore, the 2007 survey showed there was a less favorable response overall, by the Martinez refinery as measured among the company's other refineries in the following areas:

- Workers are informed about the results of process related incident, accident, and near miss investigations;
- Workers at all levels of my location actively participate in incident and accident investigations; and
- Workers at this location feel pressured to work considerable overtime from their own sense of loyalty to their operating units.

When asked, "What suggestions do you have for improving process safety at Tesoro?" the top responses were:

1. Procedures and equipment
2. Process Safety Training
3. Safety Values / Commitment to Process Safety

Some employee written comments indicated that the refinery was perceived as having inadequate resources dedicated to keeping procedures updated and to repairing damaged equipment. Some workers stated that in their opinion management placed inadequate emphasis on process safety training and the refinery demonstrated more commitment to production than to process safety. Written comments also consistently expressed strong disagreement over the refinery's reduction for safety department staffing.

Tesoro's 2013 safety culture survey identified numerous areas where the refinery could strengthen its process safety programs. Once again, workers provided significantly less favorable responses to questions than management. Tesoro's results showed the refinery safety culture performance was significantly less favorable in all six categories than "best-in-class" refining industry benchmarks. In addition, Tesoro underperformed the typical refining industry benchmarks to a statistically significant degree in four of the six process safety categories:

- Worker Professionalism and Empowerment;
- Safety Values and Commitment to Process Safety;
- Process Safety Reporting; and
- Procedures and Equipment.

In addition, the least favorable results from the 2013 survey indicate workers believed:

- There was pressure to work considerable overtime from management, supervisors, and due to loyalty;
- The commitment to process safety was more words than action;
- Equipment was not regularly tested, maintained, or properly restored as soon as possible; and
- A culture at the refinery that encouraged raising process safety concerns did not exist.

Compared to the 2007 survey results, the 2013 survey showed statistically significant declines in areas where workers believed:

- Process equipment was not being regularly maintained;
- Disabled or failed process safety devices were not restored to service as soon as possible;
- Long-term process safety improvement was compromised by short-term financial goals;
- Refinery management does not put a high priority on process safety through actions; and
- Formal hazard assessments were not always performed to ensure that changes affecting processes will be safe.

Some employee written comments indicated that workers were concerned that positive gains in the safety culture at the refinery since the 1999 Tosco incident had been lost and the refinery safety culture had deteriorated. Such worker comments included:

> "This refinery has become Tosco all over again. We are back to the days of do not fix it until it burns up or blows up. A refinery cannot operate safely when it is being run from the corporate office. It all comes down to money and the bottom line. Save the dollar now by not fixing equipment, so the books will look good. The end result is that it costs us more in lost production when the units are down."
>
> "At the Operator level you quite often hear 'We are going back to Tosco.' As I lived through that difficult time I can say we are not that bad yet, but there is certainly a shift towards that level of short term thinking. The real profit will come with sustained safe operations, where everyone goes home safely."
>
> "… [W]e the workers in the field have a fear amongst us that we are back to the Tosco way of making money at the cost of lives."
>
> "After more than 20 [years] of service in this refinery the attitude of middle management reminds me of the end days of Tosco."

As stated previously, despite identifying concerning findings from its 2007 survey Tesoro Martinez did not conduct any follow-up corrective actions. Following the February and March 2014 sulfuric acid incidents, Tesoro Martinez refinery employees informed the CSB that the refinery was working to develop action items stemming from the 2013 safety culture survey results, but plans to strengthen process safety at the refinery had not yet been adopted. The CSB is not aware of the status of those action items. In the Final Chevron investigation report, the CSB made a recommendation to Contra Costa County (CCC) to conduct more robust safety culture assessments with an oversight committee comprised of the regulator, the company, the company's workforce and their representatives, and community representatives. The committee would not only administer periodic safety culture surveys, but would also oversee the development and implementation of action items to address identified safety culture issues. Such a process could help resolve safety culture deficiencies like those identified at the Tesoro Martinez refinery and help prevent future sulfuric acid releases.

