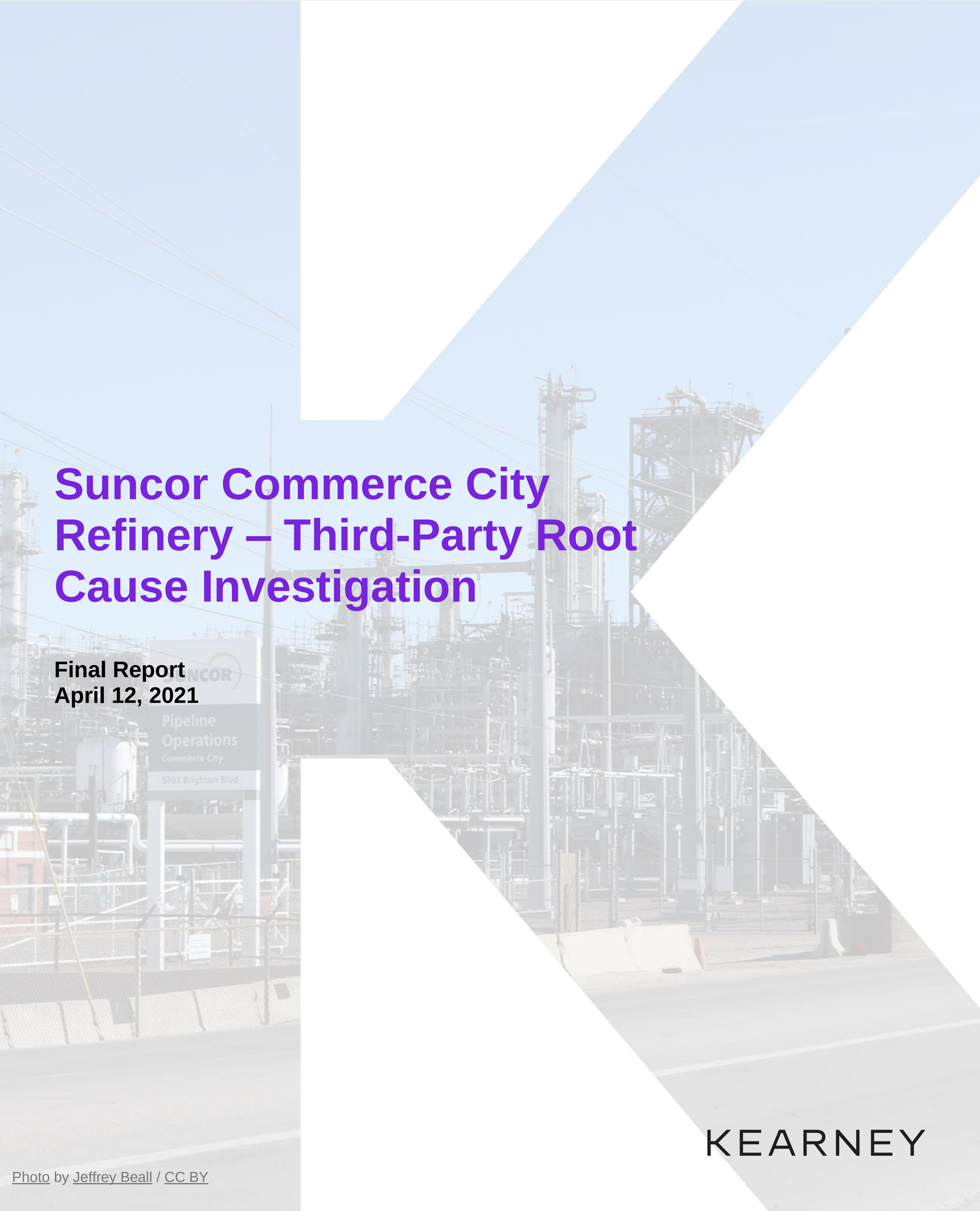

Suncor Commerce City Refinery – Third-Party Root Cause Investigation

Final Report
April 12, 2021

KEARNEY

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Executive Summary

As part of a settlement with the Colorado Department of Public Health and Environment (CDPHE), Suncor Energy (U.S.A.) Inc. (Suncor) engaged Kearney to: (1) investigate root causes of air emissions exceedances[1] at the Commerce City refinery from July 2017 to June 2019, including any causes relating to the design of the refinery's fluidized catalytic cracker units (FCCUs) and sulfur recovery units (SRUs) and/or Suncor's operating or maintenance practices or procedure relating to this equipment; and (2) recommend measures to minimize or prevent future recurrences of emissions exceedances at the FCCUs and SRUs.

Kearney is a leading global management consulting firm with more than 3,600 people working in more than 40 countries. We have conducted assessments of safety, environmental, and operations performance for more than 50 refineries and petrochemical facilities. We assembled a senior team with over 75 years of refinery operations and management experience to conduct this investigation of the Commerce City refinery.

The investigation included review of documents related to key operational areas, interviews with refinery and corporate employees, three weeks of on-site activities (including observation of a fluidized catalytic cracking unit's start-up), and extensive analysis of site data, including procedures, operating parameters, and safety analyses.

The site experienced multiple Title V air emissions exceedances from July 2017 to June 2019, including releases of catalyst, hydrogen sulfide, sulfur dioxide, hydrogen cyanide, nitrogen oxides, carbon monoxide, and opacity exceedances. We evaluated the root causes for these exceedances to identify the degree to which the site spending and headcount, equipment design, and systemic or human factors were contributors to these incidents. Our analysis examined environmental and safety incidents at the site during this period, including those that did not result in air emissions exceedances or Title V violations and those for which a start-up, shutdown, or malfunction defense was claimed.

The site's overall cost structure, maintenance spending, and headcount were benchmarked against industry standards, and found to be in line with other US refineries of similar size and complexity. In addition, there were no deliberate reductions in operating expenses or staffing levels over a five-year period prior to the multiple Title V exceedances. Therefore, we concluded that budgets and headcount were not inappropriately low and were not a primary contributor to the incidents at the refinery.

The design of the site is sufficient to meet environmental permits in place during steady-state operations. Therefore, refinery design was ruled out as a *root cause* (although the report does contain recommendations for capital investment to mitigate the *impact* of future incidents). The site has experienced air emissions exceedances during start-up, shutdown, and malfunction (SSM) conditions, and claimed an SSM defense for these.

Given that the site design, budget/spending, and staffing levels were ruled out as root causes of the incidents, we focused on systemic (human factor) root causes, and ultimately, we identified opportunities for improvement in the site's environmental performance by comparing the refinery's key work practices with leading practices derived from Kearney assessments of more than 50 refineries and petrochemical facilities globally. These practices are grouped across four categories: culture, staff capabilities, processes, and technological/physical safeguards.

We identified a number of gaps when comparing performance against leading practices across these four areas at the site and have developed recommendations to address the most critical gaps identified (across culture, staff capabilities, processes, and technology).

Most of the gaps relate to the site culture, staff capability and/or processes that collectively led to underestimating the risk associated with certain activities and operating conditions. While the site (and Suncor corporate) have very clear and appropriate policies for dealing with identified risks, the frequent underestimating of risk contributed directly to most of the exceedances and incidents within the scope of this report.

To help advance a culture that is focused on environmental performance and does not tolerate actions that increase the risk of future Title V air emissions exceedances, we recommend:

- Continuing to expand and reinforce a culture focused on safety and environmental responsibility above all.
- Increasing the involvement of the Suncor Technical Expert Network (STEN), which is comprised of technical experts across Suncor's enterprise at other locations and other external technical experts in critical safety and environmental

[1] Exceedances are instances where the site operated outside the normal limits in its Title V permits. Not all exceedances are penalized, as violations as the Title V permits make allowances for specific equipment deviations during start-up, shutdown, and malfunction periods.

reviews to reduce the likelihood that potentially high-risk activities are undertaken.

– Focusing on excellence across a critical few initiatives, so as to avoid mediocrity across the ‘impossible many’.

To improve in areas related to staff capabilities, we recommend:

– Implementing innovative recruiting strategies to address immediate operations and technical staffing needs resulting from recent higher-than-expected voluntary attrition levels.

– Improving technical and operations staff training with additional training techniques and greater incorporation of experts and full-time trainers.

To improve processes at the refinery, we recommend:

– Transferring operating procedure accountability from technical staff to operations.

– In times where significant corrective maintenance is required, using risk assessments to ensure the most critical maintenance work is prioritized (and less critical work deferred where appropriate).

Finally, to improve technological and physical safeguards that help mitigate the impact of abnormal conditions, we recommend:

– Installing automated unit shutdown capability at the FCC unit in Plant 2 to minimize the potential for large catalyst releases when operating incidents do occur.

– Leveraging digital technology to increase real-time availability of critical procedures and expertise.

The Commerce City refinery has already made progress in many of these areas since the end of the study period, but additional action is required in several areas.

We have identified prioritized initiatives to be implemented using the $5 million Suncor committed to invest as part of the settlement with CDPHE. These are the initiatives that we believe will have the most significant long-term impact on operational integrity and minimizing or preventing future emissions violations, and include: the installation of emergency shutdown equipment, training improvements including a training simulator, and the increased use of digital technology to increase the availability of critical procedures, and improve engagement with the Suncor Technical Expert Network (STEN) or other external technical experts. We estimate that the emergency shutdown equipment installation alone will require a capital investment of greater than $5 million. A training simulator would require investment in the $ 0.5 – 1 million range and three to five work years of effort to fully implement.

Background and Context

This section provides a brief overview of the Suncor Commerce City Refinery, the investigation's context and objectives, and our scope for the analysis.

Refinery Overview

Suncor's Commerce City Refinery is a 98,000-barrel-per-day refinery, whose products include gasoline, diesel fuel, jet fuel, paving-grade asphalt, and several other minor products.[2]

The refinery has three plants southwest of Interstate 265, near the intersection with Brighton Boulevard, in Commerce City, Colorado.

Suncor acquired Plants 1 and 3 from Conoco in 2003, following a merger between Conoco and Phillips Petroleum.[3] The company acquired Plant 2 from Valero Energy in 2005.[4]

Plants 1 and 2 contain fluidized catalytic cracker units (FCCUs), which process heavy oil feedstock in the presence of a fine-grained catalyst to produce gasoline, diesel, and other products.

Context for Investigation

As part of a settlement with the CDPHE, Suncor was required to engage a third-party firm to investigate root causes of emissions exceedances at the site and recommend measures to prevent future violations of the site's environmental permit.

Suncor engaged Kearney, a leading global management consulting firm with more than 3,600 people working in more than 40 countries. We assembled a senior team with over 75 years of refinery operations and management experience.

Mandate and Scope

Objectives

The investigation had three objectives:

1. Confirm the causes of Title V exceedances for the study period from July 1, 2017 to June 30, 2019.
2. Make recommendations, including improvements or changes to design, operations, or maintenance, to minimize or prevent future recurrences of Title V violations.
3. Prioritize initiatives to be implemented using the $5 million Suncor committed to invest as part of the settlement with CDPHE.

Scope

For this investigation, in-scope equipment consisted of the Plant 1 and Plant 2 FCCUs and sulfur recovery units (SRUs), identified as AIRS Point IDs 025, 100, 217, and 220.[5]

In-scope Title V exceedances included, but were not limited to, catalyst releases, opacity exceedances, and releases of hydrogen cyanide (HCN) and hydrogen sulfide (H_2S). All incidents at the site during this time were included in the scope of the investigation.

During the investigation, we examined 140 incident reports that occurred within the study period. In-scope incidents included environmental incidents occurring during steady-state operations, environmental incidents for which Suncor asserted SSM defenses, and other incidents that did not result in Title V exceedances (e.g., safety incidents).

The incidents include both those resulting in Title V exceedances and others with actual or potential regulatory, environmental, safety, or financial impacts. In our experience, it is appropriate to provide such a broad set (beyond those that violated the operating permit), including near misses, because the underlying root causes are often systemic and similar across multiple incidents. Conversely, limiting the assessment to a relatively small set of more serious incidents could result in a failure to identify and correct the true underlying root cause(s).

