Chevron

Steve Wildman
Manager

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April 12, 2013

Randall L. Sawyer
Hazardous Materials Program Director
Contra Costa Health Services
4333 Pacheco Boulevard
Martinez, CA 94553-2229

RE: Seventh Update to the 30-Day Report for the CWS Level 3 Event of August 6, 2012

Dear Mr. Sawyer:

In accordance with the December 14, 2004 Contra Costa Health Services ("CCHS") Hazardous Materials Incident Notification Policy, Chevron U.S.A. Inc. ("CUSA") is providing an update to the 30-Day Report for the Community Warning System ("CWS") Level 3 Event that occurred at the Richmond Refinery on August 6, 2012. The attached "Update to 30-Day Follow-Up Notification Report Form" updates sections IX and X to reflect that CUSA has now completed its investigation into the August 6 CWS Level 3 Event and is submitting its report summarizing the investigation results to the CCHS. This letter provides a brief summary of the investigation report findings and recommendations, as well as an update on the actions CUSA is taking to prevent a similar incident in the future.

Incident Investigation

CUSA's investigation was conducted by a team that included external scientific and engineering experts, members of the United Steelworkers Union, and CUSA's technical experts. The team gathered and reviewed historic information and data, interviewed relevant personnel, visually inspected the damaged portions of the No. 4 Crude Unit ("Crude Unit") where the incident occurred, collected samples, and observed testing of the failed pipe section performed by Anamet Inc. ("Anamet"), a testing laboratory.

Based on this investigation, the report concludes a failure occurred in a five-foot long piping component of the 8" carbon steel atmospheric gas-oil pipe line from the atmospheric distillation tower (known as the "4-sidecut") in the Crude Unit, resulting in a hydrocarbon leak. Subsequently, a fire erupted in the area of the failure. Consistent with the metallurgy evaluation report on the failed piping component prepared by Anamet, our investigation found that the five-foot carbon steel component where the leak occurred failed due to thinning caused by sulfidation corrosion, which was accelerated by the low-silicon content of the failed component. Individual carbon steel piping components with low-silicon can, and here did, corrode at an accelerated rate not readily detectable by multiple corrosion monitoring locations.

Causal Factors, Additional Considerations, and Recommendations

CUSA's investigation team identified four "causal factors"[1] of the August 6 incident:

- The response and assessment after discovery of the leak did not recognize the risk of piping rupture and the possibility of auto-ignition.
- A measurement performed in 2002 showed one-third wall loss in the failed pipe component just downstream of a corrosion monitoring location ("CML"). This information was only captured as a comment in the inspection management software tool and not elsewhere in the inspection management system. Documenting wall thickness information in a comment without adding it to the inspection management software database limited the ability for future decision-makers to utilize the data.
- Relevant information regarding carbon steel sulfidation corrosion – including the understanding that components with low-silicon are especially susceptible to sulfidation corrosion and the recommendation to perform 100% component-by-component inspection – was not transferred to the Refinery inspection management system. The 2009 Reliability Opportunity Identification/Intensive Process Review ("ROI/IPR") did not identify the need for 100% component-by-component inspection or the replacement of the 4-sidecut piping.
- Inspection during the 2011 Turnaround did not include every component in the 4-sidecut piping circuit because the recommendation to identify and inspect every component was not built into the inspection plans for the Crude Unit. A 100% component-by-component inspection would have required the inspection of the pipe component that failed in August 2012, which could have alerted the Refinery to the component's accelerated metal loss.

To address these causal factors, the investigation team made the following recommendations:

- Revise Refinery policies and checklists to ensure appropriate information – including process safety and inspection information – is considered when evaluating leaks and addressing the issue of whether to shut down or continue operation of equipment.

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[1] Based on the methodology used to perform the investigation, a "causal factor" iws a mistake or failure that, if corrected, could have prevented the incident from occurring or would have significantly mitigated its consequences..

- Enhance the Refinery's mechanical integrity program to ensure the Refinery properly identifies and monitors piping circuits for appropriate damage mechanisms using a standardized methodology and documentation system.

- Implement certain improvements concerning inspector training and competency, oversight of mechanical integrity, inspection plans and escalation procedures. Develop and implement a process to review and act upon mechanical integrity-related recommendations from industry alerts, Chevron Energy Technology Company ("ETC"), and other subject-matter experts. Inspect Crude Unit piping that falls under the ETC Sulfidation Inspection Guidelines criteria for sulfidation corrosion prior to restarting the Crude Unit, and implement the ETC Sulfidation Inspection Guidelines for the remainder of the Refinery.

- Ensure relevant technical studies and inspection data are considered for the Refinery's equipment reliability plans and incorporated into the ROI/IPR process.

In addition to the four causal factors of the incident, the investigation report also found six "additional consideration" which, while not considered a direct cause of the August 6 incident, represent opportunities to prevent a similar incident from recurring (with specific additional recommendations noted):

- The Chevron Fire Department did not complete a Hazard Material Data Sheet and positioned Engine Foam 60 too close to the leak source when responding to the Incident.
    - Review the Pre-Fire Plan to ensure sufficient guidance is provided on equipment positioning.

- The leaking line could not be isolated on the upstream side to mitigate loss of containment.
    - Review company/industry loss history on large fractionating towers to determine if internal Engineering Standard FRS-DU-5267 (Emergency Isolation and Depressuring Valves) adequately addresses mitigation of accidental releases from these systems. Revise the standard as warranted by the findings of this review.

- The ETC Sulfidation Inspection Guidelines were not fully implemented and action items were not tracked to completion.
    - Ensure Refinery business plans provide for the appropriate implementation of process safety recommendations.

- The minimum thicknesses calculated for the 4-sidecut washout spool piping did not include safety factors considered in the Refinery Piping Inspection Guideline and American Petroleum Institute Recommended Practice 574, which may have triggered a Fitness for Service analysis and led to additional inspections and resulting data.

  - Ensure sufficient organizational capacity and competency for minimum thickness Fitness for Service determinations.

- The June 2012 inspection of the P-1149/A suction piping was not entered in the inspection management system.

  - Consider additional training on expectations under the "Richmond Refinery Piping Inspection Guidelines" and "RFMS Piping Data Entry (Reliability Focused Maintenance System) and ACD (Add/Change/Delete) Guideline."

- The Crude Unit Process Hazard Analyses did not consider the potential for sulfidation corrosion.

  - Review and modify the Process Hazard Analysis ("PHA") procedures to ensure that teams consider known corrosion threats/mechanisms.

  - Consider a project to evaluate the purpose and methods of various process safety management ("PSM") reviews to determine if these activities can be combined or better sequenced to improve risk understanding across the various functions and promote better process safety outcomes.

Actions to Address Report Findings and Recommendations, and To Prevent Recurrence

In our Fourth Update to the 30-Day Report for the CWS Level 3 Event of August 6, 2012, submitted January 28, 2013, we summarized the measures the Refinery is implementing to prevent a recurrence of the incident. We are providing CCHS a further update of those measures, and the status of their implementation. In addition to previously sharing these measures with CCHS, we have previewed these actions with Cal/OSHA and the CSB in order to ensure alignment with their understanding of the causes of the incident.

Low-Silicon Carbon Steel and Piping Component Inspections

- The Refinery has inspected every piping component in the Crude Unit potentially susceptible to sulfidation corrosion. Of the approximately 4,600 piping components inspected, we replaced four carbon steel piping components that appeared to have higher corrosion rates than other piping components in the system.

- Our enhanced inspection programs are being implemented throughout the Refinery, and we are replacing every component found as indicated by the results of these inspections. Over the longer-term, we will conduct 100 percent piping component inspections throughout our refining network.

Mechanical Integrity Program

- We are strengthening the Refinery's reliability program for piping and equipment to ensure it covers potential damage mechanisms applicable to those systems. As part of this effort, CUSA has begun implementing an enhanced process for regular damage mechanism reviews for each unit and piping circuit so as to formalize the evaluation of known damage mechanisms, the consequences of a failure, and the safeguards necessary to mitigate failures and other potential risks from those damage mechanisms.

- We also are reviewing and modifying our PHA procedures to ensure that known corrosion threats/mechanisms have been appropriately considered.

- The Refinery is implementing an enhanced process to better review, prioritize, and act upon mechanical integrity-related recommendations from internal and external technical experts, including industry standards and alerts, to ensure that the right information gets into the hands of the right people at the right time so the right decisions can be made.

Assessment, Decision-Making, and Oversight

- The Refinery is implementing a process for additional oversight of mechanical integrity-related recommendations, inspection plans, and turnaround work lists.

- We are reviewing and improving our mechanical integrity training as a way to further support our leaders, inspectors, operating groups, and engineers. We are also making certain that the appropriate technical resources are readily available to assist any evaluation of the fitness of equipment for service.

Leak Response

- We have implemented a new protocol for evaluating leaks with simple guidance for making sometimes necessary rapid decisions around leak response and further enhancing situational awareness skills. We recently shared our new leak response protocol with CCHS, Cal/OSHA, and the CSB, as well as other refineries and industrial facilities in Contra Costa County.

Process Safety Focus

- We are reemphasizing our expectations around process safety and the responsibility of all personnel for process safety performance, including the importance of incorporating process safety into decision-making.

With the submission of its investigation report, CUSA believes that, absent new information coming to light or a request for additional information from CCHS, this will be the final update to the 30-Day Report.

If you have questions or comments, please feel to contact me directly at the number above, or Karen Draper of my staff at (510) 242-1547.

Sincerely,

Steve Wildman

Steve Wildman

For CCHS Use Only:
Received By: ______________
Date Received: ______________
Incident Number: ______________
Copied To: ______________
Event Classification Level: ______________

ATTENTION: Randall L. Sawyer
Hazardous Materials Program Director
Contra Costa Health Services Department
4333 Pacheco Boulevard
Martinez, CA 94553

INCIDENT DATE: August 6, 2012
INCIDENT TIME: 6:30 PM
FACILITY: Chevron U.S.A. Inc. Richmond Refinery

PERSON TO CONTACT FOR ADDITIONAL INFORMATION: Karen Draper
Phone Number: (510) 242-1547

PROVIDE ANY ADDITIONAL INFORMATION THAT WAS NOT INCLUDED IN THE 30-DAY REPORT WHEN THE 30-DAY REPORT WAS SUBMITTED, INCLUDING MATERIAL RELEASED AND ESTIMATED OR KNOWN QUANTITIES, COMMUNITY IMPACT, INJURIES, ETC.:

I. SUMMARY OF EVENT

On August 6, 2012, a piping failure occurred in the #4 Crude Unit at the Chevron U.S.A. Inc. refinery in Richmond, CA, and subsequently a fire ignited in the area of the failure. The rupture involved an 8" carbon-steel atmospheric gas-oil pipe line from the atmospheric distillation tower.

The primary location of the fire was near P-1149 (C-1100 Atmospheric Column No. 4 Sidecut pump). At the time of the fire, Operations personnel were in the process of evaluating a reported leak with the assistance of Chevron Fire Department personnel.

The #4 Crude Unit distills crude oil into various fractions of different boiling ranges, each of which is then processed further in the other refinery processing units. The #4 Crude Unit at Richmond Refinery has both an Atmospheric Distillation column and a Vacuum Distillation column. This incident involved equipment associated with the Atmospheric Distillation column.

The company's investigation into this incident is now complete, and is included with this Update. The information below has been updated accordingly.

II. AGENCIES NOTIFIED, INCLUDING TIME OF NOTIFICATION

Primary: Community Warning System (CWS):

- Level 3 CWS (shelter in place) activated at approximately 6:35 PM (which served as the initial notification to most of the agencies below)
- The shelter in place was lifted by Contra Costa County Hazardous Materials Programs (CCHMP) at 11:30 PM

Secondary: Subsequent notifications via telephone to the agencies below:

State of Emergency Services	Bob McRae	800-852-7550 or 916-845-8911	6:53 PM
National Response Center (NRC)	Garther	800-424-8802	6:59 PM
Contra Costa Hazardous Materials Program (CCHMP)	Melissa Hagen	925-335-3200	7:28 PM
Bay Area Air Quality Management District (BAAQMD)	Mr. Scott	415-749-4979	7:33 PM
Richmond Fire/ Police Central Dispatch	Dispatch	510-620-6933	7:40 PM
California Division of Occupational Safety and Health (Cal/OSHA)	Clyde Trombettas	925-602-6517	10:09 PM

III. AGENCIES RESPONDING, INCLUDING CONTACT NAMES AND PHONE NUMBERS:

The list below does not include all representatives from the respective agencies

Cal/OSHA	Clyde Trombettas	925-602-2665
CCHMP	Trisha Asuncion	925-335-3200
BAAQMD	Jackie Huynh	415-749-4979
OSPR– Dept. Fish & Game	Bob Chedsey	707-864-4975
U.S. EPA	Scott Adair	415-947-4549
Richmond Police Department	Responding Officers	510-233-1214
U. S. Chemical Safety and Hazard Investigation Board (CSB)	Dan Tillema	303-236-8703

IV. EMERGENCY RESPONSE ACTION:

At or around 3:48 PM on August 6, 2012, an operator noticed a small leak from insulated piping on the C-1100 Atmospheric Distillation Column of the 4 Crude Unit. The operator immediately notified the Head Operator and Supervisor for the unit and initiated a dialogue regarding next steps and how to isolate the leak.

The standard practice of the Chevron Fire Department (CFD) is to respond to leaks, spills, and releases. In this instance, the CFD was notified at 4:02 PM that a leak had been discovered at the 4 Crude Unit. The CFD was asked to deploy a crew to the location as a precaution. The CFD arrived at the location between 4:07 PM and 4:09 PM and initiated air monitoring and assessment.

From 4:09 PM to 4:19 PM the rate of feed to the unit was reduced. Then, from 4:20 PM to 6:24 PM, Operations personnel, in conjunction with the CFD, investigated and assessed options. While the leak was being assessed, the CFD set up an engine and had two hose teams in place, one directed at the potential source of the leak and one directed at the personnel assessing the leak. At approximately 6:22PM, a small flash fire occurred on the insulated piping going to P-1149/A. The CFD and Plant Operators activated water spray and extinguished the small flash fire. At some point shortly before 6:25 PM, the size of the release abruptly increased. Between 6:25 PM and 6:28 PM, the order was given to shut down the unit. Around this time a white cloud was visible. At or around 6:32 PM, the fire that is the subject of this report and ongoing investigation ignited.

At 6:38 PM, a Community Warning System Level 3 alert was initiated by Chevron U.S.A. Inc. and the CWS alarm sounded. At or around this timeframe, both Petro-Chem Mutual Aid and Municipal Mutual Aid were called in for support. This included: Richmond Fire, El Cerrito Fire, Berkeley Fire, Contra Costa County Fire, Moraga/Orinda Fire, Hercules/Rodeo Fire, Phillips 66, Valero, Shell, Tesoro and Dow Fire. Also at or around this timeframe, a shelter-in-place order was issued for Richmond, San Pablo, and North Richmond. The shelter-in-place order advised residents to remain indoors until the fire was controlled. At 11:12 PM, the shelter-in-place order was lifted by CCHMP.

V. IDENTITY OF MATERIAL RELEASED AND ESTIMATED OR KNOWN QUANTITIES:

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-To-Know Act (EPCRA) require reporting when a facility releases more than a "reportable quantity" of a hazardous substance. The reportable release thresholds are based upon EPCRA & CERCLA reporting requirements. There was a reportable quantity of sulfur dioxide released from the fire and the flaring associated with the fire.