5.2 Management Commitment to Worker Safety

Andrew Hopkins noted in his book *Safety, Culture and Risk* that identifying and controlling hazards using systematic hazard identification procedures requires a "*management* mindset that every significant hazard will be identified and controlled and a *management* commitment to make available whatever resources are necessary to ensure that the workplace is safe."[82] The CSB found that the culture at the Tesoro Martinez refinery's alkylation unit lacked a sufficient focus on process safety, which was causal to the February and March 2014 incidents. The following section addresses safety culture and human factors[83] weaknesses that the CSB found contributed to the significant number of sulfuric acid release incidents at the Tesoro Martinez refinery in recent years.

Site Ends Participation in Two Voluntary Worker Safety Programs

In 2012, Tesoro ended the Martinez refinery's participation in two voluntary worker safety programs – the United Steelworkers ("USW") Triangle of Prevention Program[84] ("TOP") and the California Voluntary Prevention Program, or Cal/VPP.[85] A spokesperson for Tesoro stated that safety indicators in

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[82] Hopkins, Andrew. *Safety, Culture and Risk;. The Organisational Causes of Disaster.* Sydney, New South Wales: CCH Australia Limited. 2005; p 6 (emphasis in original).

[83] "Human factors refer to environmental, organizational and job factors, and human and individual characteristics which influence behavior at work in a way which can affect health and safety. A simple way to view human factors is to think about three aspects: the job, the individual and the organization and how they impact people's health and safety-related behavior." UK Health and Safety Executive. *Introduction to Human Factors*. http://www.hse.gov.uk/humanfactors/introduction.htm (accessed June 14, 2016).

[84] The USW Triangle of Prevention Program is a joint union-management workplace safety program that applies the knowledge of the workforce to understand and eliminate workplace hazards.

[85] Cal/VPP is a joint safety and health leadership program between management, workers, and Cal/OSHA, for fixed and non-fixed facilities in California. The federal program is known as the Voluntary Protection Program, or VPP. *See* https://www.osha.gov/dcsp/vpp/all_about_vpp.html for more information.

Tesoro's performance review made it technically ineligible to participate in the VPP.[86, 87] The only indicators the CSB identified that are not permitted under VPP are indicators that could provide a disincentive for workers to report injuries, such as using recordable injuries as part of an incentive or bonus program.

Some Tesoro workers believe dropping these programs demonstrated further deterioration in Tesoro's commitment to process safety. Some workers made strong statements against dropping these two programs in their comments to the 2013 safety culture survey. Comments included:

> "The VPP was on the right track for identifying Safety issues and offering corrective actions when it was discontinued. In 2+ decades in this refinery, VPP was the only safety program that I saw making a difference in the culture."
>
> "We recently had the VPP, TOP programs removed from our facility. In my opinion, these were outstanding safety programs that brought to light many of the safety issues in our facility. With these programs in place, the safety culture improved greatly. Now they are gone."
>
> "I think it is very sad that the company decided not to follow through on the VPP program. I think it sent a message that Tesoro was backing off a bit on its commitment to safety."
>
> "I feel that the elimination of safety programs (TOP and VPP) and the company's pursuit of the elimination of several Health and Safety positions show a growing neglect for safety at our refinery. If this attitude continues I believe our safety record will suffer and our employees will be more susceptible to injury in the near future."

Encouragement of near miss reporting is another measure of effective management commitment and leadership the ISO safety culture assessment guidance provides.[88] Some alkylation unit workers, however, informed the CSB that a culture of blame exists at the refinery and consequently many less

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[86] Rogers, Robert. Tesoro bashed for dropping worker-safety programs at Contra Costa refinery where acid spills occurred. *The Mercury News,* March 12, 2014. http://www.mercurynews.com/marcus-thompson/ci_25323196/ (accessed June 14, 2016).