We also evaluated site practices and processes, at the time of the major incidents under review and up to the present time (August 2020), to assess the extent to which actions to minimize or prevent future recurrences of Title V violations have been taken, are in progress, or are planned.

[2] Suncor website

[3] https://www.bizjournals.com/denver/stories/2003/04/14/daily13.html

[4] https://www.denverpost.com/2005/06/01/suncor-purchases-valero-oil-refinery/

[5] AIRS stands for aeromatic information retrieval system.

Approach

This section outlines the data-gathering approach, areas of analysis, and actions taken during the investigation to confirm the causes of Title V exceedances and develop recommendations to minimize or prevent future recurrences of Title V violations.

First, we assessed whether the site budget and staffing levels were in line with comparable refineries and whether the refinery had recently made significant changes in either area. We then looked at the site's design to ascertain its capability for stable operations, as defined by its operating permit, and whether there were safeguards to prevent significant safety or environmental impact, should excursions occur.

We then examined the root causes of environmental and safety incidents at the site to identify the presence of systemic issues.

Finally, we compared Commerce City operations against leading practices to reduce the risk of significant safety and environmental incidents. The goal of this exercise was to identify tangible actions and areas for additional investment that would reduce the risk of future incidents similar to those occurring during the study period.

Document Review

As part of the investigation, we reviewed a significant amount of data and documents related to areas important for safe and reliable operations, including those pertaining to the site's culture, staffing, capabilities, processes, technology and design. This included confidential data and documents related to refinery goals, plans, policies, processes, procedures, operational performance, benchmarking, maintenance, incidents, inspections, audits, human resources, organizational charts and training. The scope and categories of the data and documents analyzed were reviewed with CDPHE. The specific data and documents are not listed in this report as they are and/or contain confidential business information.

Interviews

The investigation process included approximately 30 interviews with personnel across all levels of the refinery and supporting organization in management, operations, maintenance, and technical areas, as well as Suncor corporate. This included: members of the refinery leadership team responsible for overseeing operations, engineering, maintenance, safety, reliability, and environmental performance; refinery managers, supervisors, engineers, operators, emergency response and training personnel; and enterprise technical experts.

Site Visit

The investigation included three weeks of site visits to observe general site operations, conduct in-person interviews, and review the preparations leading up to No. 2 FCCU start-up. Kearney observers were on site for 12 days in August 2020.

During the site visit, we observed preparations for start-up, procedure review and updates, troubleshooting and equipment testing, pre-start-up safety reviews, and cross-functional team meetings. Kearney observers sat in on multiple technical meetings.

The site visit also included observations of the condition of relevant equipment and general site hygiene, and validation of selected critical data (such as procedures, operating parameters, and safety analyses).

Our on-site activities during the observation period included the No. 2 FCCU start-up, from catalyst loading and circulation, to addition of torch oil, which was an area of concern, given prior Title V exceedances during FCCU start-up.

Critical Success Factors for Effective Refinery Operations

Based on our previous work in similar assessments at over 50 sites operated by several leading refining and petrochemical companies, we have developed a set of leading practices—common get-right factors that lead to reliable, safe, and successful refinery operations. We considered these leading practices in the context of broader site performance when we assessed the potential systemic root causes of the incidents within this study's scope.

This section provides a brief overview of these factors.

Factors

Four overriding factors present in all high-performing refineries are:

– Safety and environmental responsibility. In any refinery or other manufacturing operation where hazardous materials are processed at relatively high temperatures and pressures, a focus on personal safety, process safety, and environmental responsibility is of paramount importance.
– [6] A culture of safety and environmental responsibility is critical and must be established by corporate and site leadership.
– Operations reliability and integrity. In all operations with a significant installed capital base, sites need to operate reliably with very high utilization of key equipment. Top performance is driven by a combination of excellence in design, maintenance, and operating discipline. This is particularly important for a facility such as the Commerce City Refinery, which would cost billions of dollars to replicate.
– Workforce capability. Robust and consistent employee capabilities and staffing levels are at the heart of safe and reliable refinery operations. Sufficient staffing is key, with the right employees highly trained in complex refining operations and, ideally, select operations and maintenance employees cross-trained to allow the site to operate effectively when absenteeism, retirements, and other employee attrition occurs.
– Appropriate cost structure. In our experience, it is possible to have a consistent and leading cost structure only when the other three factors are present. They drive cost structure but are affected by it, too. For example, it is unlikely that a site with poor operating reliability will have continually low maintenance costs, because it likely spends more on unplanned equipment breakdowns.

A lower cost structure, if combined with excellence in the other three factors is generally acceptable and sustainable.

We have typically found that sites performing strongly across all four factors have a low risk for significant safety and environmental incidents. However, if a facility has a low-cost structure relative to peer refineries, but lags in the other areas, we typically see much higher potential for safety and environmental incidents.

This applies across all categories of refineries, in terms of size, location, complexity, and other parameters. However, in our experience conducting similar site assessments at over 50 leading refineries and petrochemical sites, we have seen no correlation between safety and environmental performance and factors such as age of the equipment, size of the refinery, and degree of maintenance outsourcing.

Cost and Staffing Levels

Given that the Commerce City Refinery experienced an increase in environmental and safety incidents during the period on which the investigation focused, the first step was to assess whether the overall cost structure (including maintenance spend) and staffing levels were in line with similar sites, and whether significant reductions had occurred in the years leading up to the period of significant incidents.

To assess this, we evaluated historical spending and headcount trends at the refinery to determine whether they had been decreased to reduce costs. We also compared Commerce City with peer refineries to determine whether

[6] Process safety combines design, engineering, maintenance, and operation practices to prevent conditions that would have a negative impact on equipment or the environment.

overall spending and headcount were in line with industry standards. Peer refineries are those in North America with similar processing capacity (barrels of oil per day), number of process units, and process complexity.

The site participates in proprietary and confidential industry benchmarks to compare a variety of performance metrics against other refineries in the United States. These benchmarks, shared only with participants in the benchmarking exercise, rank facilities in a variety of categories, including maintenance spending and headcount. Facilities that are leaders, with low maintenance spend or headcount for their size, are assigned to the first quartile of performance in these metrics. Facilities with high maintenance spend and headcount compared to peers are assigned to the third or fourth quartile.

Based on cost and staffing benchmarks conducted on the Commerce City Refinery, the details of which have been omitted for confidentiality reasons, costs and staffing levels were not leading (i.e. low), but rather at higher than average levels for both cost and staffing relative to industry peers. Benchmarks also show there were no significant changes (specifically no reductions) made in either of these areas during the study period, or in the immediately preceding period.

In conclusion, overall costs, maintenance costs, and staffing levels were at or above industry standard levels throughout the study period, and there was no evidence of deliberate reductions in spending or headcount. Therefore, these factors can be ruled out as primary causes of the incidents in scope.

Site Design Review

Operational Control and Deviation Prevention

For sites where maintenance spend is not of primary concern, the next area to consider is the design of the facility. An acceptable design allows the site to operate in compliance with environmental permits and helps prevent escalation of incidents.

To assess the site's ability to operate in compliance with its Title V permits, we reviewed the site design and operating parameters, limits and conditions in the Title V permits, historical ability to maintain operations within these limits during steady-state and start-up/shutdown/malfunction operations, and conducted discussions with Suncor and Kearney technical experts.[7]

For the units in question, including Plant 1 and Plant 2 FCCUs and sulfur recovery units (SRUs), we conducted analyses to understand:

1. The ability of the refinery units to maintain stable control of critical process variables and avoid exceedances under normal operation,
2. The ability of the refinery units to recover and return to normal operations when abnormal conditions or disruptions occur,
3. In the event that the site was not able to return to normal operations and an exceedance occurred, whether equipment design was the underlying root cause for that exceedance, and
4. The ability of the refinery's design to prevent incident escalation, including its emergency shutdown capability, in the event of an exceedance or incident.

Our investigation revealed the following:

1. The refinery's site design ensured maintenance of stable control of critical process variables and avoidance of exceedances under normal operating conditions.
2. The site was able to mitigate critical process variable excursions in most instances of an abnormal condition or disruption to normal operations.
3. In the event of an incident, including exceedances, we thoroughly investigated and evaluated the underlying root cause to understand why the site was not able to return process variables to the normal operating range. The findings of our investigation into underlying root causes are available in this report, as explained more fully in the 'Root Causes' subsection on the following page. The root causes for approximately 80 percent of the incidents were determined to be the result of one of three common factors: procedures, interfaces and escalation (detailed definitions of these factors are provided on the following page). Only 2 percent of the incidents had a design-related underlying root cause, and these causes were not related.
4. The refinery's design was appropriate to prevent incident escalation for the SRUs and Plant 1 FCCU. For Plant 2 FCCU, we recommended the site invest in additional equipment to mitigate the impact of

[7] Title V operating permits are required for major sources—typically, those emitting more than 10 tons a year of hazardous air pollutants—under the Clean Air Act, and set limits for emissions, require specific equipment operating conditions, and may contain other requirements. Holders of Title V permits must certify their compliance with requirements.

potential incidents (specially, to reduce the likelihood of significant catalyst releases to the atmosphere).

Based on our analyses and findings in items 1 through 4 above, we concluded that site design was not a significant underlying root cause of the incidents in question.

Contaminant Emissions

During normal operations, the refinery has the potential to emit a variety of contaminants, including catalyst, particulate matter leading to opacity, hydrogen sulfide, and hydrogen cyanide (HCN).

Analysis of design information in the context of these contaminants concluded that the design of the site enables it to operate in compliance with current environmental permits and regulations during steady-state operations. However, during normal operations, the site exceeded its annual limit for HCN emissions set in its Title V permit. Find additional analysis of this violation in Appendix 1 – Emission Sources.

The refinery emits small levels of HCN during normal operations. There were no incidents of unusually high levels. However, most refineries have not requested an emission limit for hydrogen cyanide in their Title V permit, as Commerce City has done.

The catalyst regeneration process that results in HCN emissions at Commerce City is typical for oil refineries, and others have similar emissions. Commerce City's design regarding these emissions is not unusual. In agreement with CDPHE, Suncor is conducting HCN monitoring at the refinery site and CDPHE is planning to conduct community monitoring of HCN levels. The results of this monitoring will dictate follow-up actions on the HCN limit in the site's Title V permit.

Historically, in the face of changing regulations, the site has made investments to comply with regulations, making a $445 million upgrade in 2005 to meet clean-fuels regulations, for example.

Incident Evaluation

A holistic assessment of site performance included examining all adverse events (from near misses to major incidents) to identify potential systemic issues. Our experience shows that focusing on specific, individual incidents can lead to false conclusions about root causes. Instead, we recommend a focus on the initiating event and underlying risk factors as keys for determining prevention and mitigation.

Overview

Incidents typically occur when an overall risk level intersects with a random initiating event. Looked at individually, there can be a bias that favors technical or design-based root causes and their solutions. While this may address one event, it may not lower overall risk, because a significant investment in a technical solution to prevent a single incident from happening again may not reduce overall risk of future incidents at the site.

As an example, consider an incident where someone is driving, uses a cell phone, has an accident, and breaks a wrist. A technical-based response could involve requiring wrist braces while driving. This may prevent the exact injury from happening again, but it would not prevent other injuries from accidents caused by distracted driving. An appropriate systematic response would be to develop and enforce procedures for driving that forbid distractions and penalize those who cause them.

In our experience, based on evaluating hundreds of safety and environmental incidents—from near-misses to those with significant safety and environmental impact—most lack a primarily technical or equipment-related root cause. Instead, we have identified three dominant factors that account for more than 80 percent of root causes: procedures, interfaces, and escalation.

Procedures: Incidents arise when the right procedures are not in place, or there is insufficient training or operational discipline to ensure people follow procedures.