As a result of our continuing investigation, emission calculations from flaring associated with the event have been refined and summarized below.

Flare emissions (8/6 – 8/10)*	
Material Release	**Quantity Released**
Vent Gas Volume	8,021,389 SCF
Sulfur Dioxide (SO_2)	8,772 pounds
Methane	1,713 pounds
Non-Methane Hydrocarbon	3,794 pounds
Hydrogen Sulfide (H2S)	46 pounds
Nitric Oxides (NOx)	270 pounds

* Flare emission data includes emissions from the initial release and from depressuring the unit through August 10, 2012

As a result of our continuing investigation, emissions calculations from the fire that were in excess of a reportable quantity have been refined and summarized below:

Fire Emissions		
Material Released	**Quantity Released**	**Reportable Release Thresholds**
Sulfur Dioxide (SO_2)	2,017 pounds	500 pounds

Emission estimates herein are based on currently available data and are subject to change based on further investigation and analysis.

VI. METEROLOGICAL CONDITIONS AT TIME OF EVENT:

Wind Speed	11.5 MPH
Wind Direction	134° (SE)
Precipitation	None
Temperature (F)	75°

VII. DESCRIPTION OF INJURIES:

The following employee injuries were associated with this incident (all were part of the emergency response):

1) Employee received minor burn to small area of the left ear
2) Employee received minor burn to left wrist
3) Employee suffered abdominal discomfort
4) Employee suffered respiratory irritation
5) Employee suffered blister to lower leg from boot wear
6) Employee suffered bruise to a finger

All employees received first aid onsite by the Chevron Fire Department and/or the onsite clinic. All employees returned to work on the same shift. There were no injuries to contractor personnel associated with this incident.

VIII. COMMUNITY IMPACT:

A shelter-in-place order was issued for Richmond, San Pablo, and North Richmond, which advised residents to remain indoors until the fire was controlled. According to the Contra Costa Health Services website, a large number of people sought medical attention at local emergency rooms (three individuals were admitted to the hospital). Most cases have been minor complaints of nose, throat or eye irritation or respiratory issues.

a) Chevron U.S.A. Inc. established a claims process to compensate community members for medical and property expenses incurred as a result of the incident. As of January 21, 2013, approximately 23,900 claims have been initiated, and Chevron U.S.A. Inc. has spent approximately $10 million to compensate area hospitals, affected community members with valid claims, and local government agencies in Richmond and West Contra Costa County.

b) On August 6, 2012, seventeen (17) direct-reading samples were taken using an Industrial Scientific MX6 iBrid multi-gas monitor. The data from these samples confirms that concentrations for Hydrogen Sulfide (H2S), Sulfur Dioxide (SO2) and Carbon Monoxide (CO) were below detectable limits (<0.1ppm, <0.1ppm, and <1ppm respectively). Additionally, nineteen (19) grab samples were collected in Tedlar bags in various downwind locations in Richmond, California, El Sobrante, California, and El Cerrito, California. These samples were sent for analysis of sulfur compounds and hydrocarbons to Air Toxics Ltd., a laboratory specializing in the analysis of air using a wide variety of methods. All results from these samples were well below both the California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA) Reference Exposure Levels and California Occupational Safety and Health Administration (Cal/OSHA) Permissible Exposure Limits.

Follow-up community monitoring was conducted by Chevron U.S.A. Inc. at various locations throughout Richmond, California on August 7-8, 2012. Twenty (20) direct-reading air samples were taken during this timeframe using an Industrial Scientific MX6 iBrid multi-gas monitor. The data from these samples also confirms that concentrations of Hydrogen Sulfide (H2S), Sulfur Dioxide (SO2) and Carbon Monoxide (CO) were below detection limits (<0.1ppm, <0.1ppm, and <1ppm respectively). In addition, six (6) grab samples were collected in Tedlar bags during this timeframe at various locations in Richmond, California and were sent to Air Toxics Ltd Laboratory for analysis of sulfur compounds and hydrocarbons. Consistent with the above-referenced findings, all results from these samples were well below the OEHHA Reference Exposure Levels and Cal/OSHA Permissible Exposure Limits. Please note, however, that the laboratory detection limit for Acrolein is higher than the OEHHA Reference Exposure Limit.

c) Fence-line monitoring: Continuous monitoring data is gathered around the clock from instrumentation located at Chevron's Office Hill, Castro Street and Gertrude Street monitoring stations. A data point, close to or prior to the incident, is employed as a reference. The following maximum readings were recorded between the times the fire ignited and the time all-clear was called by CCHMP (between 6:30 PM and 11:31 PM on August 6, 2012). As reflected in the table below, none of the maximum readings exceeded Cal/OSHA's Permissible Exposure Limits (PELs).

Permissible Exposure Limits (PELs). Maximum Concentration Readings

	Cal/OSHA PEL	Castro Street	Office Hill	Gertrude Street
H2S (ppb) Background at 3:00 PM	10,000 ppb	3.04 ppb	3.99 ppb	2.09 ppb
H2S (ppb) Max.	10,000 ppb	3.27 ppb	5.41 ppb	2.51 ppb
SO2 (ppm) Background at 3:00 PM	2 ppm	0.006 ppm	0.003 ppm	0.002 ppm
SO2 (ppm) Max.	2 ppm	0.007 ppm	0.006 ppm	0.002 ppm

Note: The Cal/OSHA PEL are concentrations averaged over an 8-hour period.

IX. INCIDENT INVESTIGATION RESULTS:

Following the incident, Chevron U.S.A. Inc. promptly initiated an investigation of the incident using the TapRooT® methodology. The investigation is now complete. The investigation was conducted by a team that included external scientific and engineering experts, members of the Unites Steelworkers Union, and the company's technical experts. The team gathered and reviewed historic information and data, interviewed relevant personnel, visually inspected the damaged portions of the No. 4 Crude Unit ("Crude Unit") where the incident occurred, collected samples, and observed testing of the failed pipe section performed by Anamet Inc. ("Anamet"), an independent laboratory.

The investigation report concludes a failure occurred in a five-foot long piping component of the 8" carbon steel atmospheric gas-oil pipe line from the atmospheric distillation tower (known as the "4-sidecut") in the Crude Unit, resulting in a hydrocarbon leak. Subsequently, a fire erupted in the area of the failure. Consistent with the metallurgy evaluation report on the failed piping component prepared by Anamet, the investigation found that the five-foot carbon steel component where the leak occurred failed due to thinning caused by sulfidation corrosion, which was accelerated by the low-silicon content of the failed component. Individual carbon steel piping components with low-silicon can, and here did, corrode at an accelerated rate not readily detectable by multiple corrosion monitoring locations. A copy of the final investigation report is included with this Update.

X. SUMMARIZE INVESTIGATION RESULTS BELOW OR ATTACH COPY OF REPORT:

The investigation is now complete and the final report included with this Update.

XI. SUMMARIZE PREVENTABLE MEASURES TO BE TAKEN TO PREVENT RECURRENCE INCLUDING MILESTONE AND COMPLETION DATES FOR IMPLEMENTATION

Actions to Address The Investigation Report Findings and Recommendations, and To Prevent Recurrence

In its Fourth Update to the 30-Day Report for the CWS Level 3 Event of August 6, 2012, submitted January 28, 2013, the company summarized the measures the Refinery is implementing to prevent a recurrence of the incident. Chevron U.S.A. is providing CCHS a further update of those measures, and the status of their implementation. In addition to previously sharing these measures with CCHS, the company previewed these actions with Cal/OSHA and the CSB in order to ensure alignment with their understanding of the causes of the incident.

Low-Silicon Carbon Steel and Piping Component Inspections

- The Refinery has inspected every piping component in the Crude Unit potentially susceptible to sulfidation corrosion. Of the approximately 4,600 piping components inspected, the Refinery replaced four carbon steel piping components that appeared to have higher corrosion rates than other piping components in the system.

- Enhanced inspection programs are being implemented throughout the Refinery, and the Refinery will replace every component found as indicated by the results of these inspections.

Mechanical Integrity Program

- The company is strengthening the Refinery's reliability program for piping and equipment to ensure it covers potential damage mechanisms applicable to those systems. As part of this effort, Chevron U.S.A. has begun implementing an enhanced process for regular damage mechanism reviews for each unit and piping circuit so as to formalize the evaluation of known damage mechanisms, the consequences of a failure, and the safeguards necessary to mitigate failures and other potential risks from those damage mechanisms.

- The Refinery also is reviewing and modifying its Process Hazard Analysis procedures to ensure that known corrosion threats/mechanisms have been appropriately considered.

- The Refinery is implementing an enhanced process to better review, prioritize, and act upon mechanical integrity-related recommendations from internal and external technical experts, including industry standards and alerts, to ensure that the right information gets into the hands of the right people at the right time so the right decisions can be made.

Assessment, Decision-Making, and Oversight

- The Refinery is implementing a process for additional oversight of mechanical integrity-related recommendations, inspection plans, and turnaround work lists.

- The Refinery is reviewing and improving its mechanical integrity training as a way to further support leaders, inspectors, operating groups, and engineers. The company is also making certain that the appropriate technical resources are readily available to assist any evaluation of the fitness of equipment for service.

Leak Response

- The Company has implemented a new protocol for evaluating leaks with simple guidance for making sometimes necessary rapid decisions around leak response and further enhancing situational awareness skills. The Refinery recently shared its new leak response protocol with CCHS, Cal/OSHA, and the CSB, as well as other refineries and industrial facilities in Contra Costa County.

Process Safety Focus

- The Refinery is reemphasizing our expectations around process safety and the responsibility of all personnel for process safety performance, including the importance of incorporating process safety into decision-making.

XII. ADDITIONAL INFORMATION. DETAILED EVENT TIMELINE, CORRESPONDENCE, RELEVANT HISTORY OF INCIDENTS WITH SIMILAR EQUIPMENT OR PROCEDURES:

The detailed event timeline is included in the final investigation report, which is included with this Update.

Richmond Refinery 4 Crude Unit Incident

August 6, 2012

Prepared by the CUSA Richmond Investigation Team

April 12, 2013

Event Title: Richmond Refinery 4 Crude Unit Leak and Fire

IMPACT ERM Record Number(s): #43094

PSM Related Event: Yes | **PSM Related Near Miss: No**

RISO MCAR Event: Yes | **RISO MCAR Near Miss: No**

Contents

List of Figures

Glossary

Term	Description
4CU	4 Crude Unit
4SC	4 sidecut
ABCR	Atmospheric Bottom Circulating Reflux – drawn off the light gas oil collection tray – plays an important role in heat balance of the Atmospheric Distillation Column
AOA	Alarm Objective Analysis
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	ASTM International, an organization that develops and distributes international consensus technical standards
CBO	Control Board Operator
CCHS	Contra Costa Health Services
CFD	CUSA Fire Department
CFR	Code of Federal Regulations
CML	Corrosion Monitoring Location – also known as Thickness Monitoring Location (TML) – locations where inspection is periodically conducted
COA	Control Objectives Analysis
Condition Manager	Meridium's database of CML measurements
CSB	U.S. Chemical Safety and Hazard Investigation Board
CUSA	Chevron U.S.A. Inc.
CWS	Community Warning System
Distillation	Process to separate a mixture into its component parts by boiling point
EPA	U.S. Environmental Protection Agency
ETC	Energy Technology Company
Flag Thickness	A wall thickness value used for triggering the need for quantitative minimum thickness and half-life assessment
HO	Head Operator
LGO	Light Gas Oil
MCC	Motor Control Center
Meridium	Inspection management software tool
MSDS	Material Safety Data Sheet

Term	Description
OA	Operations Assistant – an exempt position outside of the chain of command between refinery management and the Head Operator and Operators
PHA	Process Hazard Analysis
PO	Plant Operator
PPE	Personal Protective Equipment
PSM	Process Safety Management
RBI	Risk Based Inspection
Reflux	Portion of the overhead liquid product from a Distillation Column that is returned to the Column to cool and condense vapors in the Column
ROI/IPR	Reliability Opportunity Identification/Intensive Process Review – reliability study that seeks to identify opportunities for improvement in the plant being reviewed
RP	Recommended Practice
RSC	Reliability Steering Committee
RSL	Refinery Shift Leader
RT	Radiographic Testing – inspection technique used for non-destructively measuring wall thickness
SC	Sidecut
SCBA	Self-Contained Breathing Apparatus
Si	Silicon
sRCM	streamlined Reliability Centered Maintenance – reliability study used to identify equipment criticality, failure modes, and strategies for maintaining the equipment
STL	Shift Team Leader – Richmond Refinery operations first line supervisor
TML	Thickness Monitoring Location (see CML)
UT	Ultrasonic Testing – inspection technique used for non-destructive measuring wall thickness

Executive Summary

On August 6, 2012 at approximately 1548 hours, a leak was discovered by an operator in an 8-inch diameter pipe carrying light gas oil (LGO) in the 4 Crude Unit (4CU) at the Chevron U.S.A. Inc. (CUSA) Refinery in Richmond, California (Refinery). At approximately 1830 hours, the hydrocarbon release from the pipe resulted in the formation of a white cloud, a subsequent fire, and a black smoke plume (collectively, the Incident). A shelter-in-place order was issued for the cities of Richmond, San Pablo, and North Richmond, which advised residents to remain indoors until the fire was controlled. The CUSA Fire Department (CFD), with assistance from Petrochemical Mutual Aid Organization and Municipal Mutual Aid, brought the fire under control and the shelter-in-place was lifted at 2312 hours on the same day. Six responders were treated for first aid injuries and the 4CU and a cooling tower sustained damage.

Immediately after the Incident, CUSA's management formed an investigation team, consisting of CUSA employees and technical consultants (Investigation Team). On August 7, 2012, the Investigation Team met on-site and began its investigation, which included gathering historical information and data, interviewing relevant personnel, visually inspecting the damaged portion of the 4CU, collecting samples, and observing testing of the ruptured pipe section at an outside laboratory. The Investigation Team also performed literature and standards reviews, analytical calculations, computational simulations, and experiments to gather additional information. The Investigation Team performed detailed technical analyses on the gathered information to determine the causes of the Incident.

The Investigation Team concluded that the 4 sidecut (4SC) carbon steel pipe in the 4CU failed due to thinning caused by sulfidation corrosion in a component that had low silicon content. The failed pipe component was part of the 4SC piping circuit with a total length of approximately 215 feet and consisting of 67 components, including fittings, elbows, and straight pipe runs. The Investigation Team determined that the components of the circuit had corroded at varying rates due to the different silicon content of the carbon steel components. The silicon content of the failed component was ten times lower than the adjacent component where corrosion was monitored [corrosion monitoring location (CML) #3].

The Investigation Team identified the following four Causal Factors[1] of the Incident:

1. The response and assessment after the discovery of the leak did not fully recognize the risk of piping rupture and the possibility of auto-ignition.

2. A measurement performed in 2002 showed one-third wall loss in the failed pipe component just downstream of CML #3. This information was only captured as a comment in the inspection management software tool (Meridium) and not elsewhere in the inspection management system. Documenting wall thickness information in a comment without adding it to the inspection management software database (Condition Manager) limited the ability for future decision-makers to utilize the data.

[1] Defined by the TapRooT® analysis method as: "A mistake or failure that, if corrected, could have prevented the incident from occurring or would have significantly mitigated its consequences."