[87] OSHA Instruction CSP 03-01-003 addresses incentive programs regarding an employer's recording of injuries and illnesses. Chapter VI Onsite Evaluations, Section III.B.1. Subsections b. and g. note that incentive programs should promote safety awareness and worker participation in safety-related activities, and must not be the cause of under-reporting of injuries and illnesses. According to OSHA, a site whose incentive program has the potential to discourage worker reporting fails to meet the VPP's safety and health management system requirements. *See* MEMORANDUM FOR REGIONAL ADMINISTRATORS, DIRECTORATES, AND FREE STANDING OFFICES, FROM DAVID MICHAELS. *Revised VPP Policy Memorandum #5: Further Improvements to the Voluntary Protection Programs (VPP).* August 14, 2014. *See* https://www.osha.gov/dcsp/vpp/policy_memo5.html (accessed June 14, 2016).

[88] ISO Guidance Document F: *Safety Culture Assessments.* June 15, 2011; p F-17. http://cchealth.org/hazmat/pdf/iso/section_f.pdf (accessed June 14, 2016).

severe incidents are not reported. Acid and caustic exposure incidents were identified as prime candidates for not being reported. If the exposure was minor, the acid or caustic could be readily washed off, and if there were no management witnesses to the incident, alkylation unit workers believed the incident would not likely be reported.

Some workers felt Cal/VPP was driving important safety improvements. For example, the Cal/VPP efforts identified that there were significant gaps between corporate standards and Tesoro Martinez site-specific procedures. One such gap was that the Tesoro Martinez procedure permitted the cutting of piping that was isolated from the process using only a single isolation valve, such as the butane piping involved in the March 10, 2014 incident that injured two workers, yet the Tesoro corporate standard prohibited this approach. PSM compliance audits conducted by Tesoro in 2009 and 2012 did not identify this gap. In addition, some workers raised issues with procedures in their comments to the 2013 safety culture survey.

> [Refinery] Rules and Standing Instructions are difficult to use (locate specific Information) and therefore not adequately used as a decision making tool. They are often mis-quoted. The VPP was on the right track for identifying these issues and offering corrective actions when it was discontinued.

Pressure to Operate with Unstable Conditions

Some Tesoro Martinez alkylation unit operators said there is a "constant battle" with management wanting to cut acid feed to the alkylation reactors. Acid runaways are a significant concern with sulfuric acid alkylation units and can occur when acid concentrations fall below the operating limit. At these low acid strength conditions undesired reactions cause unstable plant conditions that are commonly referred to as "acid runaways." Acid runaway events cause loss in alkylation capacity and a potential for equipment damage that results in a loss of primary containment. Operating at low acid strengths that are close to the operating limit is, however, more economical. As a result, there is a financial incentive to operate with lower acid strength.

According to alkylation unit operators, Tesoro management had been trying to achieve more economical operation and was routinely pushing operators to run near these limits. In theory, there is nothing wrong with this type of approach, provided it can be done safely. Operators stated, however, that they believed existing alkylation unit controls were not sufficient to manage the process at the edge of safe operating parameters and the unit was not stable at these low acid strength conditions. Contra Costa County's inspection report conducted following the February 2014 acid release incident noted that Tesoro's alkylation unit operating manual indicates that "'Acid Runaway' episodes have occurred at the Golden Eagle unit a number of times." Tesoro workers informed the CSB that the refinery experienced recent acid runaway incidents in October 2013 and in January 2014. Workers stated to the CSB that these incidents also resulted in accelerated corrosion and leaks in the spent acid piping system that contributed to worker injuries from sulfuric acid burns. In contrast, when the CSB evaluated other nearby refineries with sulfuric acid alkylation units, investigators were shown more advanced control systems and other significant technology improvements. These systems provided economical operation while retaining sufficient control to avoid acid runaway incidents.

Some worker comments to the 2013 safety culture assessment also reflected pressure from site supervisors. One worker wrote:

> Pressure from our supervisors, everything is easily said in safety meeting (safety is #1, take time to do work safely). But when you are out in the field you are pushed and safety is overlooked.

Cycle of Worker Injuries and Pressure to Fill Positions

Tesoro reported that its worker safety performance in 2013 was the best in the history of the refinery, "with the equivalent of three recordable injuries in approximately 3.5 million working hours."[89] For a variety of reasons that included numerous injuries to alkylation unit workers, however, at the time of the March 10, 2014 incident only six of the 12 operator positions were filled. Alkylation unit workers told the CSB that injuries in 2013 resulted in pressure to fill the gap with overtime, which resulted in some workers having as many as 1,300 hours of overtime in 2013 as they filled the roles of their injured coworkers. In addition, Tesoro records show that in 2013 workers in the alkylation unit averaged nearly 800 hours of overtime, more than any of the other 15 units within the refinery and 180 percent above the refinery average.