Interfaces: Incidents also arise when clearly delineated responsibility and accountability across departments and functions within a facility are absent, or sharing of knowledge and expertise is insufficient or ineffective. In particular, the effectiveness of interfaces between operations, maintenance, and technical staff is critical.

Escalation: More severe incidents occur when staff underestimate the risk and/or incorrectly respond to a minor incident, which results in more significant impacts that could have been reduced with a faster or more appropriate reaction.

Root Causes

At the Commerce City Refinery, we conducted an incident root-cause evaluation to determine the underlying cause of incidents there from July 2017 to June 2019. During this period, there was a steady increase in the number and consequence severity of incidents.

Our investigation covered 140 occurrences, the majority of which occurred at 5 units: Plants 1 & 2 FCCUs and the #1, #2 & #3 Sulfur Recovery Units. The distribution of incidents across units was as follows: #1 FCC (24%), #2 FCC (26%), #1 SRU (10%), #2 SRU (10%), #3 SRU (11%).Of the 140 occurrences, we found a significant majority were a result of one of the three common factors: procedures, interfaces, or escalation.

Fifty incidents (36 percent) were procedural in nature, meaning they occurred because either a procedure for proper response to events was not followed correctly, or a procedure for events leading up to incident did not exist, leaving operators without a defined response.

Twenty-four incidents (17 percent) were due to a lapse in communication. An incident occurred because either an operator lacked sufficient knowledge to respond immediately to the event and required a discussion or additional training to understand how to properly act under those circumstances, or a breach in communication led to an improper or slow response. For example, someone left a valve open during routine maintenance and failed to inform operators, who then did not know to check the valve when a unit began to malfunction.

Thirty-six incidents (26 percent) involved a situation where the event had started to occur or had already occurred, and an individual did not properly or adequately use resources to prevent it from growing or becoming more severe. Of these, seven (5 percent) occurred because an initial minor event was not addressed in a timely manner and escalated. Examples could include a leak where the source is not correctly identified, leading to greater volumes of material released. 17 incidents (12 percent) occurred due to human error, and 12 incidents (9 percent) were repeated cases caused by inadequate remediation of a root cause the first time it occurred.

In examining each of these three common factors, we found that the distribution of root causes was consistent across all of the refinery units, in scope as well as across the types of incidents. For example, 21 of the incidents were sulfur dioxide (SO2) emission exceedances and the distribution of root causes for these was similar to the overall distribution.

The aim of this incident evaluation was to determine whether the incidents occurring at Commerce City were driven by one of the three typical systemic causes found across other industry refineries. This analysis indicated that 110 incidents (79 percent) could be attributed to procedures, interfaces or escalation, while only 24 incidents (17 percent) were driven by technical or equipment-related root causes. Of the incidents that were equipment-related, only 3 incidents (2 percent) had design as the primary underlying root cause, and these were unrelated relief valve, control valve and piping issues.

Summary

Kearney did not find cavalier, or inappropriately low, costs or headcount structure to be a concerning or influencing factor in connection with incidents and environmental exceedances at the Commerce City Refinery. The site's design is sufficient to meet environmental permits during steady-state operations.

Given our conclusions on incident root causes, and cost and design practice analysis conducted, driven by previous research and analysis conducted across many other sites, we believe there were other contributing factors that must be understood to minimize the site's overall risk. In our experience, these factors are likely to be systemic or human factor-related, and we assess these by comparing Commerce City operations with leading practices across several dimensions. Given that the root causes are, in most cases, systemic in nature, and not due to budget, staffing, or design issues, the next step was to assess site practices across culture, staff capabilities, process, and technological/physical safeguards.

Leading Practices to Reduce the Risk of Major Incidents

The key to preventing major incidents is to minimize the overall risk level at the refinery. This section outlines key practices that, in our experience, lead to operating with an acceptable level of risk and therefore contribute to safe and environmentally responsible refinery operation. These leading practices have been developed from previous assessments of more than 50 refineries, petrochemicals sites, and other capital-intensive continuous process industries.

Assessment Framework

The factors associated with operating with an acceptable level of risk are similar to slices of Swiss cheese (see graphic below). Holes in the cheese are the gaps in protective measures at the refinery. From company culture to physical safeguards, these measures help prevent or mitigate the impact of incidents, but occasionally safeguards fail to catch an initiating event, resulting in an incident.

There are four key areas that, when executed properly, close the gaps and result in effective, reliable, and safe refinery operations: culture, staff capabilities, process, and technological and physical safeguards.

The presence of gaps implies potential for increased risk and requires remediating actions to be taken to address the gaps and lower risk. Stronger operating practices result in fewer gaps and prevent more incidents. Most important is culture; without a culture of safety and environmental responsibility in place, it is very difficult to have strong performance in the other areas.

Within each area, there are categories of leading practices. We detail the leading practices in each category that are relevant to the Commerce City refinery in the sections that follow.

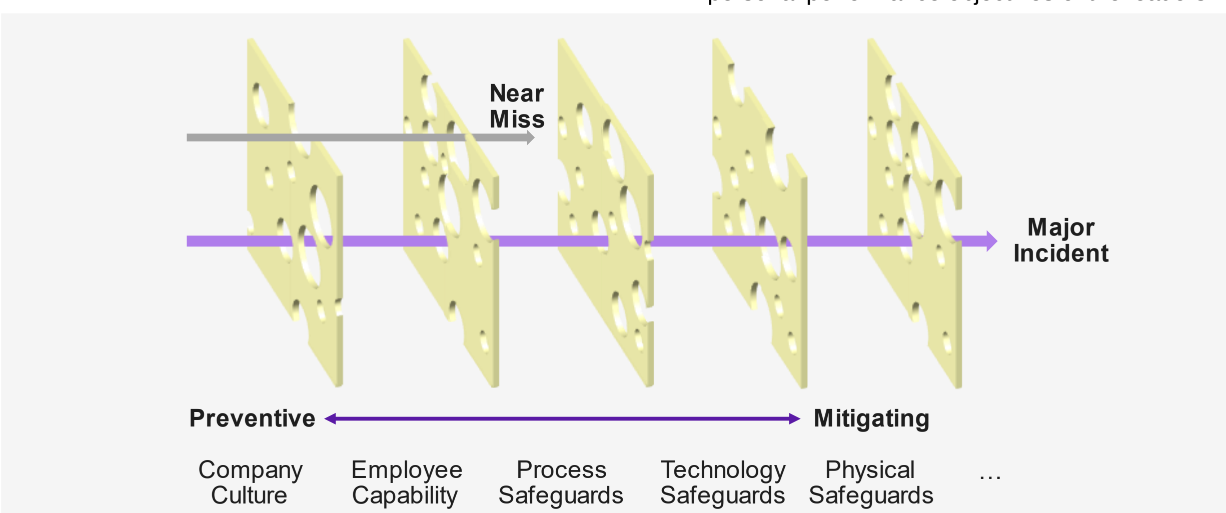
Culture

Commitment and focus

Leading practices are:

– Safety and environmental performance feature prominently in overall corporate and site performance objectives and metrics.

– Focus on personal safety, process safety, and environmentally responsible operations is reflected in the personal performance objectives of the leadership team.[8]



[8] For process safety, emphasis will be on preventing process incidents and maintaining containment of hydrocarbons and other potentially hazardous materials.

- Safety and environmental performance improvements feature prominently in the site's overall improvement plan and represent a significant portion of the site's capital budget.
- Presence of a joint management-union safety/environment committee that meets regularly to discuss and resolve emerging safety and environmental concerns.
- Effective and proactive management of change process in place for any moderate- to high-risk activity.
- Empowering staff at all levels to ensure responsible operation.
- An integrated operational integrity program with a small set of critical priorities.

Communication

Leading practices are:

- Leadership's regular, strongly communicated commitment to safety and environmental responsibility.
- Clear staff alignment on and delivery against site-wide priorities.

Site engagement

Leading practices are:

- Strong integration with corporate and industry experts provides external challenge to topics such as safety reviews and procedure updates.
- Full staff awareness of and alignment with priorities and prioritization process at all levels.

Staff Capabilities

Site leadership

Leading practices are:

- A leadership team with strong technical capability and experience, and a demonstrated track record for safe and reliable operations, with safety and environmental performance history considered in leadership career progression evaluation.
- Formal training and programs for leadership that include a focus on leading practices to ensure safe, reliable, and environmentally responsible operations.

Technical staff capabilities

Leading practices are:

- Cross-training, apprenticeship, and succession planning in place to ensure technical coverage is retained in the event of unexpected attrition.
- Technical staff are trained through a formal program with strong connections to corporate technical experts.

Operations and maintenance staff capabilities

Leading practices are:

- Adequate succession planning and "bench strength" to support resiliency after turnover and attrition.
- A formal training program for all jobs, with refresher training to reconfirm competence. The program includes competency assessment.
- Competency requirements assessed against long-term needs.
- Shift structures developed, and discretionary work managed to ensure that excessive overtime does not occur.
- Clear processes in place to understand and address reasons for absenteeism.
- Regular training exercises, tabletop exercises, and emergency drills are conducted.
- Clear capability and experience requirements in place and adhered to for all operations staff.
- Clear time-in-role expectations in place to ensure operations staff develop appropriate experience before lateral moves or promotions.

Process

Change management

Leading practices are:

- Effective management of change, with formal risk-based Management of Change (MOC) process in place and fully adhered to.
- Approval and authorization requirements are addressed throughout the process, prior to implementing a change.
- Safe operating procedures/safe working procedures are maintained and reviewed on a scheduled basis or as part of the MOC process.
- Operations ownership of procedure development, communication of changes, and verification processes.

Incident investigation and follow-up

Leading practices are:

- Risk assessments used to manage risks are comprehensive and kept up to date.
- Process safety information packages are documented, maintained, and communicated to all relevant personnel.
- Root causes fully understood.
- Effective and timely responses to incidents, including investigations and implementation of corrective actions.
- Limited overdue inspections.

Maintenance

Leading practices are:

- Maintenance strategy is well-developed and well-executed to focus on the key activities that drive high operational reliability.
- Appropriate maintenance performance data available and used to drive improvement plans.
- Clear alignment with operations and technical.
- Aligning overall maintenance spending with industry expectations to maintain asset integrity.
- Spending consistently on preventive and predictive maintenance, regardless of incidents or other factors that may require reactive/corrective maintenance.
- Incidents are trended through statistical analysis.
- Structured program targeting problematic equipment that focuses on the most critical items, rather than an unrealistic laundry list of actions.
- Holistic integrity management program in place covering operating envelope, inspection intervals, corrosion strategy and sustaining capital.
- Design standards are formalized, consistent across a company's refining network, and used.

Operations

Leading practices are:

- Regularly scheduled reviews and updates to procedures.
- Zero tolerance policies regarding critical procedure adherence.
- On-demand availability (ideally digitally) of procedures at unit / equipment location.
- Rigorous tracking and management of alarms and exceedances outside safe operating limits.
- Effective interface management processes, including shift change meetings with a focus on any abnormal conditions, and pre-job reviews with maintenance prior to any significant activity.
- Structured rounds to ensure regular monitoring of key equipment.
- Formal approval processes for non-standard operations.

Technological and Physical Safeguards

Design for normal operations

Leading practices are:

- Ensuring design of refinery allows equipment to operate within expected operating envelope, as required by process conditions, Title V requirements, etc.
- Operating envelope clearly defined, documented, communicated.
- Effective process control technology, with all critical process data available in real time to both field and board operators.

Design for abnormal conditions and SSM

Leading practices are:

- Ensuring refinery design can meet environmental requirements and regulations during start-up and shutdown.
- Providing technology safeguards to minimize the potential for incidents and mitigate the impact of those incidents if they occur.
- Installing appropriate automation to assist in incident response to both internally and externally caused incidents (e.g., automated shutdown of FCCU to prevent significant catalyst releases).

In the next section, we present our observations regarding all of these areas at the Commerce City refinery and identify gaps between operations during the study period and leading practices.