3. Relevant information regarding carbon steel sulfidation corrosion—including the understanding that components with low silicon content are especially susceptible to sulfidation corrosion and the recommendation to perform 100% component-by-component inspection—was not transferred to the refinery inspection management system. The 2009 Reliability Opportunity Identification/Intensive Process Review (ROI/IPR) did not identify the need for 100% component-by-component inspection.

4. Inspection during the 2011 Turnaround did not include every component in the 4SC piping because the recommendation to identify and inspect every component was not built into the inspection plans for the 4CU. A 100% component-by-component inspection would have required the inspection of the pipe component that failed in August 2012, which could have alerted the Refinery to the component's accelerated metal loss.

The Investigation Team makes the following recommendations to prevent future recurrences of these Causal Factors:

1. Revise Refinery policies and checklists to ensure appropriate information—including Process Safety and Inspection information—is considered when evaluating leaks and addressing the issue of whether to shut down or continue operation of equipment.

2. Enhance the Refinery's Mechanical Integrity program to ensure the Refinery properly identifies and monitors piping circuits for appropriate damage mechanisms using a standardized methodology and documentation system.

3. Implement certain improvements concerning inspector training and competency, oversight of mechanical integrity, inspection plans and escalation procedures. Develop and implement a process to review and act upon mechanical integrity-related recommendations from industry alerts, ETC and other subject-matter experts. Inspect 4CU piping that falls under the ETC Sulfidation Inspection Guidelines criteria for sulfidation corrosion prior to restarting the 4CU, and implement the ETC Sulfidation Inspection Guidelines for the remainder of the Refinery.

4. Ensure relevant technical studies and inspection data are considered for the Refinery's equipment reliability plans and incorporated into the ROI/IPR process.

The Investigation Team also identified six Additional Considerations.[2]

The findings presented in this report are made to a reasonable degree of scientific and engineering certainty based on the information possessed by the Investigation Team as of the date of this report.

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[2] A mistake or failure that contributed to the incident, but that did not rise to the level of a Causal Factor.

1. Introduction

On August 6, 2012 at approximately 1548 hours, a leak was discovered by an operator in an 8-inch diameter pipe carrying light gas oil (LGO) in the 4 Crude Unit (4CU) at the Chevron U.S.A. Inc. (CUSA) Refinery in Richmond, California (Refinery). At approximately 1830 hours, the hydrocarbon release from the pipe resulted in the formation of a white cloud, a subsequent fire, and a black smoke plume (collectively, the Incident). A shelter-in-place order was issued for the cities of Richmond, San Pablo, and North Richmond, which advised residents to remain indoors until the fire was controlled. The CUSA Fire Department (CFD), with assistance from Petrochemical Mutual Aid Organization and Municipal Mutual Aid, brought the fire under control and the shelter-in-place was lifted at 2312 hours on the same day. Six responders were treated for first-aid injuries (Appendix 1). The 4CU and a cooling tower sustained damage. The general location of the Incident is shown in Figure 1.

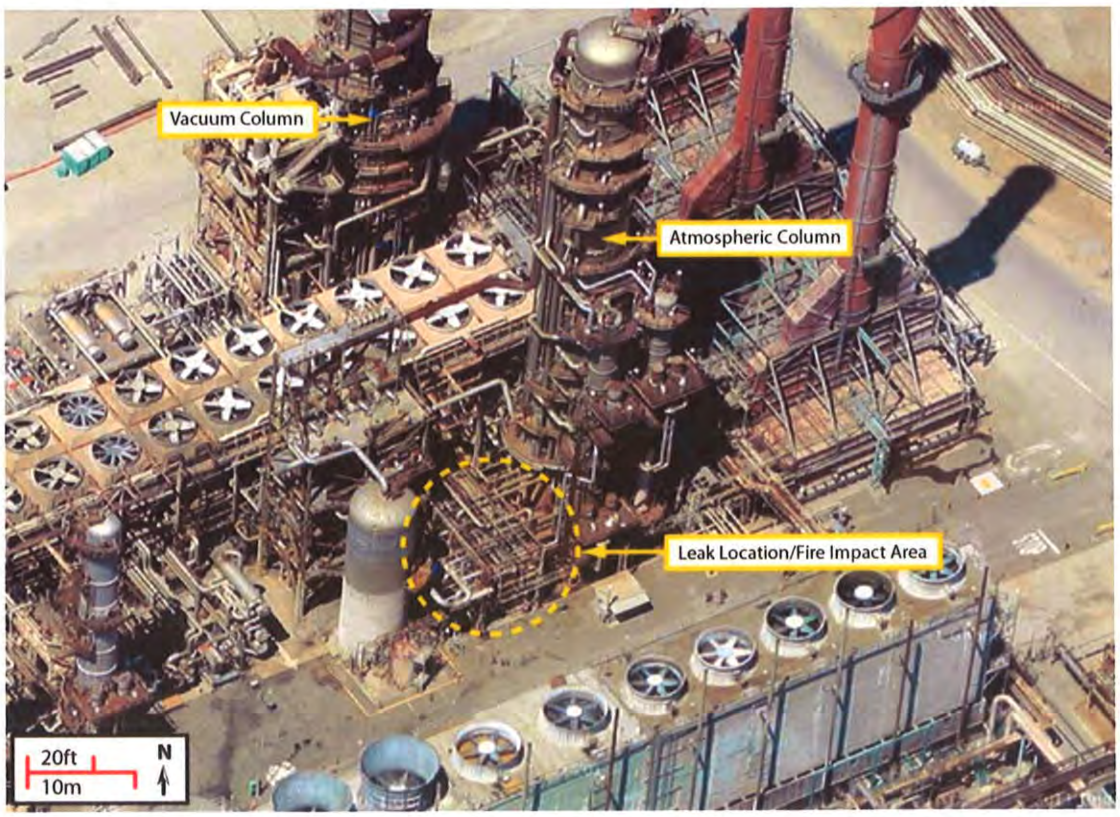


Figure 1. Overhead view of the 4CU prior to the Incident with the location of the rupture circled in yellow (image from Google Maps®).

CUSA formed an investigation team of selected CUSA personnel, both from the Richmond Refinery and elsewhere in the corporation, and outside technical consultants to investigate the Incident (Investigation Team). The charter of the Investigation Team was to establish a timeline of the events leading to the Incident until the Community Warning System (CWS) was activated, to determine the causes of the Incident and make recommendations to prevent a recurrence. The Investigation Team met on August 7, 2012 and began the investigation. The Investigation Team immediately began gathering historical information and data, interviewing relevant personnel, and collecting samples.

Numerous federal, state, and local government agencies also responded to the Incident, including the U.S. Chemical Safety and Hazard Investigation Board (CSB), U.S. Environmental Protection Agency (EPA), California Department of Industrial Relations-Division of Occupational Safety and Health (Cal/OSHA), Bay Area Air Quality Management District, and Contra Costa Health Services (CCHS). Following the fire, Cal/OSHA issued a preservation order and an order prohibiting use related to the immediate fire-damaged area of the 4CU due to concerns over the integrity of various overhead structures. In addition, the CSB and Cal/OSHA requested that all evidence be preserved in its as-found condition. An agreed upon third-party consultant (BakerRisk) assisted with evidence collection, documentation, and storage. After the Investigation Team and other interested parties visually inspected the ruptured 4SC pipe, it was removed and taken into evidence by BakerRisk and transported to Anamet, Inc. (Anamet), an outside laboratory in Hayward, California for subsequent testing and analysis, which the Investigation Team observed.

The Investigation Team also performed literature and standards reviews, analytical calculations, computational simulations, and experiments to gather additional information. The Investigation Team performed detailed technical analyses on the gathered information to determine the causes of the Incident. In performing the analyses, the Investigation Team employed various techniques based on the scientific method, including the TapRooT® root cause analysis method, which is a structured technique that facilitates the identification of Causal Factors and Additional Considerations, all of which are identified in the body of the report and discussed in more detail in Section 6 and Section □.

This report summarizes the findings and recommendations of the Investigation Team. The purpose of these findings and recommendations is to assist CUSA in understanding the causes of the Incident to prevent a recurrence. The consideration of off-site impacts was beyond the scope of this investigation.[3]

1.1 4CU Process Description and 4SC Design

The 4CU distills crude oil to produce various product streams (sidecuts or SCs), atmospheric overheads, and vacuum residuum. The crude oil is heated, desalted and split into different product streams, which then are sent to intermediate storage tanks or to downstream processing units as feed.

The 4CU was put into service in 1976. All crude oil processed in the Refinery passes through the 4CU, which has two distillation columns: (1) the Atmospheric Distillation Column (C-

[3] *See* the sixth "Update to the 30 Day Follow-Up Notification Report Form" for the CWS Level 3 Event of August 6, 2012, dated March 29, 2013.

1100), which is fed with heated crude oil; and (2) the Vacuum Column, which is fed with the heated bottoms stream from the C-1100. Figure 2 shows a simplified flow diagram for the 4CU.

The 4SC and the Atmospheric Bottom Circulating Reflux (ABCR) are drawn via a 20-inch nozzle from the C-1100 (Figure 3). The piping branches to a 12-inch ABCR pipe and a separate 8-inch 4SC pipe. Post-Incident inspection showed that there were 67 components, including straight pipe and fittings (elbows, tees, flanges, etc.) in the 4SC piping between the piping branch and the 4SC stripper pumps.

All of the 4SC and the ABCR piping was specified as carbon steel piping with Schedule 40 thickness for sizes 6-inch to 16-inch. In the past, the industry followed carbon steel piping specifications in ASTM International (ASTM) A53, which did not include minimum silicon content.

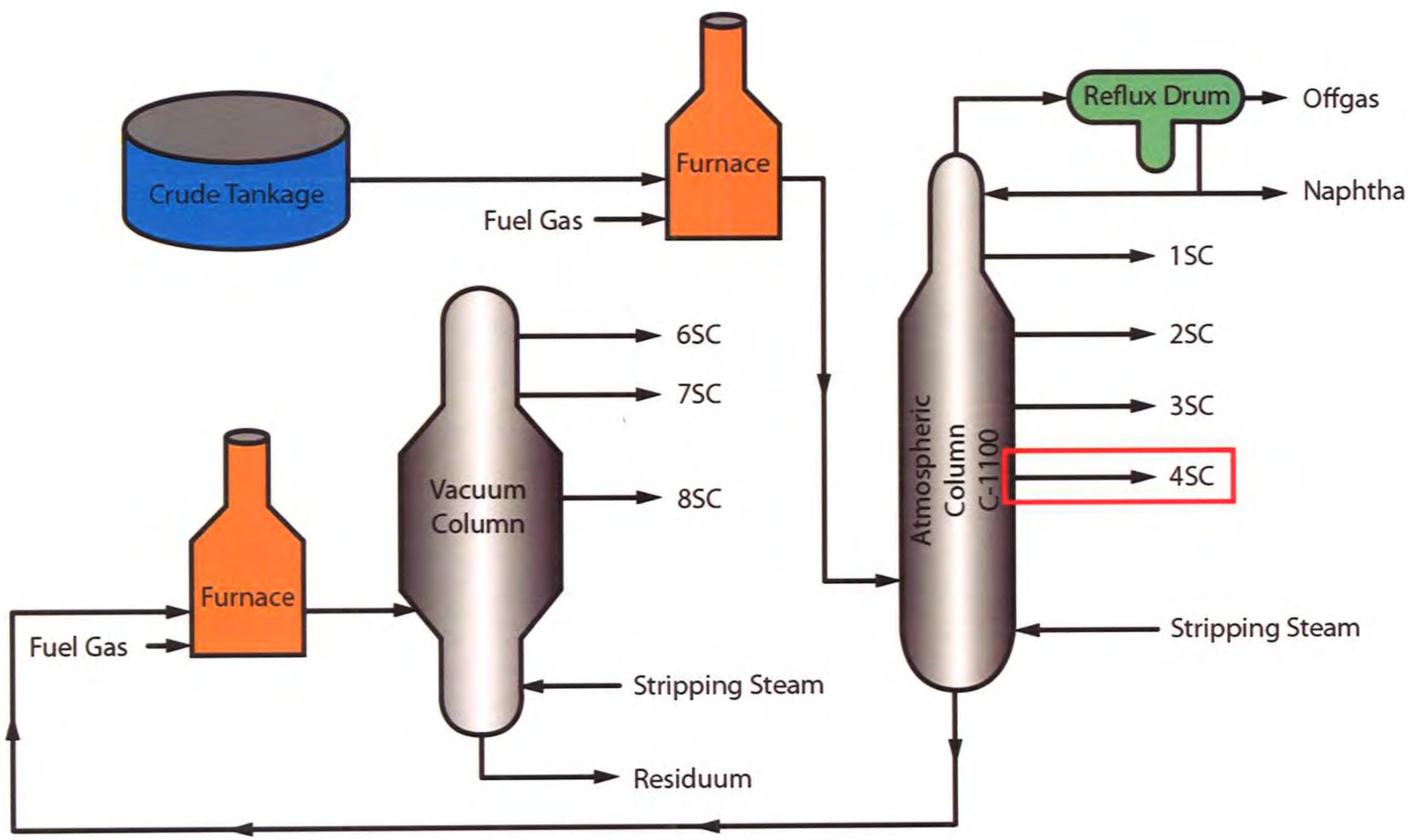


Figure 2. Simplified 4CU flow diagram. The failure occurred in the 4SC piping of the C-1100 (marked in red).

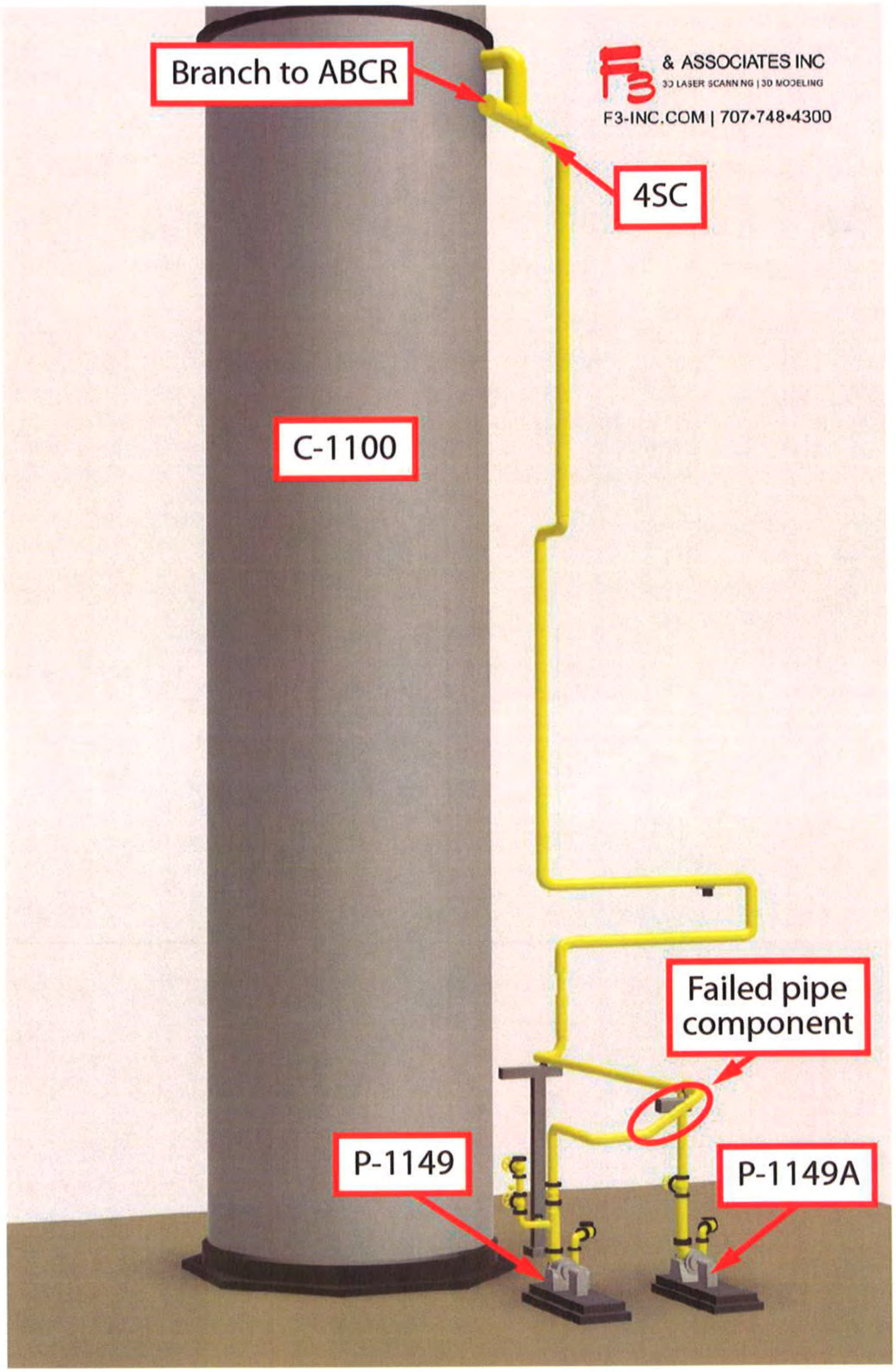


Figure 3. Three-dimensional model showing the 4SC and the ABCR drawn via a 20-inch nozzle from the C-1100. Note: the ABCR piping is not shown beyond the initial branch.