The ISO guidance for safety culture assessments calls out allocation of adequate resources to perform work safely as another focus area to evaluate effective management commitment and leadership.[90] Due to the limited number of qualified operators in the alkylation unit, Tesoro attempted to reduce the required staffing to do some jobs, which would then increase the operator workload. Some alkylation unit operators who perform these tasks stated they strongly believed that in some situations, Tesoro has gone too far and the low staffing level resulted in unsafe conditions. As a result, some operators informed the CSB that they have resorted to signing documents "under duress" or something equivalent to communicate their disagreement with the modifications.

Some operators stated that due to the low number of qualified operators in the alkylation unit, they have perceived tremendous pressure to expedite training to get qualified for the alkylation operator position. The CSB learned that while senior operators who qualified six to seven years ago typically had up to 12 months of training in order to get qualified, Tesoro more recently pressured operators to qualify in as little as 44 days. Some alkylation unit operators believe this pressure contributed to at least two of the recent operator injuries that occurred during training. Including the February 12, 2014 incident, alkylation unit workers informed the CSB that there were four operator injuries in the previous six months during training in the alkylation unit. One worker stated, "But the problem is they're out there busting their butts trying to get qualified, trying to avoid getting written up, because you've got this 44-day window you're

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[89] Rogers, Robert. Tesoro bashed for dropping worker-safety programs at Contra Costa refinery where acid spills occurred. *The Mercury News,* March 12, 2014. http://www.mercurynews.com/marcus-thompson/ci_25323196/ (accessed June 14, 2016).

[90] ISO Guidance Document F: *Safety Culture Assessments*. June 15, 2011; p F-17. *See* http://cchealth.org/hazmat/pdf/iso/section_f.pdf (accessed June 14, 2016).

giving them." Some comments workers made in the 2013 safety culture assessment also reflected the intense pressure to complete training.

> "Add the 3 hours of cross-training we are responsible for each day and that doesn't leave much for time for getting familiar and really learning the unit. This is the pressure I feel as an operator. My stress level has increased significantly. With this added stress and constant pressure from the supervisor put in charge of training, I could easily not be focused on safety while performing my job as an operator."

> "Stop rushing training and pressuring people to qualify on their positions. I feel like I'm training with a gun to my head. I used to love this job, now I hate this place. Someone is going to get hurt because I'm so worried about losing my job that I'm willing to have my qualification 'pencil whipped.'"

Communication of Safety Issues

Another area the ISO guidance identifies to evaluate management commitment and leadership is management's emphasis on communication of safety issues.[91] Alkylation unit operators expressed concern to the CSB that Tesoro's inspection department does not inform them of significant mechanical integrity issues, such as when they identify piping below its minimum required thickness. As a result, operators believe they may spend time near potentially dangerous equipment. Operators have requested that management inform them of these potential hazards so they can minimize their exposure, but alkylation unit workers indicated that this has not always occurred.

Workers stated to the CSB that following the multi-fatality Tosco incident, many improvements were made. For example, health and safety staffing increased to provide full 24/7 coverage. Since Tesoro purchased the refinery, however, some workers believe that the health and safety department positions were cut and workers stated that many shifts now operate without health and safety coverage. One worker summarized their understanding of the staffing changes as, "[w]e hired all these health and safety guys and now they're cutting those people back." As previously stated, some workers cited the deterioration of the health and safety department in their 2013 safety culture comments to support their view that Tesoro was not committed to worker safety.