Commerce City Site Observations and Key Gaps

Kearney compared the Commerce City refinery's operations to the leading practices we outlined above for preventing major incidents, evaluating each area and identifying key gaps.

These key work practices strongly correlate to safe and environmentally responsible operations.

The following subsections identify the leading practice, relevant observations from the investigation, and key gaps between operations during the study period and the leading practices. These gaps were a significant contributor to a systemic underestimating of risk at the site, which contributed directly to most of the Title V exceedances within the scope of this report.

Culture

Commitment and Focus

Safety and environmental performance feature prominently in overall corporate and site performance objectives and metrics.

A close review of the site scorecard for this period determined that safety, as well as environmental responsibility, have been leadership's primary focus for some time. Of the top five 2020 goals for the site, four were related to improving personal safety, improving process safety, and reducing environmental incidents; these were followed by meeting production and cost targets. The fifth objective was to carry out an improvement plan that included increasing technical competency, leadership, risk management, and operational discipline at the site. These factors contribute significantly to a site culture of safety and environmental performance. This was confirmed by our interviews at all levels of the organization.

We reviewed leadership team discussion materials covering the study period. Personal safety, process safety, and environmental compliance were consistently identified as top priorities, ahead of production and commercial performance. In addition, personal safety was consistently identified as the number-one priority. The site should continue to work to elevate the importance of environmental performance to be in line with expectations for safety.

Performance related to each of these dimensions are prominent in leadership discussion material, including recordable injuries, environmental excursions, first aid events, loss of containment frequency, and safe operating limit excursions.

Focus on personal safety, process safety, and environmentally responsible operations is reflected in the personal performance objectives of the leadership team.

Reviews of the site leadership team goals and objectives indicated that there is a strong focus on process safety and reliability in their performance objectives. A review of leadership team goals identified personal safety (including safety leadership, incident investigations, risk management, and loss of containment reduction) and long-term sustainability (including Title V exceedance reductions, hydrogen cyanide monitoring, and ozone attainment) as objectives. This focus was verified through interviews with the leadership team.

Safety and environmental performance improvements feature prominently in the site's overall improvement plan and represent a significant portion of the site's capital budget.

The refinery's capital budget is heavily focused on safety and environmental performance. In 2020, only one percent of the capital budget was allocated to economic growth.

The site has a prioritized list of integrity initiatives. This list drives the allocation of capital budget, focusing on reducing risk.

Presence of a joint management-union safety / environment committee that meets regularly to discuss and resolve emerging safety and environmental concerns.

The site has a joint management-union health and safety committee with senior leadership representation and attendance. The committee meets regularly and discusses specific safety and environmental concerns, as well as other factors that affect operational integrity (e.g., new operator training progress, management of change items).

Effective, proactive risk assessment process in place for any moderate- to high-risk activity.

Despite the site's robust management of change policy, incident reports and interviews indicated that in the past the site did not correctly estimate the risk associated with certain high-risk activities and allowed these to occur without an appropriate approval process or sufficient planning.

These higher-risk activities resulted in at least one injury during the study period. The site's level of tolerance continues to evolve, with less tolerance of higher-risk activities.

Interviewees indicated they had concerns with the consistency of risk estimation for maintenance work orders, PHAs, and incident reports. Sometimes, they observed that risk estimates were too low, resulting in deferral of items that should have been done earlier, or received a greater level of attention.

Additionally, the site experienced loss of primary containment incidents that resulted in prolonged leakage of substances (e.g., lube oil) that were addressed with temporary fixes and later escalated to higher-volume releases.

Empowering all staff to take steps for ensuring responsible operation.

Site data (e.g., modified start-up procedures) and interviews indicate that environmental compliance, including during start-up, is achievable and a high priority. Reviews of key procedures (e.g., #2 FCC start-up) and interviews with operators indicated that there is a strong focus on operator empowerment; operators and chiefs can stop the start-up process and hold the unit if they believe a major incident is imminent. Operators indicated this direction came from the refinery vice president with alignment and support from all line managers.

An integrated operational integrity program with a small set of priorities.

Given the link between high operations reliability, low process safety incidents, and strong environmental performance, we evaluated the site's reliability improvement plan. This plan is focused on maintaining and improving the integrity of systems at the plant and ensuring the integrity of hazardous processes is not compromised. While ambitious, given the large number of items in the reliability improvement plan, the site risks not doing them well. We believe it is better to prioritize the top few items and ensure that they are focused on and addressed well, with good sustainment, rather than attempting to execute a large portfolio of improvement items.

The refinery struggles with using available resources to execute top priorities. Due to the complexity and breadth of planned initiatives, the refinery is not always able to execute all activities that are strategic and important.

Communication

Leadership's regular, strongly communicated commitment to safety and environmental responsibility.

The site has a formal process for communicating goals from leadership to individual employees. This process is formally outlined and communicated in the site's leadership team goals and objectives document. Goals are set to advance five value drivers. The first two drive continuous improvement in safety, environmental performance, and sustainability. The focus on these two areas is part of a regular, structured process that reinforces the company's commitment to safety and environmental responsibility.

Interviews with operators indicated strong messaging from leadership around the commitment to safety and environmental responsibility, which they identified as a significant change from 2016–2017.

Clear staff alignment on, and delivery against, site-wide priorities.

The formal goal setting process includes communicating site-wide priorities and strategies to the site. One objective is to provide a forum where employees can discuss their role in achieving team, area, and overall business goals.

This process is intended to set clear measurements and targets for employees, while goals focus on outcomes rather than tasks. Leaders are responsible for translating strategic goals to ensure their workers understand what they must accomplish.

Interviews with operators indicated that they were aware of the goals at the site, with a focus on avoiding environmental exceedances and staying within limits.

We believe that the goals translation process is effective for creating consensus site-wide priorities.

Site Engagement

Strong integration with corporate and industry experts provides external challenge to topics such as safety reviews and procedure updates.

Based on incident investigation results and discussions with leadership, we concluded there was limited involvement during the study period of the Suncor Technical Expert Network (STEN) in procedure development and safety reviews.

Suncor enterprise technical experts were involved on an ad hoc basis, but no formalized process was in place to determine when it was appropriate to bring in Suncor enterprise technical or other external technical groups.

This allowed the development of 'myths' regarding processes, as the site historically built operational experience in relative isolation. For example, during FCC start-up, there was a genuine belief that the only way to safely proceed with start-up and avoid major safety or environmental incidents was to do it quickly and tolerate any minor environmental exceedances that occurred during start-up.

Full staff awareness of and alignment with priorities and prioritization process at all levels.

We previously identified that leadership formally communicated their commitment to safety and environmental responsibility to staff at the site. Through interviews, we assessed whether staff at all levels were aligned with these priorities and were committed to making necessary changes in the way they work.

We observed that front-line operations staff are aware of the importance of personal safety, process safety, and environmental compliance as priorities for the site. Several operators we interviewed commented that site leadership had been moving in the right direction on this issue, and the attention paid to these issues was more visible than it had been historically. Operators appeared to be committed to these goals and commented that recent changes to procedures and mindset at the site were positive.

Summary and Gaps

Based on document review and interviews with site leadership and staff, we concluded that the site's performance objectives appropriately prioritized environmental performance, that these objectives were adequately communicated to site staff and that site employees – from the leadership team to operators – are aligned and committed to strong environmental performance.

However, we observed several gaps to leading practice:

- A culture (coupled with a significant number of newer operations and technical staff, who lack sufficient experience to challenge this culture) that resulted in tolerance of higher risk activities relative to what we typically observe at leading refineries and/or a risk assessment and change management processes that frequently underestimated risk.
- Linkages with Suncor enterprise technical and other external technical experts that are less effective than what we've seen at leading refineries, which have independent experts challenge, and likely improve, the status quo – for example, in regular process safety and hazard reviews – not allowing incorrect 'myths' on effective operations to persist.
- A tendency to develop overly long and likely unrealistic improvement agendas rather than a focus on, and commitment to, a critical few.

Staff Capabilities

Site Leadership

A leadership team with strong technical capability and experience, and a demonstrated track record for safe and reliable operations, with safety and environmental performance history considered in leadership career progression evaluation.

Review of experience profiles of the refinery leadership team highlighted their strong technical capability and experience.

Senior leadership is highly competent in operations, with chemical engineering backgrounds and broad exposure to refinery work. At the director level, tenure with Suncor and predecessor companies exceeds 20 years, leading us to conclude that the site leadership team is appropriately qualified to lead the refinery.

Formal training and programs for leadership that include a focus on leading practices to ensure safe, reliable, and environmentally responsible operations.

Corporate training standards focus appropriately on safety and environmental aspects. Formal leadership training programs are in line with those of other major refiners. However, as noted in the culture section, the site—at all levels—would benefit from increased exposure to Suncor experts, selected external experts, and the broader refining industry. There is an expectation that those resources would continue to bring leading practices and innovative thinking to enhance the site's safety and environmental capabilities.

Technical Staff

Cross-training, apprenticeship, and succession planning in place to ensure technical coverage is retained in the event of unexpected attrition.

In our experience, high-performing refineries typically have highly capable and highly experienced engineering staff.

Because of its location, the site faces structural issues that are uncommon in the refining industry. As the only refinery in Colorado, Commerce City is not part of an ecosystem of oil and gas jobs and does not have a large pool of local, experienced talent readily available when unplanned needs arise. The area also has a relatively high cost of living compared to other refining clusters in the US. Experienced hires typically must be hired from outside the state. Compared to refineries in the Gulf Coast, it is more difficult for Commerce City to fill open roles, and succession planning will always be a bigger challenge at the site than is typical in the industry. It is also challenging to rotate staff internally.

A review of organizational charts and technical role succession plans at the refinery revealed that there is limited depth within technical areas to ensure technical coverage is not affected by unexpected attrition. The site targets an appropriate level of staffing in line with industry benchmarks but faces challenges in recruiting to fill open positions. This is the result of a challenging recruiting environment, rather than deliberate decisions to lower headcount, and the site is working to fill open roles.

This creates an imperative for both comprehensive cross-training and succession planning for technical staff, as well as innovative approaches to quickly fill technical positions when unexpected attrition occurs, including short-term support from the broader Suncor technical network.

Technical staff are trained through a formal program with strong connections to corporate technical experts.

The site has structured training requirements for technical staff. A review of training records and requirements for technical staff indicated that compliance with requirements is high, with over 98% of training requirements completed on time.

However, most of the training is delivered peer-to-peer on the job. There has historically been limited involvement from Suncor enterprise technical experts both in delivery of training and expert support for less experienced technical staff. Due to the potential of attrition and importance of preserving technical knowledge, engaging Suncor enterprise technical experts is even more important.

Operations and maintenance staff

Adequate succession planning and "bench strength" to support resiliency after turnover and attrition.

We reviewed the site's maintenance and operations staffing strategy and structure, as well as planned staffing levels. As indicated earlier, overall staffing levels at the site were in line with industry benchmarks during the study period.

As with technical staff, the site faces unique structural issues with no local academic program that leads directly to the required skill sets for operators (where two-year programs in technical colleges are becoming the norm for entry level roles). At other sites, Suncor has stronger partnerships with local colleges, but those sites have a much larger demand for this skill set.

A detailed review of staffing in the operator ranks identified some concerns with the "bench strength" to preserve existing knowledge and experience while managing workload and fatigue. Because of retirement and attrition in the senior operator ranks, as well as inability to cross-train across plant divisions, the staffing levels for operators were lower than the staffing strategy targeted, which resulted in pockets of very high overtime levels for senior staff in certain divisions.

In maintenance, the challenges are similar to those for technical staff. The local craft labor market is relatively small, and contractors typically come from outside the state; it is challenging to recruit and relocate new staff compared to other refinery locations with a strong labor market.

The situation remains a concern given the likely proximity to retirement of the senior operator group.

A formal training program for all jobs, with refresher training to reconfirm competence. The program includes competency assessment.