2. Incident Summary

This section provides an overview of the Incident and the response. A detailed timeline of events is attached as Appendix 2. The Incident began with the development of a small leak on the 4SC stream emanating from the C-1100. This initial, small leak was detected by a Plant Operator (PO1) at approximately 1548 hours on August 6, 2012. Prior to this time, the 4CU was in stable condition and running at approximately 250,000 barrels of feed per day.

2.1 Response to the Leak

At 1548 hours, the PO1 notified the Head Operator (HO1) and together they reportedly determined that the leak was coming from the insulated 8-inch suction piping to the 4SC stripper pump (P-1149) and its spare (P-1149A).[4] Figure 4 shows the relevant portion of the 4SC piping after the leak was discovered. The exact location of the leak was not visible due to the insulation and weather jacketing on the piping. When the leak was first discovered, the leak rate was estimated at 20-40 drips per minute.

The Shift Team Leader (STL1) was notified at 1553 hours and went to the 4CU. At 1602 hours, the CFD was also called and went to the 4CU with two monitor trucks and Engine Foam 60. Upon arrival, CFD personnel performed gas testing and determined that the atmosphere around the leak was not flammable based upon a Lower Explosive Limit (LEL) reading of 2%. CFD personnel completed a Scene Safety and Action Plan form, but they did not complete a Hazard Material Data Sheet for this leak as directed by the Scene Safety and Action Plan form. Based upon the perception that they were responding to a minor leak, CFD personnel positioned Engine Foam 60 close to the cooling tower. Responding CFD personnel did not consider the risk of pipe rupture or fire in the area when they positioned Engine Foam 60.

<u>Additional Consideration 1</u>: **The CFD did not complete a Hazard Material Data Sheet and positioned Engine Foam 60 too close to the leak source when responding to the Incident.**

At 1619 hours, Operations personnel reportedly confirmed that the leaking section of the 4SC could not be isolated on the upstream side.

<u>Additional Consideration 2</u>: **The leaking line could not be isolated on the upstream side to mitigate loss of containment.**

[4] Pumps P-1149 and P-1149A together are referred to as P-1149/A in this report.

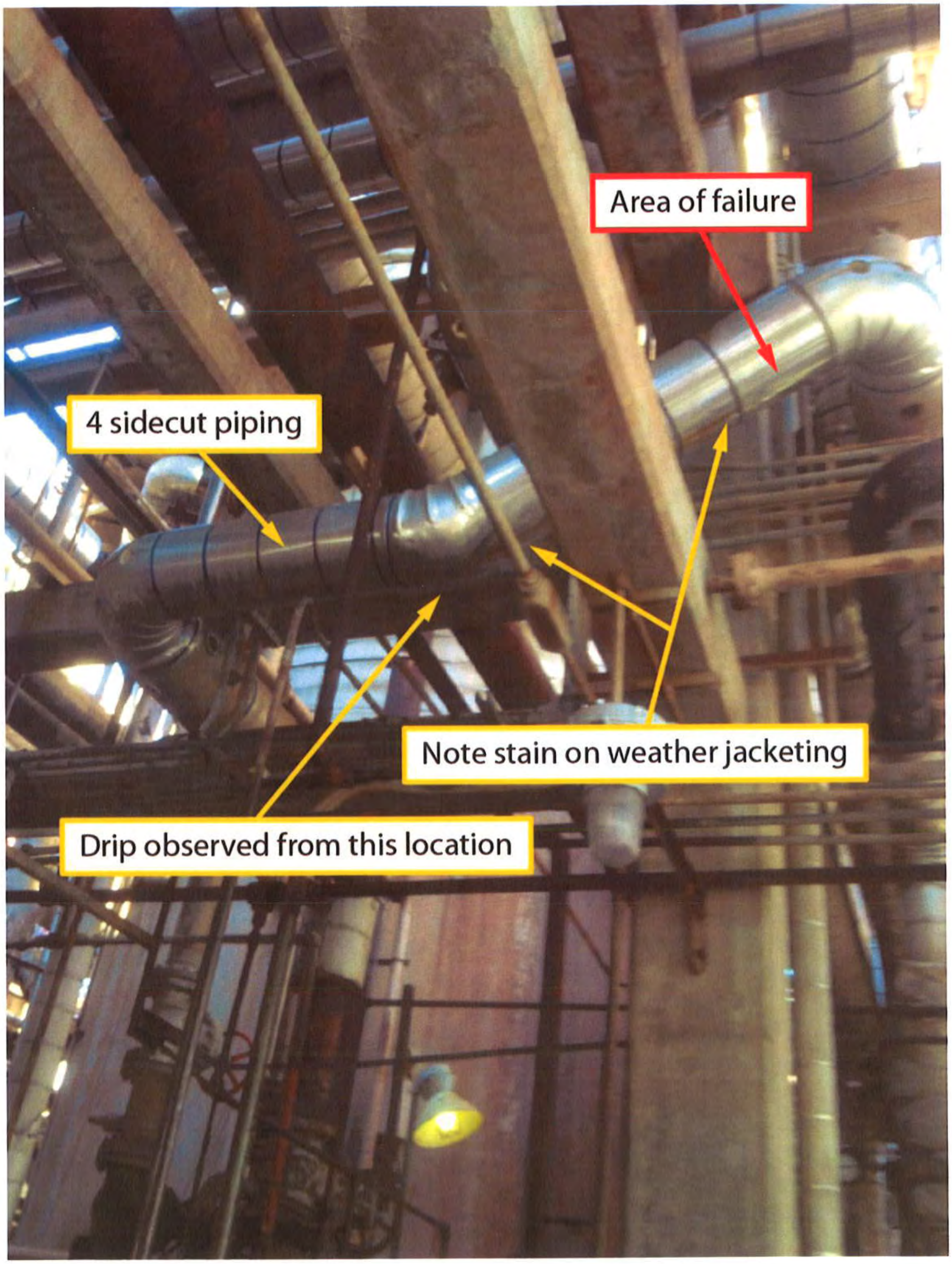


Figure 4. Photograph taken by STL2 during the initial response to the leak, but before the pipe rupture. The area where the rupture subsequently occurred (indicated by a red arrow) is approximately 16 feet from the ground.

2.2 Options to Address the Leak

Operations personnel consulted Maintenance, Reliability (Inspection), and Process Engineering personnel to assess options for addressing the leak. Because isolating the leak from the C-1100 was not possible, the assembled Operations and Operations Management personnel considered three options for addressing the leak: online repair potentially involving an engineered clamp, a routine shutdown, and an emergency shutdown. To further assess the online repair option, it was concluded that the weather jacketing and piping insulation needed to be removed so the leak could be visually assessed.

In the meantime, due to the inability to isolate the leak and the uncertainty about the option for online repair, Operations personnel directed a routine shutdown of the 4CU. At 1609 hours, the Control Board Operator (CBO) began reducing the 4CU feed rate per No. 4CU Shutdown procedure 4CUXN3000.[5]

Field personnel (Operations and the CFD) attempted to remove the insulation, starting downstream of the stained weather jacketing (Figure 5: top). From the ground, they attempted to grab onto and pull down the bands of the aluminum weather jacketing along the horizontal section of the pipe using a 10-foot fiberglass pike pole. However, due to the location and elevation of the horizontal section of pipe, approximately 13 feet above grade, this attempt was unsuccessful. The HO1, STL1, Battalion Chief (BC1), Operations Assistant (OA), and Section Head (SH) then developed a plan to remove the insulation, which involved erecting scaffolding below the leaking pipe to allow better access. This plan was communicated separately to both the Refinery Shift Leader (RSL) and to the acting Operations Manager sometime between 1630 to 1700 hours.

After addressing specific staging requirements—such as two points of egress—the scaffold contractor completed a hazard assessment form, which included personal protective equipment (PPE) requirements. In addition, the requirements for CFD monitoring and backup during the work were discussed before the scaffold builders began their work. Planning and erection of the scaffolding reportedly took approximately one hour to accomplish.

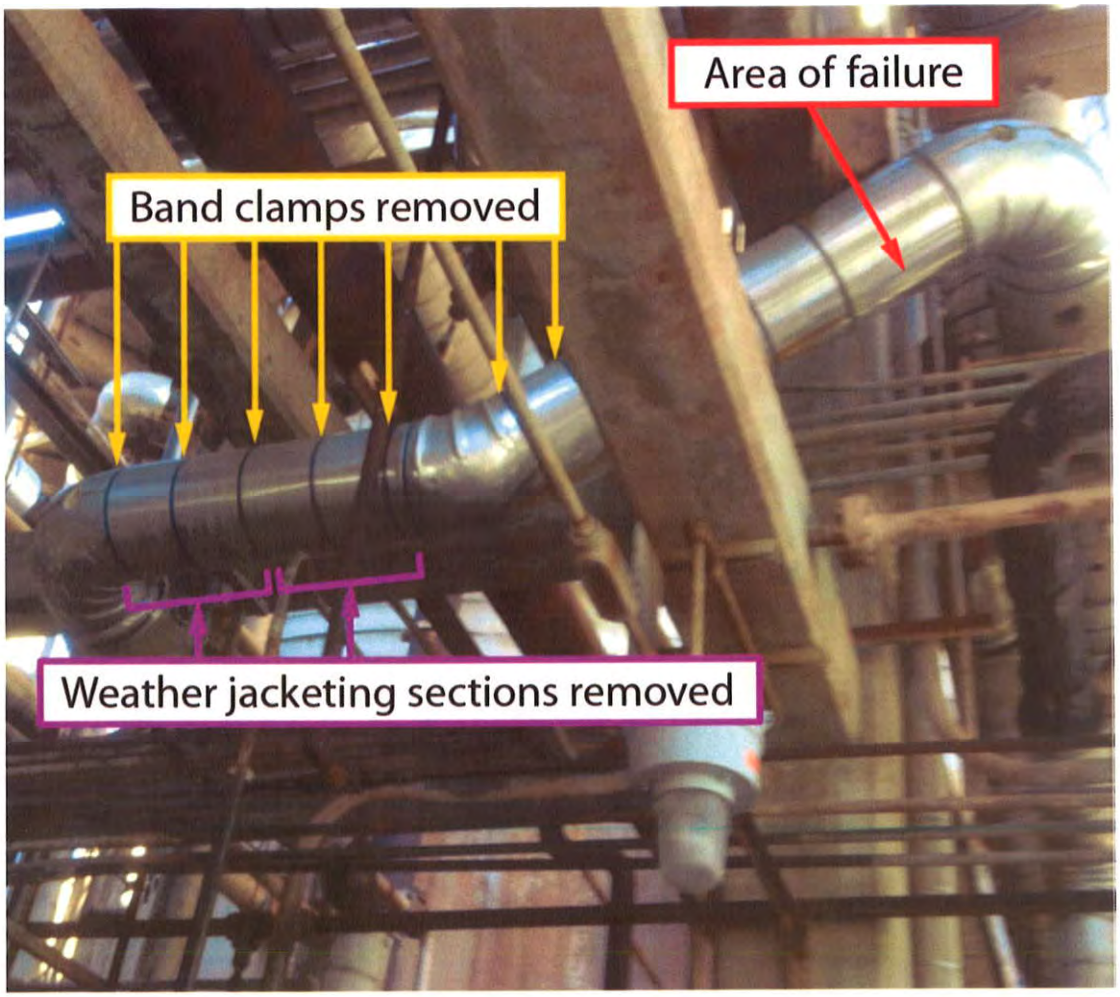
While the scaffolding was being erected, CFD and Operations personnel developed a plan for removing the weather jacketing and insulation from the leaking pipe. The plan called for two firefighters to climb the scaffold and use hand tools to first remove the weather jacketing and then the underlying insulation. Figure 5 (top) shows the band clamps that were cut with pliers, the area where the weather jacketing was removed, and the location of the failed pipe component.

As a standard precaution against a flash fire resulting from exposing oil-soaked insulation to the air, the insulation removal team wore full PPE (e.g. turnouts, self-contained breathing apparatus [SCBA], etc.) and two 1½-inch hose teams were on standby. Firefighters also performed

[5] A routine shutdown of the 4CU involves feed rate reductions of approximately 5,000 barrels per day every 30 minutes, with proportionate reductions in the sidecut draw rates. After a feed rate of 110,000 barrels per day is reached, the furnace temperatures and C-1100 overhead pressure are reduced. Vessels and lines are flushed with wash oil, water washed, and then steamed out. A routine shutdown of the 4CU takes roughly three days.

continuous air monitoring of the area to confirm that conditions did not change. While Operations understood that the 4SC stream was near its auto-ignition temperature, some CFD personnel thought the temperature of the 4SC stream was near or below its flash point.[6]

[6] The material safety data sheet (MSDS) for LGO indicates a flash point of less than 200°F and an auto-ignition temperature of 640°F. A thermocouple upstream of the failure location indicated temperatures between 614°F and 630°F during the period between initial discovery and escalation of the leak.