Pressure on Operators to Prepare Jobs for Maintenance

Tesoro alkylation unit operators informed the CSB that work delays have occurred when maintenance workers arrive to obtain a permit to perform a job and the operators have not already prepared the job for maintenance. Equipment preparation is time consuming. It typically involves removing hazardous materials, washing, draining, purging, and locking out to make the equipment safe prior to issuing a work permit. Tesoro developed a "permit readiness" program to help maximize the efficiency of maintenance

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[91] *Ibid* at p F-17.

work. Through this program, Tesoro provides the night shift operators a list of work tasks planned for the following day, so they can prepare the jobs for maintenance. The intent of this program is to increase maintenance efficiency on the day shift. With this system, a day shift operator should only need to verify the job is prepared, rather than actually conducting the preparations. This allows night shift operators to make the equipment safe and mitigate the time pressure that day shift operators would typically experience. The idea was simple enough, but Tesoro alkylation unit workers described it as a "failed system." According to alkylation unit operators, the primary problem is that Tesoro only informed night shift operators about 25 percent of permits requiring safe equipment preparation. As a result, day shift operators still experienced pressure to prepare many jobs for maintenance that could have been prepared during the previous night shift.

Operators believe that not having permits ready when maintenance workers arrive to perform work developed into a significant problem at the alkylation unit. When maintenance workers cannot get a permit because they arrive at the control room and find a long line of workers already awaiting a permit, they inform their supervisor about the work delay. Rather than effectively addressing the problems with the permit readiness program, alkylation unit operators informed the CSB that operations supervisors directed the problem back to the operators and put pressure on the operators to get the jobs prepared faster. The perception that operators held up maintenance work also escalated to investigations where operators stated that management critically assessed their performance.

> "Just over and over, investigation after investigation. Why are you holding work up?"
>
> "And so it's always a constant of people trying to run around trying to find ways to make things go faster. And we always find ourselves back at square one trying to do it back right, the way it should be."
>
> "I'll have 15 or 20 permits out on a day, or there'll be a line at 7:00, 8:00 in the morning, there'll be a line out the door of people waiting and I'm just one person."

The problem culminated in the March 10, 2014 incident when sulfuric acid sprayed two contract workers and sent them to the hospital. The job the workers were performing at the time was not on the permit readiness sheet as requiring a hot work permit (Figure 20).

TESORO Golden Eagle Refinery

Permit Readiness Request Sheet

Permit Request Date	Start Time	Unit / Short Work Description	Additional Work Description	Permit Type	Repeat?
03/10/2014	7 am	Alky / R-2	Remove Butane wash piping	Safe	New

Figure 20. Tesoro's Permit Readiness Sheet. This is an excerpt from the permit readiness sheet provided to operations to communicate what maintenance work permits were needed on March 10, 2014. As indicated on the sheet, only a safe work permit was planned, while the butane pipe cutting actually required a hot work permit that required the operator to perform additional and unexpected work.

When the maintenance supervisor arrived and needed a hot work permit instead of a safe work permit, the alkylation unit operator conducted a walk-through with the supervisor, reviewed the lockout, opened the drain valve, and checked for hydrocarbons. Workers indicated that jobs were beginning to "pile up," however, and workers felt pressured to keep other maintenance jobs moving. Therefore, the operator issued the permit and turned his attention to the next job, which like many other work tasks, was also not on the permit readiness sheet.

As previously discussed, when asked why operators might not take the time to perform extra steps that could be prudent in order to ensure a system was effectively drained, one operator stated that such actions would be "frowned upon by management." He also noted that he would be "questioned by management" as to why he was taking those potentially unnecessary additional precautions, despite the fact that such actions could have protected workers. In light of the difficulties with the permit readiness program, and resulting pressure on workers, a picture begins to emerge with respect to why supervisors might frown upon safety activities and additional precautions.

In the end, Tesoro did not effectively prepare the butane piping prior to issuing the hot work permit for maintenance, as required by the Tesoro corporate blinding and isolation standard. Tesoro used a single valve to isolate the piping from the butane still flowing to other operating reactors. The piping was under pressure and was not flushed and drained to remove hazardous residual chemicals. These omissions led to the March 10, 2014 incident. Instead of taking the time to prepare the job for maintenance more effectively, Tesoro relied on PPE, a weaker safeguard to protect against potential hazardous material inside the pipe, the failure of which led to the contract workers' injuries.