We determined that the site has a formal training program in place, including both new and refresher training. Compliance with training requirements was high. Leading practice in this area would be to have a formal training curriculum developed with input from technical experts and delivered by full-time trainers selected for their aptitude in training and coaching.

Operators at the site have a depth of progression in their training that is in line with industry standards. The site's collective bargaining agreement generally does not allow for cross-training in different divisions of the refinery, which limits the ability to cross-train operators outside their division.

Competency requirements assessed against long-term needs.

The site has an evolving site-specific operator competency program and has a medium-term staffing plan in place. This is complicated by the structure of the site's collective bargaining agreement, which limits the ability to shift operators from one production division to another. This can result in increased staffing challenges when unexpected attrition is concentrated in a particular division or unit of the refinery. In our experience, additional cross-training can be seen as a positive benefit by unionized staff both because it can help accelerate their career progression and, in most cases, is accompanied by an increase in the hourly wage as additional competencies are acquired.

Given the likely proximity of many operators to retirement, extending the operations staffing plan to a longer time horizon would be appropriate.

Shift structures developed, and discretionary work managed to ensure that excessive overtime does not occur.

We reviewed the formal shift scheduling process at the refinery, which uses an approach agreed with the union to result in more days off per year for operators. This shift structure is consistent with that used at several other refineries. Interviews with operators and leadership did not identify the shift structure as an area of concern.

In periods between July 2017 and June 2020, the site experienced overtime rates that were above a typical target range and entered an area of long- and short-term concern. In our experience, overtime levels that are consistently above the target range can result in a higher risk of safety and environmental incidents.

Interviewees indicated that due to the high workload related to incident response during the study period, some discretionary work was deferred. This included non-critical preventative maintenance activity and non-essential training. The site is working on initiatives to manage fatigue, recently hired two groups of new operators, has brought in maintenance contractors, and is seeking to hire additional maintenance craft laborers.

Clear processes in place to understand and address reasons for absenteeism.

Review of the site's collective bargaining agreement indicated that there is a clear and structured process in place to understand and address reasons for absenteeism, with increasing consequences for repeated absenteeism. Interviewees did not identify absenteeism as a significant concern at the site. Discipline records supported this perspective, with a minimal number of instances of discipline for absenteeism.

Regular training exercises, tabletop exercises, and emergency drills are conducted.

The site has increased the frequency of tabletop exercises and drills since the occurrence of the recent major incidents. There is now an initiative to conduct five operational competency drills simulating high-consequence activities per year per division to capture some of the knowledge possessed by senior operators and prevent it from being lost, and the site is on track to meet goals set for 2020. Additionally, the site met its target of 56 emergency drills during 2019.

The site does not currently have a simulator for training, which is leading practice for refineries.

Clear capability and experience requirements in place and adhered to for all operations staff.

Interviews with training staff indicated that training requirements for operations staff are well-defined and assessed as part of the formal training process. Operators are trained on all processes, operating procedures, and hazards associated with the equipment in their units. When qualifying for a new unit in their division, and every three years afterwards, operators must demonstrate knowledge of all procedures for the unit. Emergency procedures must be refreshed every year.

Training requirement compliance is high (over 90 percent, with the majority of non-compliance by operators who are on leave and must complete overdue training before returning) and tracked through a learning management system with reports provided to shift supervisors and managers. We reviewed training records to verify compliance with training requirements and timelines.

Clear time-in-role expectations in place to ensure operations staff develop appropriate experience before lateral moves or promotions.

The site's collective bargaining agreement identifies time-in-role expectations for operations staff to ensure they develop appropriate experience before promotions. Additionally, the training process ensures that operators are trained and qualified to operate new equipment before moving into a new role.

Summary and Gaps

Based on interviews and document/data review, we concluded that the site leadership is qualified and capable of effectively operating the Commerce City refinery, staffing targets are appropriate and in line with refining peers (and benchmarks), and that clear capability, experience, and time-in-role requirements are in place for technical, operations, and maintenance staff.

However, we observed several gaps to leading practice:

- The site has been challenged to maintain staffing and capability at planned levels.
- There is potential to harness technology to enable collaboration with off-site personnel to mitigate staffing challenges.
- There is a need for more structured training delivery for both technical and operations staff, with increased formal reliance on technical experts and full-time operations trainers with appropriate capability.
- Continue to shift the balance of operator training from a historical reliance on procedure reviews and tabletop exercises to include operational drills, increased job rotations, knowledge checks, and ultimately, a training simulator.

Process

Change and Risk Management

Effective management of change, with formal risk-based Management of Change (MOC) process in place and fully adhered to.

Any proposed process or equipment changes at a refinery requires an MOC request and justification as outlined in a site's management of change policy. We observed a formal risk-based process in place. Any proposed changes at the refinery require an MOC request and justification. These requests are reviewed by Process Safety Management and classified as simple or complex. Assessment of any training requirements associated with the MOC is performed by learning resources within the training group.

The current process likely underestimated the risk associated with some higher-risk activities and allowed some lower-risk situations to persist, creating the potential for escalation to more severe incidents.

In addition, interviewees indicated that sometimes minor changes are made to procedures without the procedures being formally updated in the record-keeping system. This typically depends on the criticality of the change. Approval of major changes is more involved and involves cross-functional team managers and multiple experienced operators.

We believe the MOC process should be updated to address both issues, with refinery manager sign-off for high-risk activities and ensuring that any procedure redlines are appropriately and immediately documented.

Approval and authorization requirements are addressed throughout the process, prior to implementing a change.

The MOC process has clearly defined approval and authorization requirements. Approval and authorization are required from members of the Operations group who are qualified in a particular area, as well as sign-off from a cross-functional team manager.

Our observations on-site included changes approved on a last-minute basis, which were processed through the MOC process. Based on our review of the process and actual observations, we are satisfied that approval and authorization requirements are met in practice; however, participants in the MOC process may not always have the experience to challenge decisions and fully recognize risks associated with some historical activities. For some higher-risk activities, approval authority should be elevated to ensure risk tolerance is in line with current Suncor standards.

Safe operating procedures/safe working procedures are maintained and reviewed on a scheduled basis or as part of the MOC process.

Procedures are regularly reviewed during the MOC process, involving operations experts in the relevant area and cross-functional team managers. They are also reviewed on a recurring basis even if no changes are made to the procedure that require review.

Operations ownership of procedure development, communication of changes, and verification processes.

Procedure redlines at the site are currently performed by engineers. The approval and change communication process involves operations. Interviewees identified some historical concerns with ambiguity around the distribution of duties between engineers and supervisors, and clarity around roles and responsibilities.

Most refineries will have a permanent role, typically rotated through by senior operators, with responsibility for procedure updates and maintenance.

The site is working to address concerns with procedure development, transition, and training, and has dedicated an Operations manager to drive the initiative forward.

Incident Investigation and Follow-up

Risk assessments used to manage risks are comprehensive and kept up to date.

A systematic review process for PHAs is in place and adhered to, with regularly scheduled PHA review on a five-year cycle. A review of process safety data showed that there was good compliance with this target timeline.

While PHAs were done in compliance with applicable regulations, in some cases PHAs were not fully comprehensive relative to leading practice expectations, and there was at least one example where an oversight or omission in a PHA contributed directly to an environmental incident.

This is an opportunity to involve more participation from Suncor enterprise technical experts or other external technical experts to provide rigor to critical PHAs and standardize the PHA development process to include a standard "must assess" list of failure modes to consider to reduce the risk that similar oversights are repeated.

Site PHA processes and procedures have been reviewed and updated since the major environmental exceedances occurred, and a review of the revised start-up procedure and corresponding PHA for the #2 FCC concluded that the risk assessment was thorough and comprehensive, with involvement from Suncor enterprise technical experts, and an appropriate level of detail for each critical piece of equipment.

Process safety information packages are documented, maintained, and communicated to all relevant personnel.

Process safety information packages are documented and reviewed on a five-year cycle[9] We reviewed select packages and found them to conform to the target review timeline. Process safety information is readily available to relevant personnel.

During our site visit, we verified that current versions of these packages were available to operators in the plant control system; the packages include safe operating limits for equipment and response plans for exceedances. The site is working to digitize more of these key response plans to make them readily available to operators in a digital format.

Root causes fully understood.

We reviewed detailed root cause failure analysis reports for the nine most serious incidents at the site during the study period. These more detailed reports are typically only prepared for more serious incidents, a practice which is in line with industry standard.

For incidents that necessitated a substantial root cause investigation, we found that root causes are correctly identified, and go beyond a simple technical or human root cause.

Consistent with our experience, these incidents tend to have systemic factors related to culture and broader operational factors identified as true root causes, and recommendations from these investigations are systemic in character. We are satisfied that root causes are adequately investigated and understood for more significant incidents at the site.

Effective and timely responses to incidents, including investigations and implementation of corrective actions.

A close review of all reported incidents and incident follow-up status showed that incident reporting and classification was sometimes incomplete or delayed.

Incident response is assigned to a single accountable person (typically in the senior leadership team) who coordinates individual response actions assigned to several responsible individuals. Having a single accountable person for each incident is in line with leading practices.

Finally, there were some overdue corrective actions at the refinery during the study period; however, these were assessed as lower-risk items and deferred due to the level of effort required to address higher-risk items. Overdue corrective actions are captured in reports provided to site leadership, and a risk-based assessment process is in place to defer follow-up actions.

Limited overdue inspections.

We have reviewed a list of overdue inspection items at the site, as well as key maintenance and reliability metrics related to inspections. The site has minimal overdue inspections; in 2019, there were 11 overdue regulatory inspections of a total of 18,125, a rate of approximately 0.06 percent. This is very strong performance in line with industry leaders. We are satisfied that the site adequately manages inspections. There is also an appropriate, risk-based approval process in place to manage overdue inspections.

Maintenance

Maintenance strategy is well-developed and well-executed to focus on the key activities that drive high operational reliability.

The site has a maintenance strategy in place that is primarily driven by scheduled preventative maintenance activities, with some predictive maintenance for specific pieces of rotating equipment. Scheduled preventative maintenance activities are continuously evaluated to assess their effectiveness and adjust the frequency of specific activities. There is a list of problematic equipment that is used to drive targeted maintenance activity and balance maintenance effectiveness and efficiency, further discussed below. Additionally, during the study period, there was significant corrective maintenance activity because of incident follow-up actions. This strategy is generally in line with leading practices, but there are opportunities to continue to prioritize higher-impact activities and focus on a smaller set of problematic equipment to avoid a fragmented reliability improvement strategy that is difficult to achieve in practice.

However, it was not clear that the maintenance strategy was consistently focusing on the right activities. That is, although deferred activities had a limited impact on the level of risk at the site, there was no assurance that activities that were not deferred would contribute significantly to lowering operational risk. The site's equipment maintenance strategy continues to evolve to focus on high-impact activities.

[9] Process safety information packages are required by safety regulations, and include details on the chemicals used in a particular process, process flow diagrams, safe operating limits, assessments of deviation consequences, and information on the equipment in the process.

Analysis of outstanding maintenance work orders showed that those with the highest potential severity were less than one year overdue, which is not unusual as some maintenance activities can only take place during turnarounds.

In accordance with a formal approval process in place for maintenance deferral, where planned preventative work orders were deferred, this was done after conducting risk assessments that determined these items could be deferred without unacceptable increases in risk.

Appropriate maintenance performance data available and used to drive improvement plans.

Data available to maintenance staff regarding activity and spend performance provides sufficient visibility to support development of comprehensive improvement plans.

A review of the site's maintenance scorecard identified the presence of key leading and lagging metrics, including safety-related parameters, preventative maintenance compliance, inspection compliance, asset availability, mean time between repair, schedule compliance, action items, and budgetary factors. These are used to drive performance towards targets identified in the scorecard.

Clear alignment with operations and technical.

The site has an appropriate formal process to coordinate and prioritize maintenance activities across the three operating plants in place.

The maintenance department has recently implemented a formal process to plan maintenance activities and gain alignment on plans from cross-functional teams at the refinery, enabling maintenance to prioritize activities across the three plants that make up the refinery.