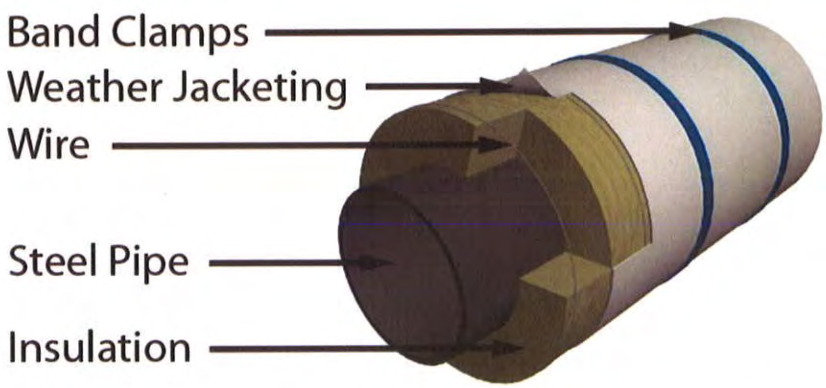


Figure 5. The steel pipe was encapsulated by insulation held in place by wire, which was covered by aluminum weather jacketing held in place with band clamps (bottom). The firefighters cut several band clamps (marked with yellow arrows) with pliers and removed two sections of the weather jacketing from the piping (marked with purple brackets).

During the erection of the scaffolding, multiple field turnovers were performed at approximately 1700 hours between the outgoing and oncoming Operations and CFD crews. Most of the dayshift personnel remained to assist if needed. Due to the shift change, personnel from the oncoming crews supported and performed the insulation removal tasks. There was not a single meeting where all parties could collectively consider the potential risks and outcomes. In addition, with the benefit of hindsight, the lack of full recognition of the risk of piping rupture led to a large number of personnel being present at the Incident location.

<u>Causal Factor 1</u>: The response and assessment after the discovery of the leak did not fully recognize the risk of piping rupture and the possibility of auto-ignition.

2.3 Initial Flash Fire

Two firefighters reportedly cut the bands holding the weather jacketing in place on the horizontal piping and the first two bands on the sloping pipe above the elbow (Figure 5: top). They then began to remove the weather jacketing on the horizontal portion of the pipe.

When the second sheet of weather jacketing was removed, a small flash fire ignited at 1822 hours. This fire was quickly extinguished by the supporting hose teams. In response to the flash fire, the firefighters descended the scaffolding, leaving the oil-soaked insulation in place.[7] These firefighters were then instructed to set up and start a portable monitor (Blitz) for additional firewater coverage.

CFD hose teams maintained a stream of water on the piping insulation that had ignited, switching from power cone to straight stream nozzle patterns in order to knock away the oil-soaked insulation from the piping where the weather jacketing had been removed. After briefly shutting the water off to assess the insulation removal, the firefighters observed that the volume of material from the leak was increasing and that the released material was beginning to smoke.

At this point (1827 hours), the HO2 gave the order for an emergency shutdown of the 4CU and supporting field personnel began to move out of the area. A radio transmission instructed the CBO to "start making preparations to bring this plant down." Additionally, at 1828 hours, the RSL was informed that the 4CU was being shut down. At 1829 hours, the CBO activated the hand switches for an emergency shutdown of the 4CU.

2.4 White Cloud and Fire

At approximately 1830 hours, the leak rapidly worsened, as confirmed by a radio transmission and video footage (Figure 6). As a result, a large white cloud formed and quickly enveloped the 4CU and downwind processing plants. Consequently, the CFD hose teams shut off the hose nozzles and withdrew from the area. Water application via the portable Blitz monitor continued and water flow from Engine Foam 60's deck monitor was activated and directed toward the general area of the leak.

[7] As shown in Figure 5, wire was used to hold the insulation in place during its installation and remained after the weather jacketing was removed on the day of the Incident. The wire would need to be cut to fully remove the insulation.

A fire ignited approximately 2 minutes and 30 seconds after the leak escalated, resulting in the formation of a black smoke plume[8] (Figure 6: bottom). Multiple personnel told the Investigation Team that they saw flames originating near the location of the ruptured pipe component. At the time the fire ignited, the weather conditions were clear, with the temperature recorded at 75°F and 11.5 mph winds coming out of the southeast (134°).

Following ignition, witnesses in the vicinity reported hearing several "popping" sounds at the location of the Incident. The Investigation Team cannot be certain of the cause of the sounds, but likely possibilities include: the lifting of one or more pressure safety valves; the rupture of fire-impacted piping; the rupture of a gas cylinder; the rupture of tires from Engine Foam 60; or arcing in the Motor Control Center (MCC).

After the fire was brought under control at 2215 hours on August 6, 2012, CUSA's Emergency Services Manager recommended to CCHS that it cancel the shelter-in-place order and deactivate the Warning Sirens. CCHS lifted the shelter-in-place order at 2312 hours that day.

[8] CUSA has reported separately on the black smoke plume in the sixth "Update to the 30 Day Follow-Up Notification Report Form" for CCHS (Appendix 1).

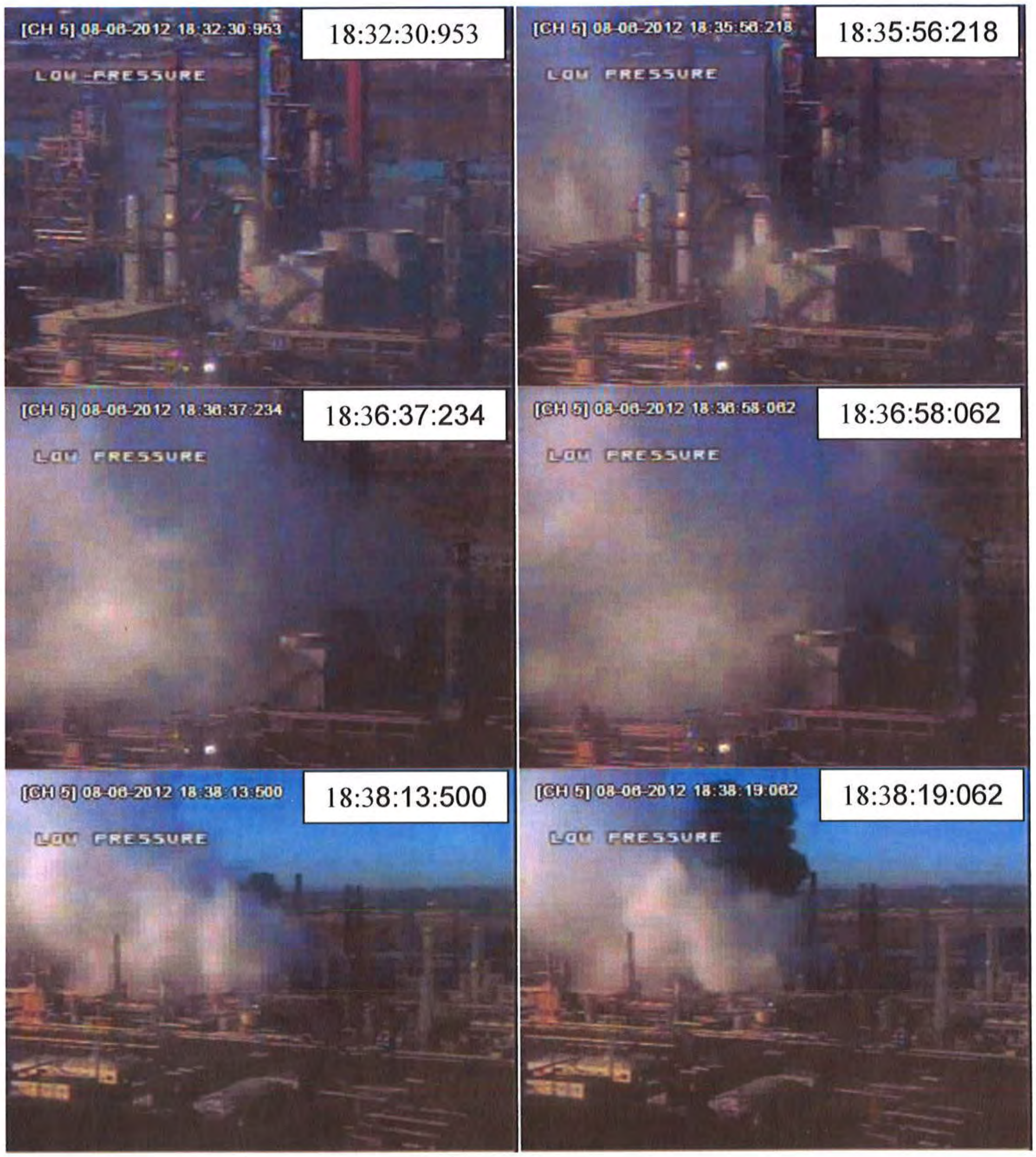


Figure 6. CUSA surveillance camera showing the 4CU (top left). A white cloud is shown forming (top-right and middle-right/left) for approximately 2 minutes and 30 seconds after the leak escalated and before the fire ignited (bottom, camera had been zoomed out). (The clock in these images is approximately 5-7 minutes ahead of actual time.)

3. Analysis of the Pipe and the White Cloud

The Investigation Team concluded that the 4SC pipe component failed due to thinning caused by sulfidation corrosion that was accelerated by the lower silicon content of the failed pipe component.

This section describes the details of the mechanism of sulfidation corrosion and the factors that affect the rate of sulfidation corrosion. This section also provides a summary of analyses performed by the Investigation Team to evaluate the properties of the ensuing white cloud and a discussion of plausible ignition mechanisms that initiated the fire.

3.1 Sulfidation Corrosion of Carbon Steel

While sulfidation corrosion for a given alloy is generally dependent on the temperature and sulfur content of the product stream, the sulfidation corrosion rate for carbon steel is highly dependent on the steel's silicon content. Carbon steel with a silicon content of less than 0.10 weight percent (wt%) can exhibit higher sulfidation corrosion rates than carbon steel with higher levels of silicon. This can result in wide variations in corrosion rates in a single carbon steel piping system composed of individual components with different silicon contents even if the components are exposed to the same process conditions.[9]

At the time of the Incident, the temperature of the 4SC was around 620°F and the historic data shows that the LGO within the 4SC contained between 0.8 and 1.6 wt% sulfur. Although the operating temperature and sulfur could have increased the corrosion rate of the piping, the historical recorded measurements at the corrosion monitoring locations (CMLs) did not show significant changes in wall thickness until 2002 (see Section 4).

[9] As noted earlier in this report, in the past, the refining industry used carbon steel piping specifications that did not include minimum silicon content (ASTM A53). Since late 2009, CUSA has used specifications that require a minimum silicon content of 0.10 wt% as specified in ASTM A106.

3.2 Evidence of Sulfidation Corrosion in the Ruptured Pipe

The ruptured pipe is shown in Figure 7 and Figure 8.

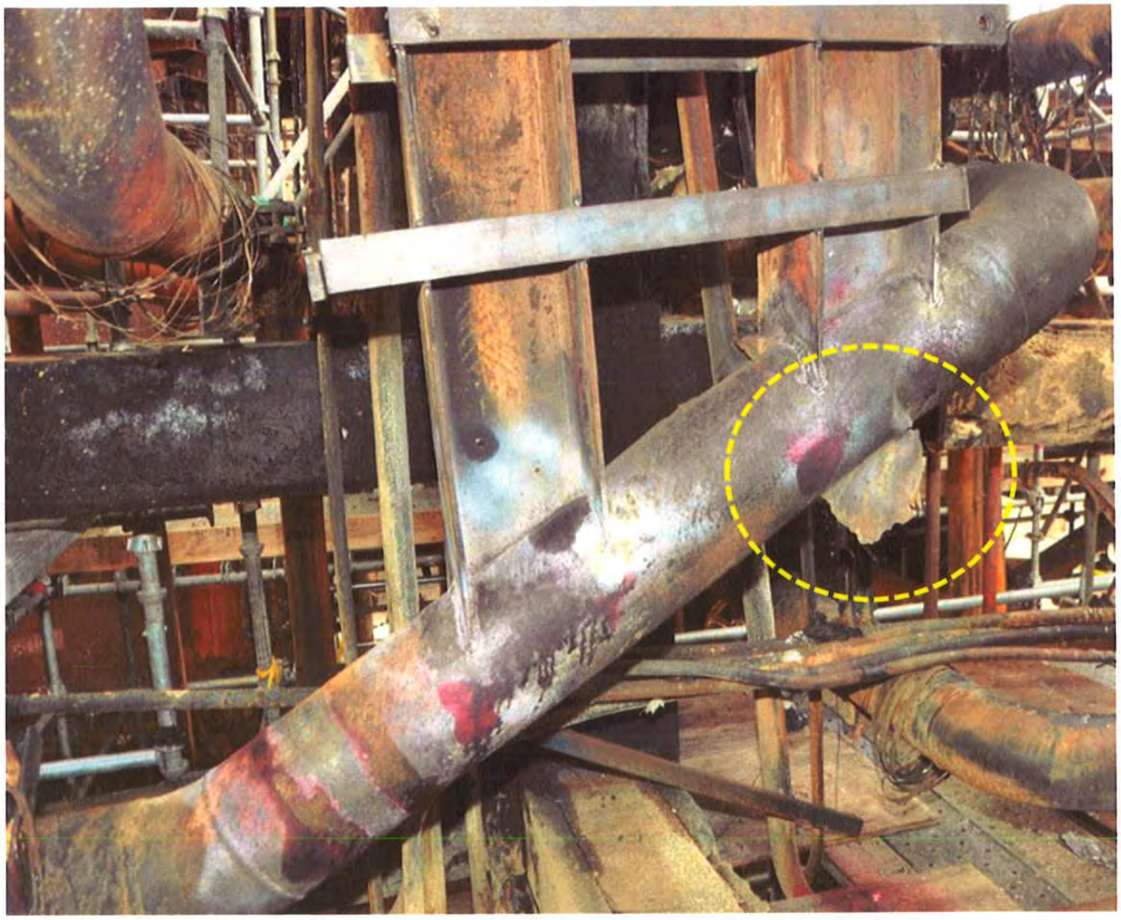


Figure 7. Photograph of the ruptured pipe component during inspection prior to removal. Area of the rupture is circled in yellow. (This photograph shows the same sloped portion of the pipe component shown in Figure 5.)

Figure 8. Close-up photograph of the ruptured pipe component taken during the inspection prior to removal.

During the laboratory analysis at Anamet, thickness measurements were taken on the ruptured pipe component on a grid layout, as shown in Figure 9. Virtually the entire 27-inch circumference and 44-inch length of the ruptured pipe component had thinned to less than 0.10 inches, with only a few readings in the vicinity of the welded pipe guide attachments showing higher values.[10] An ASME Code B31.3[11] analysis conducted by the Investigation Team determined that, in the area where the 4SC pipe ruptured, the minimum wall thickness required for containment is approximately 0.072 inches. The measured wall thicknesses of the ruptured pipe component were less than 0.072 inches (Figure 9).

In addition, many tiny perforations were visible at or near the main fracture surfaces. Several such perforations in one of the metal flaps are shown in Figure 10. It is likely that the source of the initial leak, shown in Figure 4, was these tiny holes, which grew and multiplied during the Incident, causing the leak to worsen. Eventually, cracks or tears linked the perforations,

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[10] The guides serve as heat sinks, lowering the local temperature of the pipe and, therefore, the rate of corrosion.

[11] *Process Piping: ASME Code for Pressure Piping, B31.* American Society of Mechanical Engineers, ASME B31.3, New York, 2008.

resulting in rupture. The corrosion pattern observed is considered "uniform thinning," and is consistent with sulfidation corrosion.