The safety culture at the Tesoro Martinez refinery's alkylation unit did not support the safer course of action, involving additional steps such as blinding the piping on the butane side, verifying drain valves were open and free of plugging material, and flushing the line to ensure it was free of residual hazardous chemicals. This is true despite the fact that the line typically carried butane, and that there were several documented instances of sulfuric acid getting back into the line – either of which, if present, posed a clear hazard to the two contract workers engaged in pipe cutting operations on March 10, 2014.

6.0 The Role of the Regulator

6.1 Proactive and Preventive Inspections

The CSB noted in the Chevron Regulatory and Tesoro Anacortes investigation reports that robust preventive inspections and audits by a technically qualified regulator are necessary to encourage industry to adopt safer practices and to reduce risks to as low as reasonably practicable, or ALARP. To facilitate continual improvement the regulator should have the flexibility to work with facilities to ensure the implementation of recommendations and lessons learned from significant petroleum refinery incidents without requiring extensive rulemaking or legislation, as regulators have done post-incident in countries such as the United Kingdom, Norway, and Australia. The regulator should also have the ability to examine previous incidents and require that refineries use the hierarchy of controls to identify hazards and reduce risks to ALARP or similar. The CSB found in its investigation of the Chevron Richmond fire that the California process safety management (PSM) regulator Cal/OSHA lacked the resources to conduct sufficient preventive inspections of petroleum refineries in California. In Chevron and Tesoro Anacortes, the CSB made recommendations to California and Washington to increase regulatory staffing and enhance their process safety management regulations through preventive inspections, the use of hierarchy of controls, and risk reduction to ALARP or similar. At present, California has increased enforcement funding and staffing and is working to strengthen the process safety management regulations that empower the regulator to be more proactive. Washington is holding regular PSM advisory meetings to discuss PSM reform and requested a budget increase to fund additional PSM inspectors for the state. The budget increase request was not approved; however, the CSB remains encouraged that Washington is continuing to work to improve its PSM regulations and oversight for petroleum refineries.

The acid sampling station at the Tesoro Martinez refinery is a simple example of the potential for safety improvement this approach can create. The California PSM regulator Cal/OSHA and the Contra Costa County regulator could have observed the sample stations at Tesoro Martinez and other refineries in the course of their preventive inspection programs. Depending on the nature of the regulator's powers, the regulators should have the authority to direct or encourage the adoption of safer designs in light of better practices elsewhere.

In addition, an adequately resourced, empowered regulator likely could have been more aware of and examined the many sulfuric acid incidents at the Tesoro Martinez refinery, especially because they shared many commonalities and involved unnecessary worker exposure to sulfuric acid. This awareness could have triggered additional review and evaluation of the refinery's safety systems and sulfuric acid equipment and ideally, the regulator could require the use of the hierarchy of controls to achieve greater risk reduction and accident prevention.[92] In its inspection report following the February 12, 2014 sulfuric

[92] The CSB expressed concern that the most recent draft PSM Regulations in California require a refinery to perform a hierarchy of controls analysis for process hazard analysis (PHA) recommendations, but only if they are associated with the potential for a "major incident." The CSB noted that this limits the scope and may preclude the use of a hierarchy of controls analysis as a risk reduction tool. While not all of the many sulfuric acid incidents at the Tesoro Martinez refinery were considered "major," they still resulted in worker injuries and spoke to serious safety culture deficiencies that the regulator could have identified and addressed prior to the February and March 2014 sulfuric acid incidents. *See* the CSB's comments on the State of California Department of Industrial Relations (DIR) Division of Occupational Safety and Health Proposed GISO § 5189.1, Version 5.0.

acid release incident that injured two workers, Contra Costa County did identify better sulfuric acid sampling practices that they observed post-incident at other refineries and recommended that Tesoro adopt these safer sampling practices.