Aligning overall maintenance spending with industry expectations to maintain asset integrity.

As outlined in the earlier cost assessment, industry benchmarks show Commerce City's overall maintenance spending is not an area of concern. However, as indicated in the previous discussion on maintenance strategy, there are opportunities for the site to allocate resources more effectively by increasing the focus on higher priority items.

Spending consistently on preventive and predictive maintenance, regardless of incidents or other factors that may require reactive/corrective maintenance.

An analysis of budget variances at the site during this timeframe showed that maintenance practices focused on corrective activities due to resource constraints, while deferring preventive items after conducting a risk assessment. A variance analysis of the maintenance budget showed that from 2017 to 2019, the actual cost spent on emergency corrective actions was twice the originally planned budget, while the amount spent on preventative maintenance was 10 percent less than the originally planned budget.

The site faces challenges in ramping up maintenance activities on short notice due to structural issues in the local skilled trades labor market.[10] Given this constraint, in order to ensure that critical maintenance activities are completed on schedule going forward, the site should continue the current practice of conducting risk assessments to identify less critical maintenance work that can be deferred, while focusing efforts on a critical few reliability improvement initiatives (as outlined in the site's list of equipment that generates significant maintenance effort) in order to reduce the volume of unplanned maintenance work going forward.

Incidents are trended through statistical analysis.

Data on loss of containment, environmental incident frequency, and severity statistics indicated that incident reports are generated and data is aggregated and generated into reports of overall incident trends at the equipment, unit, and plant level. Interviews confirmed that this data is used to monitor incident trends at the site.

Structured program targeting problematic equipment that focuses on the most critical items, rather than an unrealistic laundry list of actions.

The site has a structured program focused on critical items. A review of the list of prioritized pieces of equipment/systems indicated that the listing is based on a combination of value (e.g., potential for high-impact events) and complexity (e.g., cost, time to implement). The list contains items that affect combined disciplines, as well as specific electrical, rotating equipment, pump, instrumentation, and mechanical equipment. The program has a methodical approach to prioritization, but targets a long list of equipment in each discipline; leading practice is to have a shorter list of items that can be addressed more quickly, allowing new equipment priorities to be identified.

Holistic integrity management program in place covering operating envelope, inspection intervals, corrosion strategy and sustaining capital.

[10] Compared to the Gulf Coast, which is a significant hub for refining activity, it is much more difficult for Commerce City to locate and retain additional contract maintenance staff on very short notice.

We have reviewed the site's mechanical integrity and quality assurance program, operating envelope documentation and monitoring, inspection strategy and dashboard, corrosion management strategy, and sustaining capital budget. The integrity management program is in line with practices at other refineries.

Design standards are formalized, consistent across a company's refining network, and used.

Corporate design standards are in place, and there is a formal process for changes to equipment design and operating envelope. Given the age and ownership history of the refinery, not all historic equipment would meet current Suncor standards if it were installed as new equipment today. However, as part of ongoing PHAs, equipment design is reviewed, and we observed re-rating of legacy equipment operating limits and equipment modifications based on updated design standards and relevant risk analysis.

Operations

Regularly scheduled reviews and updates to procedures.

The site has a process in place to review and update procedures. Procedures are reviewed as part of MOCs, incident investigations, and PHA updates—every five years at minimum. In addition, critical procedures are reviewed with operators annually, and others are reviewed every three years. Interviews confirmed that reviews and updates to procedures happen on a regular basis.

This review and update process is in line with industry best practices.

Zero tolerance policies regarding critical procedure adherence.

Review of incident reports shows that there were gaps with operational discipline around procedure compliance related to recently updated procedures.

Interviews with shift supervisors, chief operators, and board operators highlighted cases in which operators relied more often on 'tribal knowledge'—ways of working and procedures they learned from other operators—rather than closely following published procedures. In some cases, procedures contained incorrect information.

There was a reliance on desktop reviews for procedure training at the time of the incidents, which is now shifting to knowledge checks and operational drills.

From interviews, it was determined that the use of processes and procedures is improving across the site compared to where it has been in the past. Site leadership has indicated that following procedures is a priority, and operators remarked this message was received and there was a clear focus on doing things the right way. There is an opportunity to continue building operational discipline by improving training to have a more holistic approach, with procedure reviews, operational and emergency drills, and ultimately a training simulator.

On-demand availability (ideally digitally) of procedures at unit / equipment location.

During the study period, hard copies of procedures were available at equipment locations. During the site visit, we verified that current versions of procedures were available to board operators. For critical procedures, operators are required to have a copy in hand and sign off on every step during the process.

However, to improve the potential for immediate and appropriate response as non-standard conditions occur, we recommend that procedures be made available electronically and that relevant procedures automatically be suggested to operators based on changes in specific process conditions (e.g., in the event of a power blip, procedures to re-start major electronic equipment would immediately be referenced on the operator's display screen or tablet).

Rigorous tracking and management of alarms and exceedances outside safe operating limits.

Exceedances outside safe operating limits are closely tracked. We reviewed logs of all instances where equipment operated outside safe operating limits, as well instances where equipment was close to those limits and triggered a warning alarm.

Alarms associated with exceedances outside safe operating limits require notification of chief operators, cross-functional team managers, and shift supervisors before they may be inhibited. Interviews with operators indicated there is good understanding of the process and compliance with the procedure.

Higher-criticality alarms that indicate an event that could lead to a shutdown result in immediate emergency work orders and a high-priority response.

All safe operating limit exceedances should result in an incident report, which leads to a review of the associated hazards and risk. There is a robust management of change process in place for handling nuisance alarms, which can involve additional PHA review, comparison with other Suncor sites, or updates to procedures to avoid reaching the safe operating limit in the future. The approval process for deactivating alarms and process for communicating the status of alarms between shift changes are in line with leading practices.

We observed that some pre-alarms—those that trigger when process conditions approach, but do not exceed, safe operating limits—are on for a significant percentage of the time and may not provide useful input to operators. These may act as distractions, and likely do not serve their intended purpose of a warning that process conditions are getting close to safe operating limits. There is an opportunity to reevaluate setpoints for pre-alarms that are active for more than 10 percent of the time.

Effective interface management processes, including shift change meetings with a focus on any abnormal conditions, and pre-job reviews with maintenance prior to any significant activity.

We observed shift change meetings at the refinery, which included incident reviews, discussion of site performance indicators, alarm bypasses, safe operating limit exceedances, planned maintenance activities, abnormal operation observations, and safety updates.

In interviews, operators indicated that shift change meetings are used to communicate abnormal conditions, such as equipment that is operating outside normal parameters, alarms that have been suppressed or bypassed with supervisor approval, and pre-job reviews (e.g., work permitting and LOTO)[11].

Structured rounds to ensure regular monitoring of key equipment.

We reviewed examples of structured rounds for operators, which cover key equipment. Observations on site indicated that these rounds were followed in practice, and we identified several incident reports where the initial condition was identified during an operator round. Operators had access to handheld tools to assist in the process, which was confirmed through interviews with operators.

Formal approval processes for non-standard operations.

We observed formal approval processes in place for non-standard or changed operations. The site has a robust MOC process with senior leadership involvement in pre-startup safety review when significant changes to processes are made. This is in line with leading practices.

Summary and Gaps

Based on observations during the site visit, reviews of key documents and interviews with key refinery staff, we concluded that the site has a robust management of change process in place to assess risk, approve and authorize changes, and communicate those changes to operations. However, there are some gaps in risk assessment and ownership of procedure development, as well as opportunities to improve the rigor of PHAs.

The site effectively reports incidents and has a good understanding of root causes of significant incidents, in accordance with procedures. In some cases, incident reporting and follow-up actions are delayed, and there is fragmentation of follow-up action assignment.

The site has a maintenance strategy in place that is focused on high-risk activities and effectively executes those activities within the constraints of the local craft labor market. However, there is likely opportunity to continue deferring lower-risk work following an appropriate risk assessment to focus on higher-impact activities.

Operations procedures are regularly reviewed and readily available to operators. There is rigorous tracking of exceedances outside operating limits, which is well-managed across shift changes. There are opportunities to increase compliance with procedures, increase the rigor of pre-job reviews, and reduce nuisance pre-alarms related to safe operating limits.

Overall, we observed several gaps to leading practice:

- Engineering staff are currently accountable for procedure updates vs. leading practice of a senior operator in this role.
- PHAs sometimes excluded failure methods that are assessed in leading practice and would benefit from additional external challenge.
- While incident root cause identification is adequate, follow-up action assignment is overly fragmented, and processes for monitoring completion timing (including time extension approval) need to be improved/formalized.
- Procedures are updated and reviewed regularly, but procedure ownership, documentation, and training could all be improved to ensure full compliance. Electronic availability of procedures would also help in this regard.
- While processes to ensure effective interfaces and handover between operating shifts are in place, there were instances where pre-job planning between operations and maintenance failed to identify higher risk situations and led to incidents.
- Overall maintenance spend is appropriate, but the site is challenged to maintain the optimum mix of planned vs. reactive maintenance when unplanned events occur. Given the structural challenges in the local craft labor market, the

[11] LOTO is lockout/tagout, a safety process used to ensure that equipment has been deenergized and cannot be restarted until the worker(s) performing maintenance activities complete their work.

appropriate solution is likely to continue focus on high-priority, high-risk equipment and use risk assessments and inspection data to defer low-risk, lower-priority work.

Technological and Physical Safeguards

Design for Normal Operations

Ensuring design of refinery allows equipment to operate within expected operating envelope, as required by process conditions, Title V requirements, etc.

The site is able to operate in compliance with current environmental permits and regulations during steady-state operations. The only potential exception is for hydrogen cyanide (HCN) at Plant 1 where the site is conducting ongoing monitoring, pursuant to Suncor's settlement with CDPHE, to assess and confirm compliance with annual limits. HCN emissions are discussed further in Appendix 1 – Emission Sources. Malfunctions and upsets can result in Title V exceedances. During start-up, shutdown, and malfunction conditions, the site has historically asserted SSM defenses as permitted in its Title V permit.

Hypothetically, if the conditions of the refinery's environmental permits or applicable regulations are changed, significant capital investment may be required to maintain compliance. For example, when changes to fuel standards required upgrades to equipment at the site, Suncor made a $445 million investment to comply with the new standards.

All refineries experience occasional excursions of process variables outside equipment safe operating limits. The majority of excursions do not result in an incident or exceedance of any applicable limits. In 2019, the site experienced an average of 2.2 excursions per day, which was an increase from 0.7 excursions per day in 2018.[12] Given that thousands of variables are tracked regularly by the refinery control systems, both the overall number and the relative increase in excursions from 2018 to 2019 are in line with operations at comparable refineries and therefore do not present a significant concern with regards to the design of the refinery.

Operating envelope clearly defined, documented, communicated.

The operating limit for equipment (e.g., temperature and pressure range) ensures the equipment is operated safely and fulfills its function in the process, without excess wear or safety/environmental excursions. The operating envelope for equipment is clearly defined and documented in the refinery control system. This information is readily available to operators in real time in digital form. There are automated alarms set for equipment operating limits, both to warn operators when the limits are being approached, and to warn operators that limits have been exceeded. In some cases, we identified instances where operating envelope information was not kept up to date in specific sections of PHA documents (safe upper and lower operating limits were not always the same as those in assessments of the consequences of exceedances); however, operating limits used to set alarms in the refinery's control system were the correct ones, and the refinery is updating documentation in PHAs as they go through the five-year review cycle.

We evaluated the refinery's ability to operate within the operating envelope parameters. As discussed in the Process – Operations section above, exceedances of these operating parameters that take equipment outside safe operating limits results in an incident report and further investigation which may result in a change to the safe operating limit.

Effective process control technology, with all critical process data available in real time to both field and board operators.