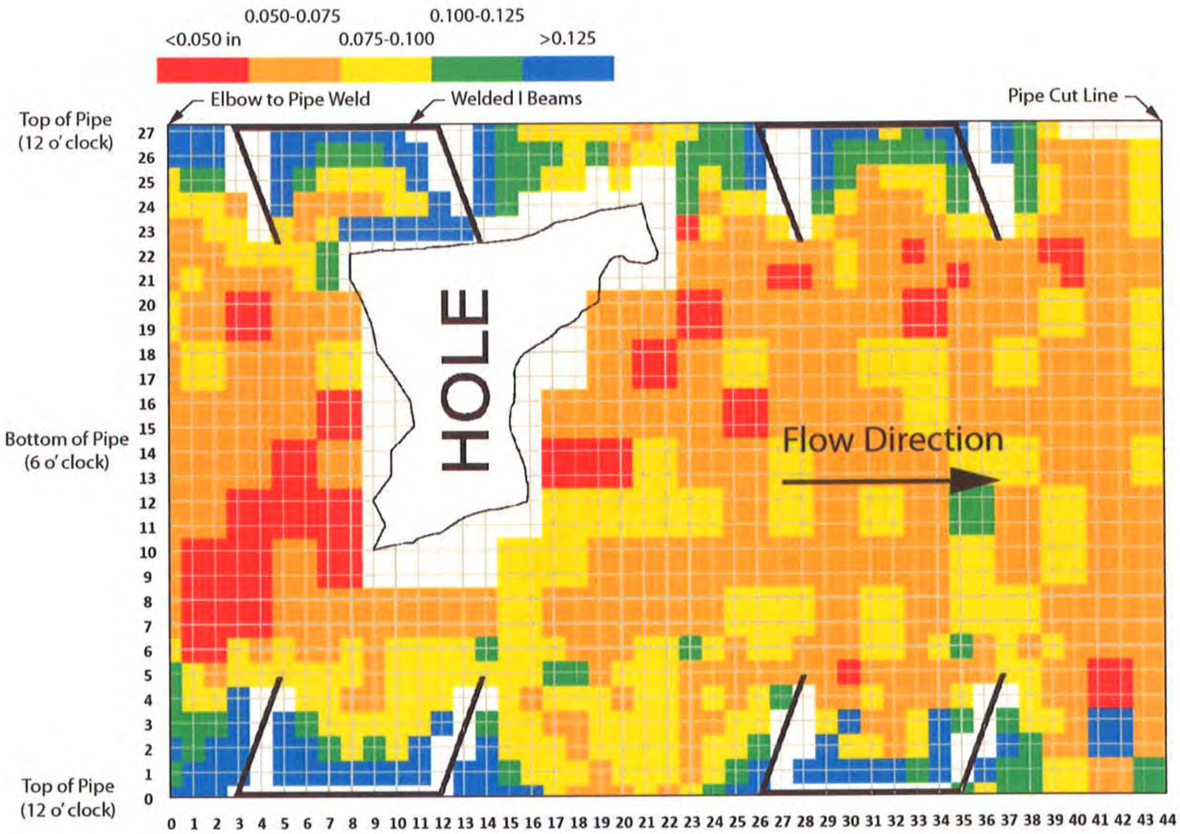

Figure 9. Thickness measurement results from the ruptured pipe component. Virtually the entire 27-inch circumference and 44-inch length of the ruptured pipe component had thinned to less than 0.10 inches, consistent with sulfidation corrosion. The graphic represents the pipe as sliced longitudinally at the top of the pipe (12 o'clock) and rolled out flat. The areas in white could not be measured.

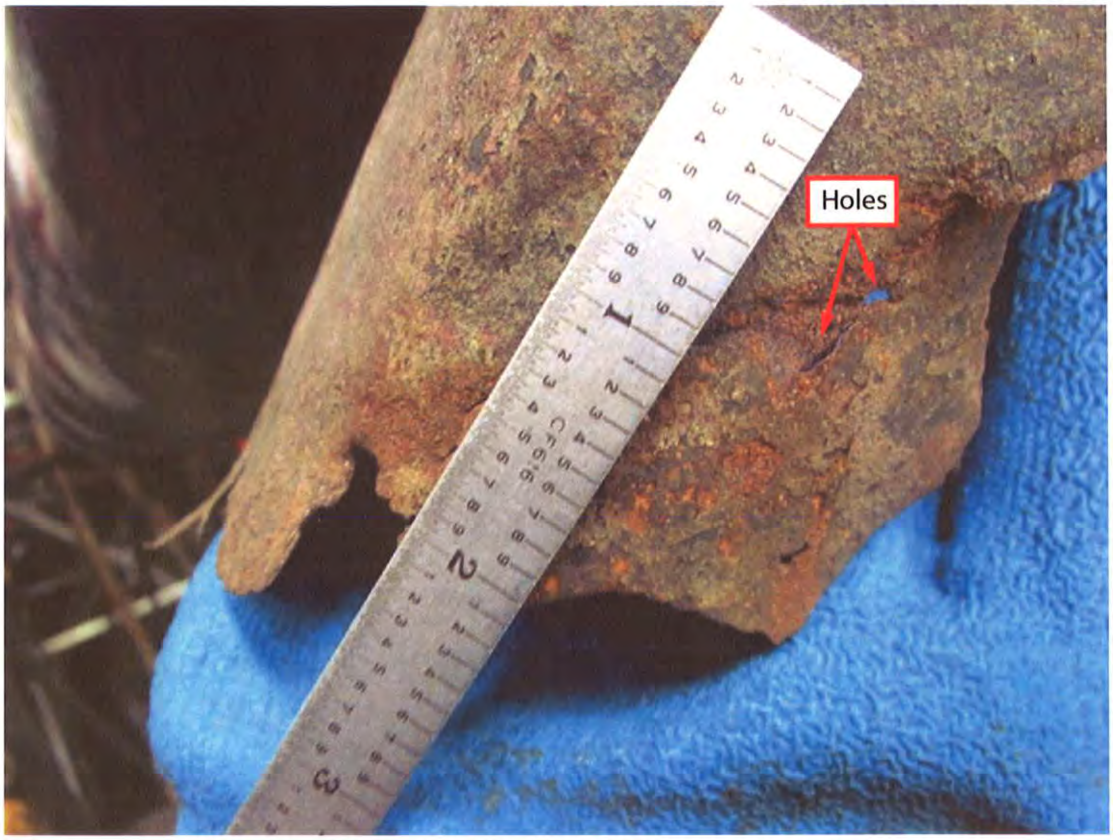

Figure 10. Photograph of one of the metal flaps associated with the 4SC rupture. Small perforations are visible in the flap.

Figure 11 shows a cross section of the ruptured pipe, the adjacent elbow, and the weld between the two. Figure 12 shows the location where the sectioned sample was removed from the ruptured pipe. The ruptured component is clearly thinner than the adjacent elbow. The results of the chemical analysis indicate that the ruptured pipe component had a silicon content of approximately 0.01 wt% and the adjacent elbow had a silicon content of 0.16 wt%. As noted earlier, carbon steel with less than 0.10 wt% silicon content can exhibit higher sulfidation corrosion rates than carbon steel with higher levels of silicon. The impact of these differing corrosion rates is discussed in Section 4.

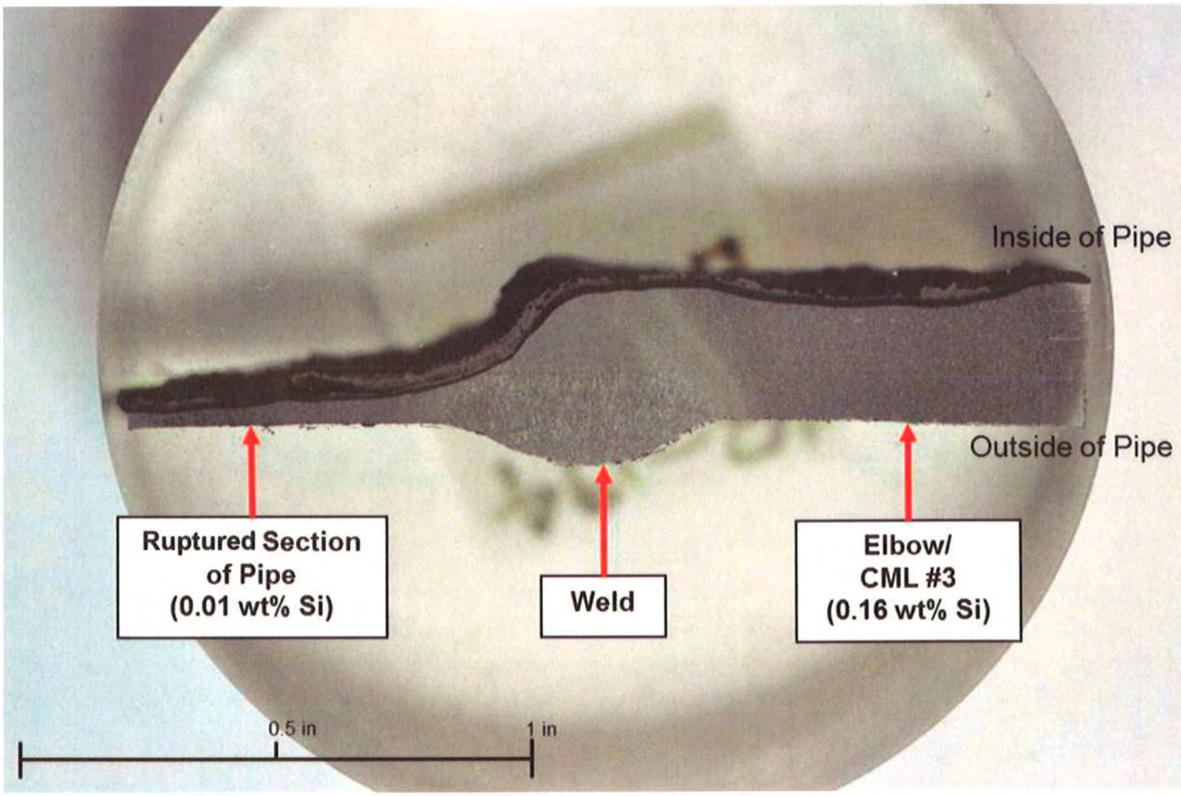

Figure 11. Cross section through the weld of the subject pipe showing thicknesses of the ruptured section (left) and the adjacent elbow, where CML #3 is located.

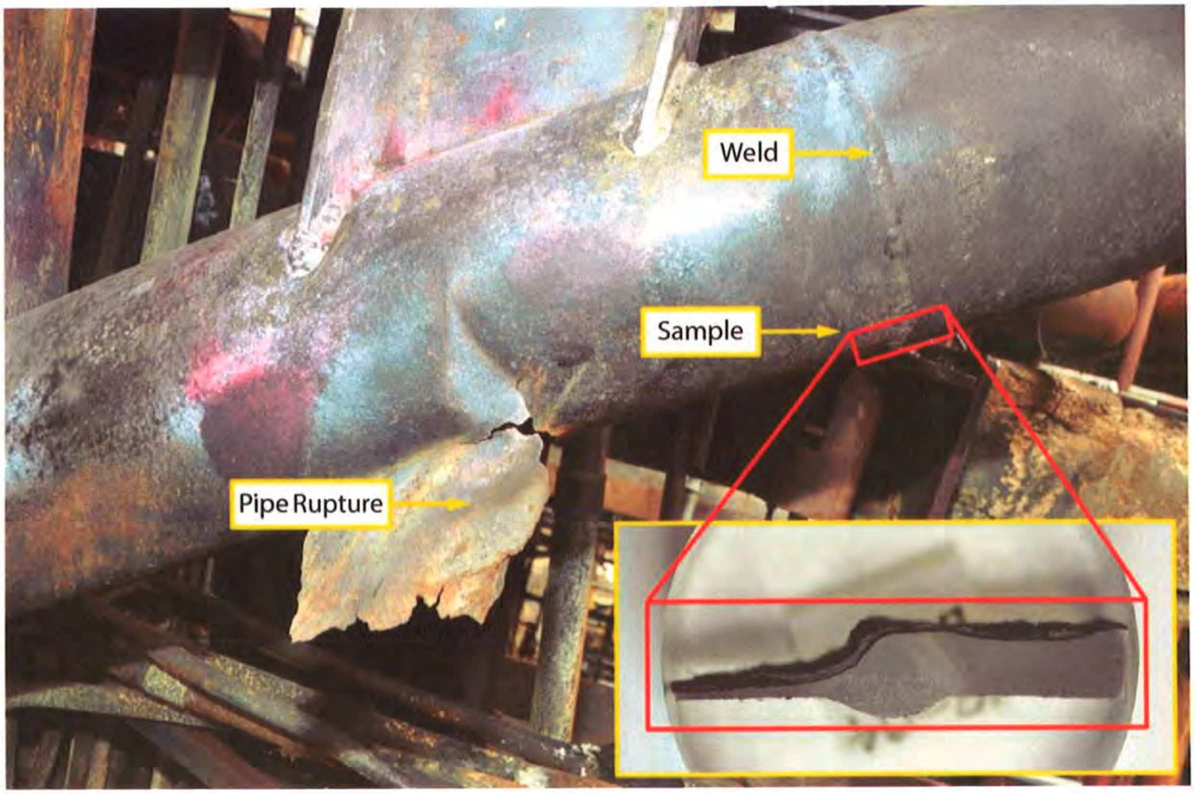

Figure 12. Image showing the location where the sectioned sample was removed from the ruptured pipe component.

Scale samples were scraped from the interior surface of each of the ten pipe components removed from non-failed portions of the 4SC and the ABCR piping systems (five from each system), and analyzed visually, and using X-ray diffraction, X-ray spectroscopy, and metallography. The results showed that all samples primarily contained iron sulfides, while three contained minor phases of iron oxides. The presence of iron sulfides is consistent with sulfidation corrosion. It has also been established that iron sulfides can be converted into oxides in the presence of air and moisture. This could account for the minor oxide phases.

The general thinning and scale measurements indicate sulfidation corrosion. The chemical analysis confirms that the ruptured pipe component corroded faster than surrounding components because of its low silicon content. None of the other data reported by Anamet contradicts this conclusion.

3.3 Leak Escalation

As discussed in Section 2.3, the rate of material flowing from the leak increased during the insulation removal activities. Given the previously identified generalized thinning of the failed pipe component, it is possible that external forces during these activities contributed to the increased leak rate by causing tearing or crack growth within the thinned carbon steel, or the expansion/linking of the small perforations that were already leaking. These external forces may have included: forces applied during weather jacketing removal, forces due to the straight stream firewater contacting the insulation and pipe, or the force from tool impact. Anamet concluded that certain physical evidence suggests that there may have been contact between the tip of a pike pole and the failed piping component. None of the witnesses interviewed by the Investigation Team, however, stated that there was contact with the insulation-covered sloping section of pipe, which includes the area of failure, after the flash fire. One witness recalled that a pike pole was used after the flash fire in an attempt to dislodge insulation from the elbow area, but this location was several feet away from the area where Anamet suggests pike tip impact may have occurred.

3.4 White Cloud Formation and Properties

A large white cloud formed after the rapid escalation of the leak. In order to better understand the potential consequences of the release (e.g., flammability/ignitability) and the impact to those exposed to the white cloud, an analysis of the white cloud was performed. In conducting this analysis, the Investigation Team was purposely conservative in its assumptions (e.g., in estimating the initial flow rate of hydrocarbons at the time of initial cloud formation). These worst case assumptions likely overestimate the amount and concentration of hydrocarbons actually present in the white cloud.