6.2 Process Safety Indicators and Incident Investigations

In the CSB Chevron Interim, Regulatory, and Final investigation reports the CSB discussed the importance of collecting and analyzing leading and lagging process safety indicators to help drive ongoing process safety improvement. Process safety indicators are a significant element of process safety management systems as they measure the strengths and weaknesses of these systems to achieve and maintain safe and reliable operations.[93] Effective regulators can use lagging indicators, such as spills, fires, or gas releases, as well as leading indicators such as timely maintenance on safety critical equipment to focus inspections, audits, and timely closure of action items resulting from incident investigations to help drive safety improvement. As a result of the Chevron investigation the CSB made recommendations to the State of California, Contra Costa County, and the City of Richmond to develop a system that collects, tracks, and analyzes process safety leading and lagging indicators from refineries to measure major accident prevention performance and to promote ongoing safety improvement. Contra Costa County revised the Industrial Safety Ordinance (ISO) in 2014 to require covered refineries to publicly report process safety performance indicators annually.[94] At the time of the February and March 2014 incidents at the Tesoro Martinez refinery, Tesoro was not required to report indicators to the regulator, nor did they voluntarily make them publicly available. The CSB has urged the State of California to require refineries to develop and report process safety indicators, particularly leading indicators that can identify process safety management issues prior to a negative outcome and allow the regulator to determine overall trends in safety and risks at California refineries, as well as the effectiveness of their own enforcement efforts.

This report details missed opportunities for Tesoro Martinez refinery management to implement lessons learned from previous incident investigations and recommendations. A proactive regulator's robust collection and assessment of leading and lagging process safety indicators such as the numerous sulfuric acid releases that occurred between 2010 and 2014 and a review of investigations into these incidents may have led to an increased focus on employee exposure to acid at the Tesoro Martinez refinery. The numerous incidents at the alkylation unit could also have illuminated leading indicators of an impending major chemical accident.[95] Ultimately, a more proactive focus on implementing corrective actions and lessons from previous sulfuric acid incidents could have helped to prevent the February and March sulfuric acid incidents.

October 7, 2015. http://www.csb.gov/assets/1/7/CSB_Comments_California_PSM_Draft_Regulations_5.0_Oct_7_2015(2).pdf (accessed June 20, 2016).

[93] CSB Regulatory Report. *Chevron Richmond Refinery Pipe Rupture and Fire*. October 2014; p 58. http://www.csb.gov/assets/1/19/Chevron_Regulatory_Report_11102014_FINAL_-_post.pdf (accessed June 14, 2016).