Refineries in the US have varying degrees of automation. While the degree of automation at Commerce City is lower than that in place at many US refineries, all critical variables required for stable, normal operations are available in real time to operators. Therefore, the degree of automation at Commerce City is not a significant factor in the frequency and severity of environmental incidents during normal operation. However, as outlined below, we do recommend some significant investment to mitigate the impact of incidents that occur during abnormal conditions.

Design for Abnormal Conditions

Ensuring refinery design can meet environmental requirements and regulations during start-up and shutdown.

We reviewed Title V exceedances at the site during the applicable period, many of which occurred during start-up and shutdown conditions. As outlined in the previous discussion on site culture, we concluded that some of these incidents occurred and were allowed to persist because of an incorrect perception that continuing to 'push through' minor incidents during SSM conditions was the appropriate action, rather than taking corrective action up to and including unit shutdown or

[12] Refer to the Process – Operations section above for additional assessment of the refinery's process for responding to alarms related to operating limit deviations.

aborting a start-up if an incident could not be brought under control. Interviewees confirmed that some of these incidents were caused by a historical tolerance of minor environmental exceedances during start-up and shutdown. There is a lower level of tolerance for these exceedances at the refinery now, with an increased focus on slow start-up and environmental compliance. Some exceedances during SSM conditions, such as brief opacity exceedances, are typical in similar refineries, and likely will continue to occur.

The changes being made at the site should result in reduced frequency, duration, and severity of the incidents.

Providing technology safeguards to minimize the potential for incidents and mitigate the impact of those incidents if they occur.

The refinery has standard emission control equipment, consistent with that at most US refineries, integrated into the process. Some US refineries have installed equipment to (e.g. electrostatic precipitators) to further reduce catalyst emissions and opacity incidents. However, in many cases, this technology has either not been effective, or has been associated with catastrophic incidents (e.g., Torrance, California explosion). Given this, we would not recommend installation of similar technology at Commerce City and believe that the funds earmarked for improving environmental performance as part of the settlement with the CDPHE would best be applied elsewhere.

At the time of the incidents, the site did not have response procedures digitized in the control system. Leading practice is to have digitized response procedures automatically available when certain process excursions occur, so these procedures can be used to inform the operator's response.

Installing appropriate automation to assist in incident response to both internally and externally caused incidents (e.g., automated shutdown of FCCU to prevent significant catalyst releases).

Appropriate automation should be in place to assist in response to both internally- and externally-caused incidents. In most cases, when a high-risk condition is realized, it is physically not possible for operators to react in time, manually close necessary valves, etc., in order to safety 'park' a unit in time to avoid a major operating, safety or environmental incident.

When a triggering event occurs, plant operators have approximately 30 seconds to react before an environmental incident occurs. With human operators and manually operated valves, it is very difficult to react in time to avoid an incident. With automated shutdown systems, shutdown can occur within 5 seconds, mitigating incidents.

Specifically, the site visit confirmed that the #2 FCCU did not have an automated emergency shutdown system at the time of the major catalyst release events in the scope of this study. Leading practice is an automated emergency shutdown system controlled by a programmable logic controller (PLC), that is independent from the refinery distributed control system (DCS) and will therefore also function if there is an outage of the distributed control system at the refinery. The refinery is planning to install a PLC-based emergency shutdown system; when complete, this investment should reduce the probability of major catalyst releases by more than 99%.

Sulfur recovery units already have suitable equipment in place to prevent hydrogen sulfide releases to the atmosphere in the event of most incidents.

Summary and Gaps

The refinery can meet environmental regulations during normal operations. During start-up, shutdown, and malfunction conditions, the refinery has experienced Title V exceedances. Exceedances during startup, shutdown, and malfunction conditions are not unusual for refineries. The operating envelope for refinery equipment is well-defined, and both design limits and current conditions are available to operators in real-time. While the refinery has standard emissions control equipment consistent with most US refineries, it did not have an automated emergency shutdown for the #2 FCCU during the study period.

We observed several gaps to leading practice:

– The site lacks emergency shutdown capability at the #2 FCCU, which would allow the site to prevent significant catalyst releases in the event of process upsets
– Emergency shutdown capability at other units in the refinery may not be in line with industry-leading practices
– Key response procedures were not available to operators in a digital format in real time linked directly to alarms
– The site has pre-alarms that are in activated mode frequently, and should be reviewed to ensure that these are indeed set at the appropriate level and not an unnecessary nuisance that is distracting operators from higher priority activities.

Gap Summary

Culture

ID	Gap
C1	A culture (coupled with a significant number of newer operations and technical staff, who lack sufficient experience to challenge this culture) that resulted in tolerance of higher risk activities relative to what we typically observe at leading refineries and/or a risk assessment and change management processes that have frequently underestimated risk.
C2	Linkages with the Suncor Technical Expert Network (STEN) and other external technical experts that are less effective than what we've seen at leading refineries, which either allowed incorrect 'myths' on effective operations to persist or missed opportunities for independent experts to challenge, and likely improve, the status quo – for example, in regular process safety and hazard reviews.
C3	A tendency to develop overly long and likely unrealistic improvement agendas (e.g., the site reliability improvement plan with 25+ items over a two to three-year timeline) rather than a focus on, and commitment to, a critical few.

Staff Capabilities

ID	Gaps
S1	The site has been challenged to maintain staffing and capability at planned levels.
S2	There is potential to harness technology to enable collaboration with off-site personnel (e.g., real-time collaboration, augmented reality) to mitigate staffing challenges.
S3	There is a need for more structured training delivery for both technical and operations staff, with increased formal reliance on technical experts and full-time operations trainers with appropriate capability
S4	Continue to shift the balance of operator training from a historical reliance on procedure reviews and tabletop exercises to include operational drills, increased job rotations, knowledge checks, and ultimately, a training simulator

Process

ID	Gaps
P1	Engineering staff are currently accountable for procedure updates vs. leading practice of a senior operator in this role
P2	PHAs sometimes excluded failure methods that are assessed in leading practice and would benefit from additional external challenge
P3	While incident root cause identification is adequate, processes for monitoring completion timing (including time extension approval) need to be improved/formalized
P4	Procedures are updated and reviewed regularly, but procedure ownership, documentation, and training could all be improved to ensure full compliance. Electronic availability of procedures would also help in this regard
P5	While processes to ensure effective interfaces and handover between operating shifts are in place, there were instances where pre-job planning between operations and maintenance failed to identify higher risk situations and led to incidents

ID	Gaps
P6	Overall maintenance spend is appropriate, but the site is challenged to maintain the optimum mix of planned vs. reactive maintenance when unplanned events occur. Given the structural challenges in the local craft labor market, the appropriate solution is likely to continue focus on high-priority, high-risk equipment and use risk assessments and inspection data to defer low-risk, lower-priority work

Technological and Physical Safeguards

ID	Gaps
T1	The site lacks emergency shutdown capability at the #2 FCCU, which would allow the site to prevent significant catalyst releases in the event of process upsets
T2	Emergency shutdown capability at other units in the refinery may not be in line with industry-leading practices
T3	Key response procedures were not available to operators in a digital format in real time linked directly to alarms
T4	The site has pre-alarms that are in activated mode frequently, and should be reviewed to ensure that these are indeed set at the appropriate level and not an unnecessary nuisance that is distracting operators from higher priority activities

Conclusions

Based on the investigation conducted at the Commerce City refinery, it is clear there were no deliberate or negligent actions regarding either funding or staffing that caused the incidents prompting this investigation. However, there are opportunities for improvement across systemic areas at the site to avoid or reduce the risk of a future, potentially serious, recurrence of incidents.

In previous sections, we laid out best practices for safe and reliable refinery operations, and the framework we used to assess operational integrity maturity at Commerce City during the time of the incidents. Our work was based on a site visit, a thorough document review and analysis of refinery data, and numerous interviews with site staff.

Kearney developed a list of gaps to outline areas where the site had room for improvement, ranking them by criticality and complexity. Criticality indicated the extent to which closing a gap was immediately necessary to ensure safe and reliable operations. Complexity indicated the extent to which correcting an identified gap would be an involved and lengthy process.

In addition, we identified actions the refinery has already taken, or plans to take, since the period in scope to make progress closing the identified gaps. The result is a list of actions and proposed or in-flight initiatives that show strong initial progress toward improvement (i.e. the site did not wait for the release of this report to begin taking corrective actions).

Ultimately, we have made recommendations and accompanying actions to address the remaining gaps. We present these in the following section. For clarity, these recommendations are provided in the order of the five key factors in Kearney's assessment framework, not in the order of importance.

Recommendations

This section identifies recommendations to minimize or prevent future occurrences of Title V violations at the site.

Context

Based on the key issues identified during the investigation, Kearney has developed recommendations across four areas—culture, capabilities, process, and technology. We focused on making recommendations in those areas that would have the most significant impact on operational integrity and reliability at the Commerce City refinery.

Rather than providing an exhaustive set of initiatives, we believe it is better to focus on a critical few and ensure they are executed well to build a foundation for further operational improvement.

This section provides our recommendations, the gaps these recommendations are intended to address, actions the site has already taken, and remaining work to be done to implement the recommendations. In each subsection, we identify the gaps to be addressed with the ID numbers listed in the Commerce City Site Observations and Key Gaps – Gap Summary section of this report.

Culture

Recommendation 1 – Continue to expand and reinforce a culture focused on safety and environmental responsibility above all and increase the involvement of Suncor and other external experts in critical safety and environmental reviews

Recommendation: We recommend continuing to transition certain behaviors at the site to be in line with Suncor's values and priorities, with safety and environmental performance as the top priority. Additionally, encourage and improve linkages with Suncor enterprise technical experts, external experts, and the local community. This will help address gaps C1 and C2.

Progress to date: The site has already made considerable progress since the study period in this area. The leadership team at the site has been consistently communicating the importance of safety and environmental performance. Certain key procedures (e.g., the #2 FCCU start-up) have been updated to reflect input from Suncor enterprise technical experts and now more closely reflect industry best practice for safe and environmentally responsible operations. The refinery has worked with the Suncor enterprise technical lead to dispel some of the operating 'myths' and updated procedures and process hazard analysis documents accordingly. Site leadership has also reinforced operator empowerment at all levels to act, up to and including unit shutdown, should they feel it necessary to prevent or mitigate the impact of incidents.

Remaining actions: Continue reinforcement of desired operational discipline behaviors in site communications (e.g., highlighting role of operational discipline in incident investigations, MOCs, etc.); increase operational discipline around critical process safety and environmental processes (e.g., mandate Suncor Technical Expert Network (STEN) and leadership participation in PHAs, critical MOCs).[13] Realign and clarify signoff authority for PHAs, risk reviews, and MOCs to ensure that signing authority is with staff with appropriate level of seniority and experience – temporarily elevating to the site leadership team. This may require the leadership team to participate in more risk assessments in the long term. The involvement of STENs and other technical experts will enable the site to test for the presence of similar operating 'myths' in other areas of the refinery and update critical procedures accordingly.

Recommendation 2 – Focus on excellence across a critical few initiatives, so as to avoid mediocrity across the 'impossible many'

Recommendation: We recommend the site transition improvement plans from an ambitious, long list of items—the "impossible many"—to focus on a critical few highest-priority items. This will help address gap C3.

Progress to date: The site prioritized ongoing initiatives at the end of 2019, with a focus on base business to reduce the "impossible many".

Remaining actions: Create an action plan to review key site improvement plans (e.g., reliability improvement plan, problematic equipment list) and re-prioritize to ensure a greater level of focus on the highest priority items (environment and personal/process safety) while deferring lower priority and lower risk items. This will ensure that areas with the greatest potential to cause future environmental incidents are addressed promptly and effectively.

[13] Operational discipline at Suncor includes five key behaviors: seeking knowledge and understanding, adhering to procedures, using a questioning attitude to surface problems, expecting accountability, and collaborating.

Staff Capabilities

Recommendation 3 – Implement innovative recruiting strategies to address immediate staffing needs resulting from recent higher-than-expected voluntary attrition levels

Recommendation: Put in place an innovative and comprehensive strategy to ensure staffing and capability remain at planned levels, including drawing on internal Suncor resources, providing additional cross-training, and considering new recruiting approaches. This will help address gaps S1 and S2.