The leak rate at the time of the initial formation of the white cloud was estimated in order to understand the composition, size, flammability properties, and health effects of this cloud. The analysis utilizing the actual hydrocarbon properties, the measured hole geometry, and the measured pipe surface roughness predicts that the initial flow through the ruptured pipe component after the white cloud began to form was approximately 19,000 lb/min (144 kg/s).

3.4.1 Composition, Properties, and Size of the White Cloud

Just after ignition, a freelance photographer at Pier 39 in San Francisco and video footage shot from Marine View Avenue in Point Richmond captured the white cloud. Analysis was performed to estimate the size of the white cloud at the time witnesses reported the fire started. The largest dimensions of the white cloud were approximately 1,100 feet wide (in the east-west direction) and approximately 1,200 feet high, as shown in Figure 13.

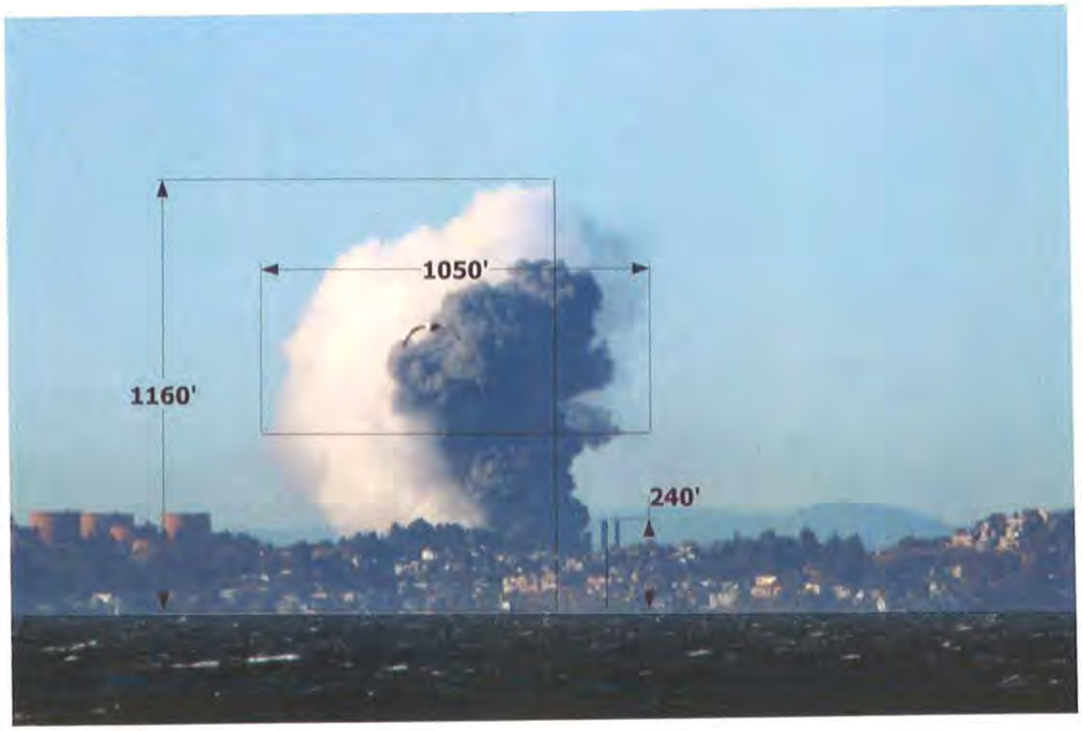

Figure 13. Estimated size of the white cloud utilizing a photograph taken at Pier 39 in San Francisco. The 240 foot dimension shows the height of the 4CU furnace stacks.

The white cloud that formed prior to ignition of the fire consisted of air mixed with vapor and droplets of both hydrocarbons and water. Initially, the composition of the release was LGO. As the leak progressed, the boiling point of the released material decreased and approximated the combination of the 1SC, the 2SC, the 3SC, and the 4SC.

As the hot LGO exited the pipe, approximately 20% (by mass) flashed to vapor and mixed with air. Prior to and during escalation of the release rate, the CFD applied water to the rupture location. Some of the firefighting water contacted the released hot liquid and other hot surfaces. The mixing of cold water and hot surfaces and liquids vaporized a fraction of the water, which then mixed with air. As the mixture of air, water vapor, and LGO vapor cooled, some of the water and LGO vapor condensed, forming a fine mist/fog that appeared as a white cloud.

White clouds can be formed by heating hydrocarbon oils sufficiently to form vapor and then rapidly cooling the vapor by mixing it with air. These white clouds, also known as "fog oil" or "smoke screen," consist of small droplets (~1 micron diameter) of condensed oil. Fog oils are stable and can persist for long periods in the atmosphere. The properties of some hydrocarbon oils used in smoke generators[12] are similar to the properties of the fluid in the 4SC (LGO). The process of creating smoke screens is similar to what occurred when the 4SC piping ruptured.

[12] Smoke generators are used by the military to screen or obscure troop movements.

3.4.2 Flammability of the White Cloud

Adding inert diluting agents, such as water vapor/droplets, can decrease the ignition hazards of fuel-air mixtures. The amount of diluent (e.g. water vapor, carbon dioxide) required to inert mixtures is equivalent or less for mists as compared to vapors of the same material.

Incident site inspections, witness observations, and video footage show that the vast majority of the white cloud did not ignite. According to witnesses, ignition occurred near the pipe rupture, resulting in a black smoke plume. A clear demarcation was observed between the black smoke plume and the white cloud, as shown in Figure 14. Flames were visible in the video footage, providing a competent ignition source for the white cloud. However, the white cloud persisted for several minutes in the immediate vicinity of the black smoke plume even after the ignition. No flames were observed propagating through the white cloud and no signs of overpressure were observed.

The literature review and analysis also supports the observation that the white cloud could not explode. The literature suggests that even an optically dense and opaque fog/mist is substantially below the lower flammability limit (LFL). Analysis of the size of the cloud, the release rate from the ruptured pipe, and the flammability limits of LGO show that the amount of LGO that leaked through the ruptured pipe component was orders of magnitude below the amount required to form a flammable mixture in the entirety of the cloud. Furthermore, fire water was added to the region of the rupture prior to and during escalation of the material release rate. The water vapor and subsequent droplets that formed from the evaporating firewater reduced the ignition hazard of the fuel-air mixture that formed as a result of the leak. In addition, the white cloud drifted past Refinery furnaces without igniting.

Figure 14. Stills from video footage taken from Marine View Avenue in Point Richmond that shows the formation of the black plume shortly after ignition of the fire (top), and after continued burning (bottom).

3.4.3 Health Effects of the White Cloud

For personnel in the white cloud, the primary route of exposure would be through inhalation. Personnel in the immediate area did not cite symptoms associated with exposure to the white cloud. While approximately half of the people in the immediate vicinity of the white cloud were wearing SCBAs, there was no difference in health effects reported between the personnel who wore SCBAs and those who did not.

CUSA industrial hygienists and toxicologists assessed the potential health effects of the white cloud. The white cloud was a spatially- and temporally-varying mixture of air with vapor and droplets of both hydrocarbons and water. The properties of the hydrocarbons (LGO) are described in the Material Safety Data Sheet, which is attached as Appendix 3.

Short-term inhalation overexposure of LGO vapor/aerosol has the potential to produce respiratory irritation and depress the central nervous system. No such effects were reported.

On-site personnel were not exposed to the black smoke plume. As such, consideration of any health effects of the black smoke plume is beyond the scope of this investigation.

3.5 Ignition

The Investigation Team sought information from responding personnel, examined video footage to estimate the location of the ignition, and attempted to identify the ignition source for the fire. Numerous ignition sources and scenarios were considered as potential candidates and evaluated based on the physical evidence, data obtained, and observations of witnesses. Evaluated ignition sources included: the auto-ignition of materials flowing from the ruptured pipe, a failed light fixture, hot surface ignition, open flames, static electric discharge, Engine Foam 60 (diesel engine), the scaffolding contractor's truck (gasoline engine), and pyrophoric iron sulfide. While most of these ignition scenarios are unlikely based on the available information, two viable candidates remain, as summarized in the following sections.

3.5.1 Auto-Ignition

Auto-ignition is the process by which a fuel-air mixture ignites in the absence of an external ignition source due to its temperature. The temperature of the liquid and pipe at the time of leak discovery was reportedly near the auto-ignition temperature of the 4SC. The flash fire experienced during the removal of the second sheet of weather jacketing likely resulted from auto-ignition of hot hydrocarbon vapors mixing with air.

Following the flash fire and before the white cloud formed, an emergency shutdown of the 4CU was initiated. This includes cutting fuel to the furnaces (F-1100A and F-1100B), which substantially reduces the vapor formation and upward flow through the C-1100. This process is commonly referred to as "slumping" of the C-1100. Slumping causes liquid held in trays above the 4SC collection tray to flow downward to the 4SC collection tray and through the 4SC line.

The composition of the liquid flowing from the 4SC collection tray to the area of rupture changed as the 4SC liquid was depleted and the 3SC, 2SC, and 1SC materials flowed down to the 4SC collection tray through the 4SC line and the ruptured pipe. The 2 minute and 30 seconds delay between the formation of the white cloud and ignition of the fire is approximately the time required to deplete the 4SC material available in the C-1100.

The 4SC, 3SC, and 2SC materials have auto-ignition temperatures of 640°F, 494°F, and 410°F, respectively. The measured temperature of the material upstream of the rupture was approximately 620°F at the time of the ignition. The auto-ignition temperature of the material released likely decreased during the Incident as a result of its changing composition. Thus, auto-ignition of the leaking material remains a viable cause of the ignition.

3.5.2 Failed Light Fixture

A photo taken after the discovery of the leak (but prior to the erection of the scaffolding) shows two light fixtures in the immediate vicinity of the failed pipe, as shown in Figure 15. The light in the upper portion (foreground) of the photograph is not energized. This light is controlled by a photocell on the north side of the MCC located approximately 280 feet west of the failed pipe. After the Incident, the light fixture was missing, but the electrical conduit remained, as shown in Figure 15.

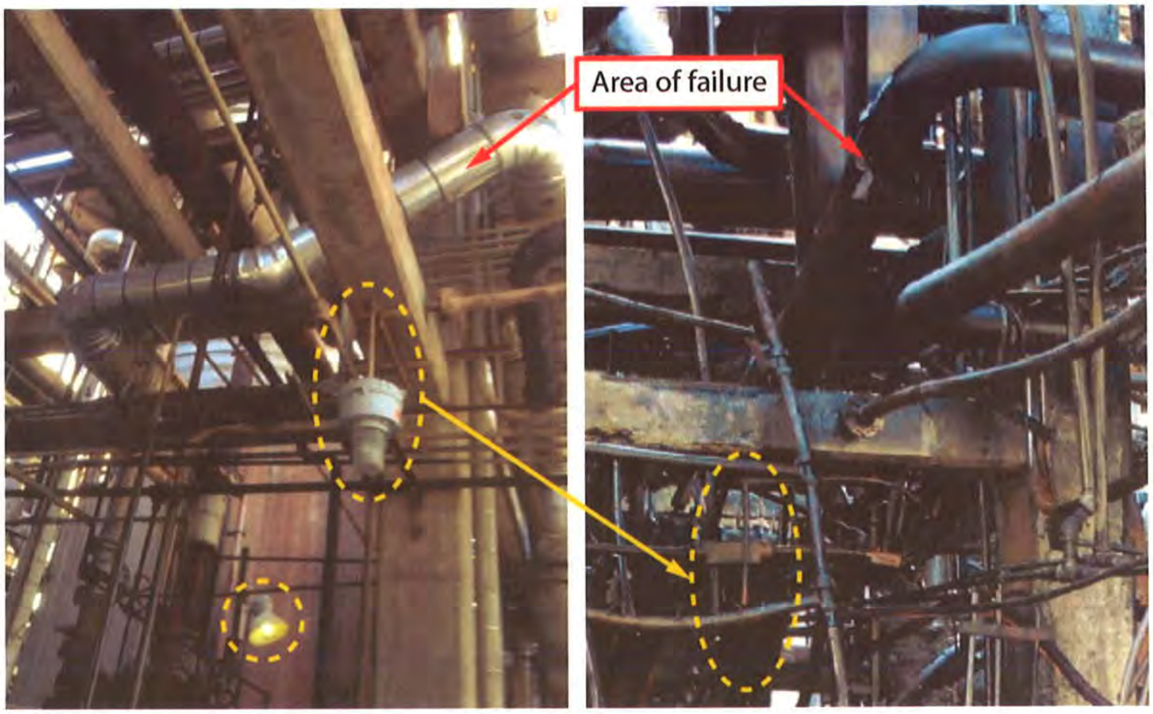

Figure 15. Lighting fixtures at the time the leak was discovered (photograph taken during the initial response) (left); and missing light after the Incident (right).

It is possible that the flow of hot liquid from the rupture location caused the lighting fixture to dislodge, exposing the wiring that provided power. After the white cloud formed and obscured the photo cell that controls the light, the lighting circuit may have energized. This photo cell was inspected and tested post-Incident. Testing showed that the photo cell activated at low light levels. With the circuit energized and wires exposed, this fixture could have provided an ignition source for the fire. This scenario also is possible if the bulb was burned out pre-Incident. Similarly, the photo shows the lower light fixture energized; this too could have provided an ignition source if the light fixture was dislodged by the flow of hot liquid.

4. 4SC Condition Monitoring History

This section briefly describes the corrosion management system and provides an overview of the inspections performed for reliability assessment of the 4SC piping.

4.1 Corrosion Management System

Equipment reliability is a key expectation of CUSA's Operational Excellence Management System. As a result, the term "Reliability" is often used interchangeably with "Mechanical Integrity," the more common process safety term.

The Reliability function is responsible for collecting information on the condition of equipment and for analyzing that information to confirm mechanical integrity and Fitness for Service. For a complex facility like the Richmond Refinery, this involves monitoring thousands of pieces of equipment and thousands of miles of piping. The condition of equipment is typically inspected using non-destructive testing and analyzed on a periodic basis corresponding to equipment damage mechanisms and rates. Threats to mechanical integrity are reviewed by Operations, Reliability, and Engineering personnel to assign priorities and develop work plans to address them. The Operational Excellence and Reliability Information website includes information on the status of planned equipment inspections to enable management oversight of these activities. Additionally, higher priority threats are periodically reviewed by the Refinery's Reliability Steering Committee (RSC) to ensure that they are being appropriately addressed.

Inspectors manage the collection and analysis of equipment and piping inspection data. In addition to American Petroleum Institute (API), National Boiler Inspection Code, and state certifications, Inspectors receive training particular to the type of plant in which they work. For example, crude unit Inspectors are trained on damage mechanisms found in crude units, inspection techniques relevant to these mechanisms, and expectations for the contents of the inspection plans developed for their particular unit.

Thickness gauging is performed on selected CMLs.[13] There are more than 8,800 CMLs on the 4CU piping. When an inspection comes due, each of these CML inspections may consist of four or more thickness measurements. The data from these CML inspections is entered into Meridium.

Meridium utilizes its database of CML measurements (Condition Manager) to calculate the corrosion rates at the CMLs and predict future thicknesses. Additional information can be entered into the Meridium system as comments, known as Meridium History Briefs (History Briefs). While History Briefs can be manually reviewed, the Condition Manager does not use the History Briefs for computations, predictions, or triggers. CUSA uses the Condition Manager's calculations to assist in scheduling re-inspections and the replacement of components.

[13] CMLs were originally referred to as TMLs (thickness monitoring locations).