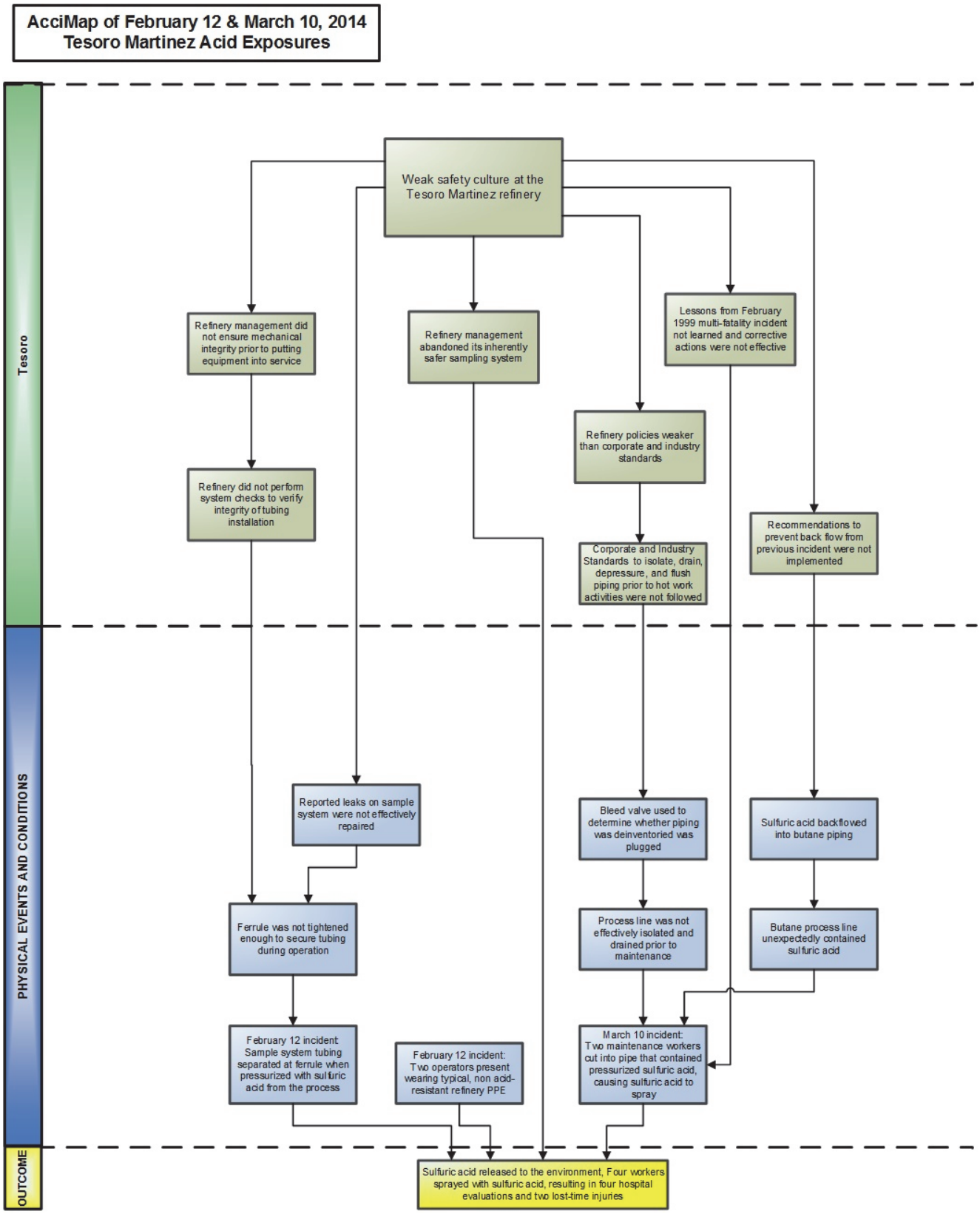
[94] County Ordinance Chapter 450-8.016 (13)(D). May 6, 2014. http://cchealth.org/hazmat/pdf/iso/Chapter-450-8-RISK-MANAGEMENT.pdf (accessed June 14, 2016).

[95] According to API, Tier 2 Process Safety Events (such as the March 10, 2014 incident) "indicate barrier system weaknesses that may be potential precursors of future, more significant incidents…[and] can provide a company with opportunities for learning and improvement of its process safety performance." API. *Recommended Practice 754: Process Safety Performance Indicators for the Refining and Petrochemical Industries.* April 2010; p 11.

7.0 Conclusion

Significant process safety culture deficiencies contributed to a pattern of sulfuric acid exposure incidents that occurred at the Tesoro Martinez refinery's alkylation unit between 2010 and 2014, including two incidents that occurred in February and March 2014 that injured four workers in total and in one instance led to a significant release of sulfuric acid. These deficiencies included Tesoro's postponement of efforts to make safer sulfuric acid sampling systems functional, tolerance of worker exposure to sulfuric acid and caustic during sampling, weaknesses in nonroutine maintenance work practices, policies, and procedures, and failure to address issues identified in safety culture surveys. In addition, Tesoro did not effectively address and/or maintain lasting safeguards to prevent major accidents, and did not adequately learn the important process safety lessons.

Furthermore, safety culture assessments, such as those presently required for petroleum refineries and chemical manufacturing facilities in Contra Costa County, California, can provide critical insight into cultural weaknesses that may contribute to process safety incidents. Simply identifying safety culture deficiencies, however, is not sufficient. Effective continual improvement programs are necessary to address safety culture weaknesses in order to prevent significant accidents, worker injuries, and the potential for community impact. The CSB encourages Tesoro to strengthen its process safety management systems and overall safety culture in order to address the significant process safety issues this case study identifies to protect workers and reduce future accident risks.

Finally, these incidents also demonstrate the importance of the collection and analysis of process safety indicators and the conduct of preventive inspections by the regulator to ensure refineries are implementing good safety practices to reduce accident risk to ALARP. Preventive inspections are critical to ensure effective implementation of corrective actions following accidents.

Appendix – Causal Analysis AcciMap