Progress to date: The site has recently hired approximately 40 operators to supplement the operations workforce, has brought in additional maintenance trades on a temporary contract basis, and is working to hire additional craft laborers to supplement the maintenance workforce.

Remaining actions: Develop a plan to reduce pockets of high workload in specific operations divisions and ensure adequate "bench strength" to prepare for retirements and unexpected attrition that will inevitably occur. In the longer term, seek ability to cross-train operators across divisions, not just across units within a division.

Recommendation 4 – Improve technical and operations staff training with additional training techniques and greater incorporation of experts and full-time trainers

Recommendation: Develop and implement a training strategy with more structured training delivery for technical and operations staff. This delivery model should incorporate internal technical experts and increase use of full-time operations trainers with appropriate capability in curriculum development and delivery. The site should also strengthen competency assessment and practice, with increased operational drills, knowledge checks, and a training simulator in the long run. In structuring the delivery of these improvements, Commerce City may look to utilize collaborative technology. This will help address gaps S3 and S4.

Progress to date: The site has created an operations support organization, with training initiatives in the planning stages. Additionally, the site is conducting more operational and emergency drills, and is increasing the reliance on knowledge checks in addition to procedure reviews for competency assessment.

Remaining actions: Continue the development of a training strategy incorporating the Suncor Technical Expert Network (STEN) and trainers at the refinery (or remotely, through the use of collaborative technology), with the long-term goal of a training simulator—a customized operator training tool that allows practicing appropriate actions to deal with potential abnormalities and incidents, so operators are much better prepared to react when these events occur in real time. This would be an appropriate use of a portion of the funds that the site has committed to spending as part of the agreement with CDPHE.

Process

Recommendation 5 – Transfer operating procedure accountability to operations

Recommendation: Reinforce that the Operations department is accountable for all operating procedure development, management of associated changes, communication, and training—with support from other functions and Suncor enterprise technical experts as needed. The formal involvement of individuals with the right skills and experience will help ensure that safety, environmental, and operability reviews are rigorous, thorough, and higher-risk situations are identified and addressed. The site should also reinforce continued operational discipline and compliance with procedures, implementing a zero-tolerance policy for any deviations from critical procedures that have not gone through a formal approval process with refinery leadership. This will address gaps P1, P2, P4, and P5.

Progress to date: Refinery leadership has decided that the Operations department will hold accountability for operating procedure development. The site has involved the STEN group for #2 FCCU procedure development. For other units, the site is working to formalize the process for involvement of technical experts for portions of operating procedure development.

Remaining actions: Finalize all documentation that confirms accountability for operating procedure development is owned by Operations department. Finalize process for involvement of Suncor enterprise technical experts or other technical experts for critical operating procedures.

Recommendation 6 – Use risk assessments to ensure the most critical maintenance work is prioritized

Recommendation: We recommend refining the equipment maintenance strategy to focus on high-priority, high-risk equipment and use risk assessments and inspection data to appropriately place other maintenance work orders. This, together with recommendation 2, will address gap P3 and P6.

Progress to date: Progress to date has included standing up maintenance execution processes, clarifying responsibilities to help streamline the prioritization process, and brought in coaches to help with the process roll-out. The site is already conducting risk assessments to identify preventative and corrective maintenance actions.

Remaining actions: The site is already making progress to implement this recommendation and no "net new" actions are required. Continue this risk-based approach when faced with corrective activities, prioritizing them appropriately with a formalized risk assessment process. Continue to review any overdue items as they arise, with management sign-off on any time extension, following existing procedures.

Technological and Physical Safeguards

Recommendation 7 – Install automated unit shutdown capability to minimize the impact of incidents that do occur

Recommendation: Automate emergency shutdown of the Plant 2 FCCU (specifically ability to remotely close catalyst slide valves and feed valves tied into the emergency activation system), allowing the site to reduce the likelihood of significant catalyst releases. As part of ongoing PHAs, engage the broader Suncor network to assess refinery emergency shutdown capability. This will address gaps T1 and T2.

Progress to date: The site has installed a DCS-controlled emergency shutdown system on the #2 FCCU and plans to add PLC-controlled emergency shutdown systems to the #1 and #2 FCCU.

Remaining actions: Complete installation of planned PLC-controlled emergency shutdown systems at the Plant 2 FCCU. Ensure that Suncor's PHA process includes an assessment by Suncor technical experts whether further emergency shutdown capability is warranted.

Recommendation 8 – Leverage digital technology to increase real-time availability of critical procedures and expertise

Recommendation: Take advantage of the opportunity to utilize additional emerging digital technologies to increase the quality of training and expert collaboration at the site. In addition, digitize key response procedures to make them available to operators in real time when alarms are activated. Evaluate whether pre-alarms are set at the appropriate level and not distracting operators. This will address gaps T3 and T4.

Progress to date: The site is working to digitize process technology packages and make response plans available to operators in the DCS. On an ongoing basis, the site reviews safe operating limit alarm and pre-alarm setpoints if they are persistently activated.

Remaining actions: Finalize response plan inclusion in DCS. Consider digitalization at the refinery by use of augmented/virtual reality (AR/VR) to allow remote engagement with technical experts when appropriate. In the longer term, add a training simulator at the site.

Recommendation Prioritization

We have identified prioritized initiatives to be implemented using the $5 million Suncor committed to invest as part of the settlement with CDPHE. These are the initiatives that we believe will have the most significant long-term impact on operational integrity and minimizing or preventing future emissions violations, and include the installation of emergency shutdown equipment (#7), training improvements including a training simulator (#4), and the increased use of digital technology to increase availability of critical procedures and improve engagement with the Suncor Technical Expert Network (STEN) or other external technical experts (#8). We estimate that the emergency shutdown equipment installation alone will require a capital investment greater than $5 million. A training simulator would require investment in the $0.5–1 million range, and three to five work years of effort to implement.

Appendix 1 – Emission Sources

Catalyst

During normal refinery operations, heavy oil feedstock is heated in the fluidized catalytic cracker (FCC) in the presence of a fine-grained catalyst. This "cracks," or decomposes, the feedstock into other materials that are collected and processed further. However, some of the heavy oil feedstock forms coke, a solid, carbon-rich material that adheres to the catalyst. This is called spent catalyst because its ability to decompose the feedstock is significantly reduced, and the coke must be periodically removed.

Removal takes place when the spent catalyst continuously moves from the FCC reactor to the FCC regenerator, where coke is burned off at high temperatures. To burn the coke, air is blown into the FCC regenerator to provide oxygen for the reaction. The oxygen reacts with carbon in the coke to form a variety of products, including carbon dioxide and carbon monoxide. The fresh catalyst then moves back to the FCC reactor to repeat the process.

Under normal operations, catalyst moves from the FCCU to the FCC regenerator and then back, as outlined above. However, when certain process upsets occur, this circulation can be disrupted, resulting in a rapid release of catalyst to the environment.

Similar incidents have occurred at other refineries. Leading practice is to install an independent shutdown system that is able to automatically shut down catalyst flow within two to five seconds of an upset being detected. This rapid response is essential, as total release of catalyst can happen within thirty seconds of the start of an incident (i.e. the incident at Commerce City on December 11, 2019).

[14]

Hydrogen Cyanide

The refinery emits hydrogen cyanide during normal operations. There were no incidents identified as releasing unusually high levels of hydrogen cyanide, nor was it found as a substance of concern in any incident reports.

Nitrogen compounds are present in the feedstock, and during the regeneration process, a variety of nitrogen-containing compounds are formed, including hydrogen cyanide (HCN). Under normal conditions in the FCC regenerator, HCN reacts with oxygen to form inert nitrogen and nitric oxide, which are less hazardous than HCN. However, due to the length of time the gases spend inside the FCC regenerator release, not all HCN reacts, and some HCN is left in the flue (exhaust) gas. It is in this manner that small amounts of HCN are released into the atmosphere.

This process, and the associated emissions, are typical for oil refineries, and are not unique to the Commerce City refinery.

The refinery design during the study period did not have automatic shutdown capability, nor did it have automated valves to stop catalyst release. This meant that it would take at least a minute to react, which would not prevent a major release of catalyst. It is critical to install emergency shutdown equipment with automatic valves to prevent catalyst release.

The emergency shutdown equipment recently installed at the refinery should prevent about 95 percent of major catalyst discharges, and the planned programmable logic controller (PLC) system should prevent 99 percent or more of major discharges. Cultural practices around prioritizing safety and empowering operators to slow down or halt start-up should also reduce the potential for major catalyst releases.

Opacity

Opacity exceedances are similar to catalyst releases outlined above, but typically involve small amounts of very fine particles of catalyst. These releases typically happen during start-up and shutdown, when there is not enough gas being exhausted from the FCCU and FCC regenerator to enable control equipment to remove the fine particles.

Installing automated shutdown equipment, in line with leading practices outlined above, should reduce the frequency and severity of opacity incidents significantly. In the two to five seconds it takes to shut down equipment, there may still be infrequent, less significant exceedances – typically during start-up and shutdown. Although technology to reduce opacity further, in the form of electrostatic precipitators, exists, it has not proven to be reliable and has been linked to significant safety incidents with much greater impact than occasional opacity exceedances.

[14] For example, a major explosion at the ExxonMobil Torrance Refinery in 2015 was sparked by the electrostatic precipitator used to control emissions from an FCCU

The Title V permit for the refinery's Plant 1 and Plant 3 includes an annual emission limit of 12.8 tons per year of HCN from the FCC regenerator (permit condition 22.14).

This condition is unusual for oil refineries. The relevant regulation is 40 CFR Subpart UUU – National Emission Standards for Hazardous Air Pollutants for Petroleum Refineries: Catalytic Cracking Units, Catalytic Reforming Units, and Sulfur Recovery Units.[15] It includes a requirement for emissions from FCC regenerators to meet a maximum concentration of 500 parts per million of carbon monoxide in flue gas, and for operators of FCC regenerators to conduct a one-time test to determine the concentration of HCN in the flue gas. There is no specific limit for HCN concentration or emission rate.

A selective review of Title V permits for other petroleum refineries indicated that this is an uncommon permit condition, and there is no limit on hydrogen cyanide emissions in nearly all other refinery Title V permits, with the exception of one refinery in Texas.

There are typically no controls for HCN emissions from FCC regenerators, and low carbon monoxide concentrations appear to be used by regulators as a proxy for the presence of sufficient oxygen in the FCC regenerator to reduce flue gas HCN concentration to an acceptable level.

In conclusion, Commerce City's design is not unusual with respect to hydrogen cyanide emissions, and similar emissions could be expected from other refineries. These emissions are normally not included in the Title V permit for refineries.

Hydrogen Sulfide

The refinery produces hydrogen sulfide as a byproduct of refining high-sulfur crude oils. Hydrogen sulfide occurs naturally in crude oil and is converted to elemental sulfur in the sulfur recovery units at the refinery. This sulfur is then stored in a covered pit, from which it is pumped into railcars for shipment.[16] This process is typical for oil refineries and is not unique to the Commerce City refinery.

During malfunction conditions (e.g., during an unexpected power outage), the sulfur recovery units may not convert hydrogen sulfide to sulfur. In this case, hydrogen sulfide is diverted to either an incinerator or a flare, which converts the hydrogen sulfide to sulfur dioxide. In these instances, sulfur dioxide emissions may exceed the limits in the Title V permit.

In addition, the site experienced incidents where condensed steam used to heat sulfur leaked into the sulfur pit, resulting in a reaction that generated hydrogen sulfide.

Procedural improvements made in our recommendations (particularly cultural recommendations 1 and 2) as well as faster emergency shutdowns should reduce the frequency of hydrogen sulfide-related incidents at the site.

[15] Code of Federal Regulations

[16] Source: US EPA AP-42, Vol. 1, Final Background Document for Sulfur Recovery, Section 8.13

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