4.2 4SC Inspection History

The 4SC inspection plan was to periodically measure thickness at CMLs considered representative of the piping circuit between the C-1100 and P-1149/A (see Appendix 2). The nearest CML to the failed pipe component was CML #3, which is located at the elbow directly upstream of the failure location, as shown in Figure 16.

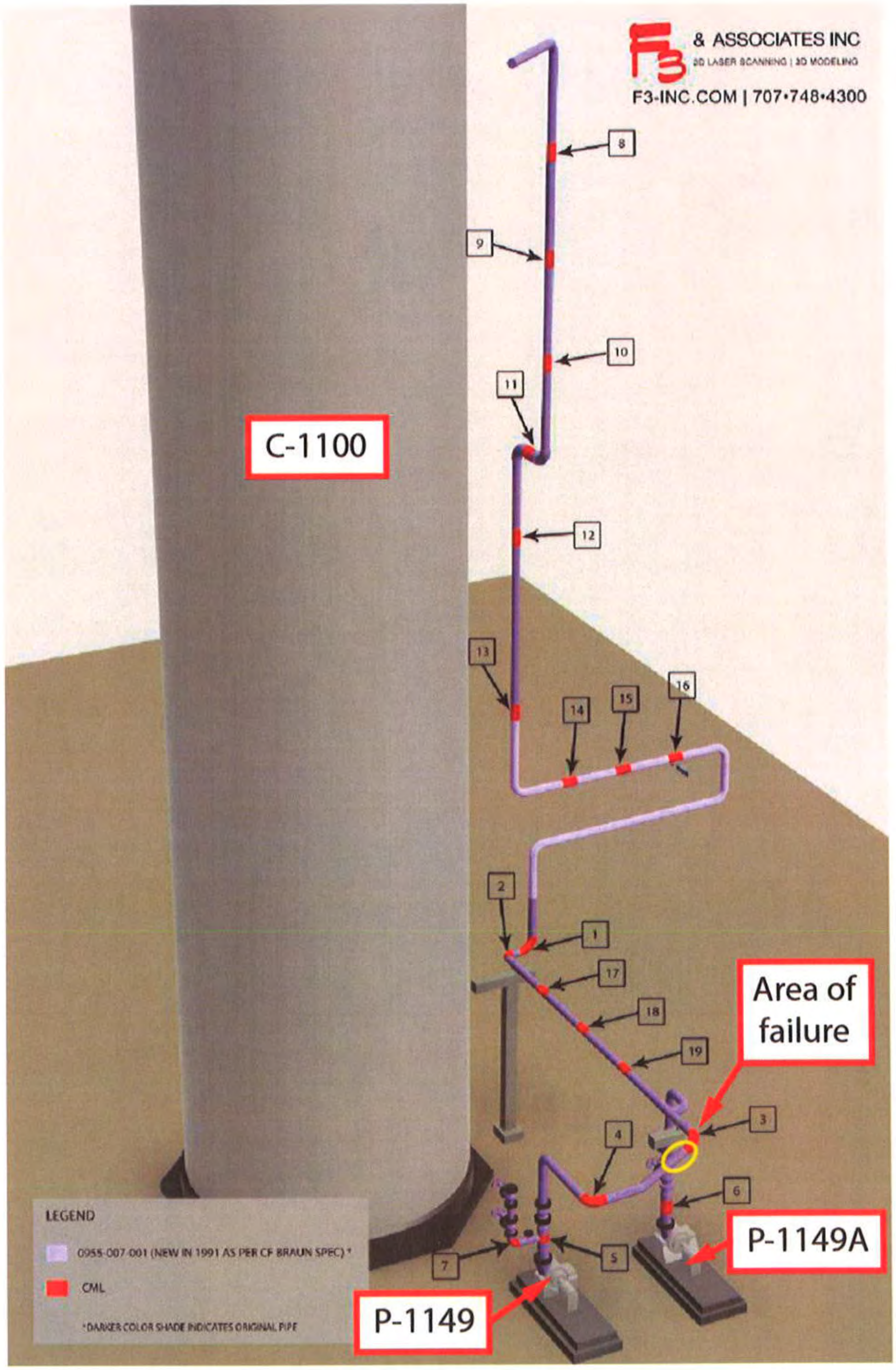

Figure 16. Three-dimensional model of the 8-inch 4SC line showing the CML locations. CMLs 1-6 were original, CML 7 was added in 2002, and CMLs 8-19 were added in 2011.

4.2.1 2002 Radiographic Testing Inspection of the 4SC

In 2002, the 4CU Inspector expanded the on-the-run inspection of the 4SC to include a one-time Radiographic Testing (RT) inspection of straight piping components by including a portion of the piping components adjacent to each CML. Normally, the findings for the existing CMLs were captured in the Condition Manager, but these expanded findings were summarized in a History Brief. This History Brief noted that one section of piping downstream of CML #3 had lost one-third of its original thickness (using the nominal thickness of 0.322 inches, the estimated thickness of the failed pipe component would have been approximately 0.21 inches in 2002) due to corrosion. The 4CU Inspector recommended the replacement of this pipe during the next turnaround, which was scheduled for 2007.

In 2006, as preparation for the 2007 Turnaround, the Turnaround Core Team[14] reviewed the worklist items submitted by the 4CU Inspector requesting replacement of the 4SC piping. The Turnaround Core Team, including the 4CU Inspector who had inspected the line in 2002, concluded that the piping downstream of P-1149/A needed to be replaced with 9-chromium steel[15] to better resist sulfidation corrosion. They also concluded that the piping upstream of P-1149/A could operate safely at least until the 2011 Turnaround, when the piping would be re-inspected to determine whether it should be replaced based on its predicted remaining life. It appears that the History Brief from 2002, noting thinning on the piping downstream of CML #3, was not used in reaching this decision.

<u>Causal Factor 2</u>: **Documenting wall thickness information in a History Brief in Meridium without adding it to the Condition Manager limited the ability for future decision-makers to utilize the data.**

A 2006 review of the metallurgy and corrosion of all equipment in the 4CU noted that the 4SC piping was operating above 600°F and that replacement of the discharge piping for P-1149/A was planned for the 2007 Turnaround. The review recognized that pipe components with lower silicon content could corrode faster than components with higher silicon content and recommended the installation of Guided Wave ultrasonic testing (UT) sensors on the remainder of the 4SC piping to determine if there were pipe components that may be thinner than indicated by the CML measurements. The Turnaround Core Team agreed to install the Guided Wave UT sensors as recommended by the metallurgical review.

During the first quarter 2007 Turnaround of the 4CU, the piping downstream of P-1149/A was replaced and 16 Guided Wave UT sensors were installed as planned. Three sensors were installed on the pipe between the C-1100 and P-1149/A. However, none were installed on the failed piping component. By the end of 2009, the data captured by the Guided Wave UT sensors was considered unreliable and the 4CU Inspector continued traditional UT and RT techniques for measuring wall thickness.

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[14] The Turnaround Core Team typically consists of representatives from Maintenance, Operations, and Capital Projects, the Design and Process Engineers, and the Inspector.

[15] Increasing the chromium content in steel increases the resistance to sulfidation corrosion. The industry typically uses 9-chromium steel as the optimal alloy when resistance to sulfidation corrosion is needed.

In approximately 2007, CUSA training for crude unit inspectors was updated to include a recommendation to inspect individual components in carbon steel systems subject to sulfidation corrosion. Richmond Refinery crude unit inspectors attended this training in September 2007.

4.2.2 Recommendations for 100% Component-by-Component Inspection

In September 2009, CUSA's Energy Technology Company (ETC) issued "Updated Inspection Strategies for Preventing Sulfidation Corrosion Failures in Chevron Refineries" (ETC Sulfidation Inspection Guidelines). These guidelines noted that different carbon steel components can experience different rates of sulfidation corrosion due to varying silicon content. The ETC Sulfidation Inspection Guidelines recommended that "*For Priority 1-3 piping circuits* inspect every component once to ensure none are corroding exceptionally fast or are near failure." Based on carbon steel operating above 600°F, the 4SC and the ABCR lines would be considered Priority 1. Hence, each component in carbon steel piping systems should be inspected at least once to document any relative differences in thickness that may suggest low silicon content. In June 2010, a Refinery materials engineer presented an overview of the new guidelines to the Refinery's RSC. Following this presentation, it does not appear that there was a specific understanding on a path forward.

In preparation for the 2011 Turnaround, the Turnaround Core Team reviewed the work requests recommending replacement of the 4SC piping. The Core Team concluded that the data reviewed did not warrant replacement of the suction piping for P-1149/A or the ABCR piping. Instead, the Core Team agreed to inspect the piping during the 2011 Turnaround. There was no indication that the ETC Sulfidation Inspection Guidelines' recommendation to conduct a 100% component-by-component inspection was considered.

<u>Additional Consideration 3</u>: **The ETC Sulfidation Inspection Guidelines were not fully implemented and action items were not tracked to completion.**

4.2.3 2011 Turnaround Inspections

During the 2011 Turnaround, the inspection of the 4SC piping, the ABCR piping, and suction piping for the P-1149/A was conducted as planned.

CML inspections of the ABCR piping showed wall thicknesses as low as 0.10 inches, indicating that the pipe could be too close to minimum thickness before the next Turnaround, scheduled for 2016, to leave it in service. Hence, portions of the ABCR piping were replaced with carbon steel piping during the 2011 Turnaround (see Figure 17).

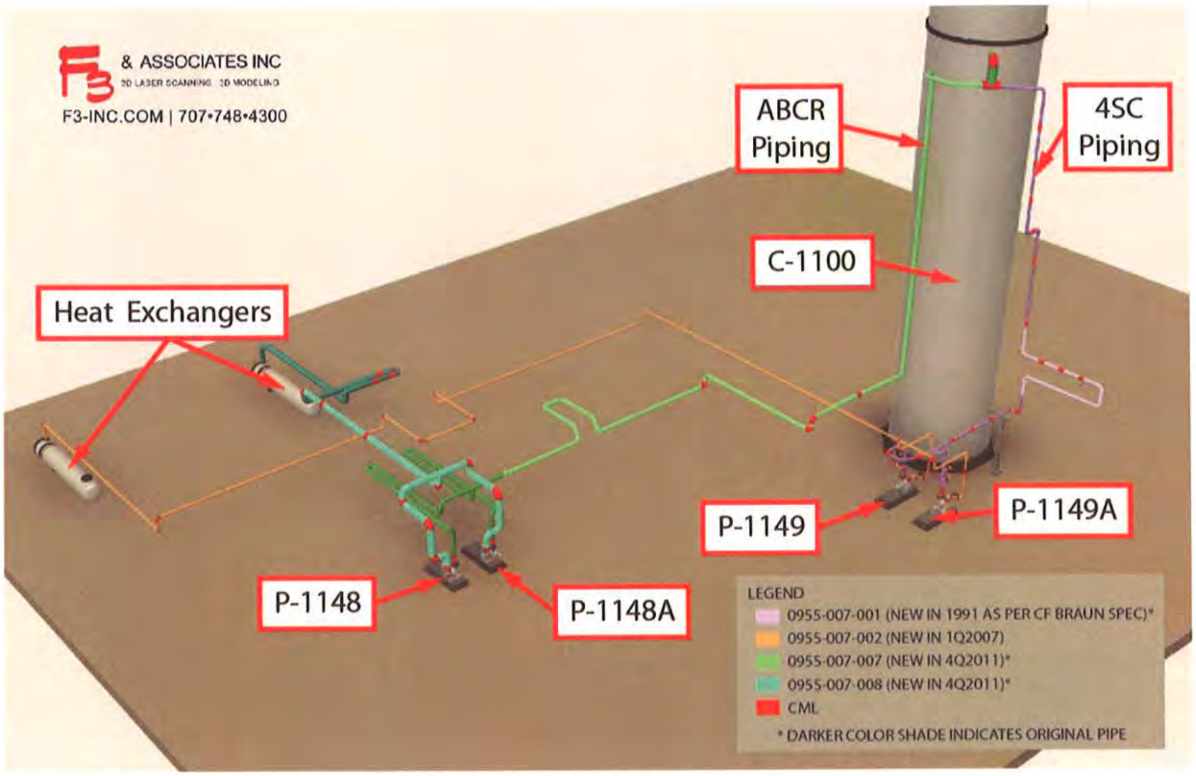

Figure 17. Three-dimensional model showing the locations of the CMLs in the 4SC and the ABCR piping within the 4CU.

Inspection of the 4SC suction piping for P-1149/A included the seven historical CMLs (CML #1 through #7 shown in Figure 16) as well as the twelve new CMLs (CML #8 through #19). The new CMLs were chosen to include a variety of straight piping components supplementing the previous CMLs on fittings (elbows and tees). However, the 19 total CMLs did not cover all 67 components. None of the CMLs were on the failed piping component near CML #3.

<u>Causal Factor 3</u>: Inspection during the 2011 Turnaround did not include every component of the 4SC piping.

In the 2011 Turnaround, the thickness at CML #3 was 0.17 inches. When the Inspector reviewed this and similar data for the rest of the CMLs, he apparently concluded that the pipe would reach the 0.14 inch Flag Thickness in three years. However, a calculated minimum thickness for a particular spool piece on the 8-inch line was determined by Engineering to be 0.036 inches, as discussed in more detail below. It appears that this calculated minimum thickness prompted the Inspector to decrease the Flag Thickness to 0.10 inches. Using a 0.01 inch per year corrosion rate, the Inspector apparently concluded that the pipe would reach the 0.10 inch Flag Thickness in approximately seven years. The P-1149/A suction piping was left in service since the data suggested that the piping would still be above the 0.10 inch Flag Thickness in 2016.

The small spool at CML #5 (shown in Figure 16) was recommended for replacement. When the Turnaround Core Team recognized that the spool could be replaced on-the-run during P-1149 maintenance, it asked Refinery Designs Engineering to calculate a minimum allowable wall thickness. The calculated 0.036 inches minimum thickness was based on simple hoop stress and deadweight stress calculations for the 8-inch pipe. Based on the estimated remaining life, the Core Team deferred replacing the washout spool. Although a Management of Change analysis was completed for this decision, other instructions in the Refinery Piping Inspection Guideline on completing Fitness for Service evaluations on pipe below Flag Thickness were not followed.

<u>Additional Consideration 4</u>: The minimum thickness calculated for the 4SC washout spool piping (0.036 inches) did not include safety factors considered in the Refinery Piping Inspection Guideline and API RP 574, which may have triggered a Fitness for Service analysis and led to additional inspections and resulting data.

Following the November 2011 Turnaround, the washout spool and the rest of the P-1149/A suction piping was re-inspected twice before the Incident using RT. One objective was to monitor the washout spool to ensure there was no significant reduction in thickness before it could be replaced on-the-run.

Concurrently with the above, data was gathered to establish current corrosion rates for the entire piping circuit. Measurements taken in February 2012 did not show significant changes and they were entered into the Condition Manager. The measurements taken in June 2012 showed primarily higher thickness than the previous readings. Most of the readings were within the tolerance for the inspection methods being used on hot, insulated pipe; however, some readings were outside the tolerance. Per the Refinery Piping Inspection Guideline, testing on the CMLs with out-of-tolerance readings should have been repeated, but was not. The readings also were not entered into the Condition Manager.

<u>Additional Consideration 5</u>: The June 2012 inspection of the P-1149/A suction piping was not entered into the Condition Manager.

5. Sulfidation Corrosion Threat and Risk Assessment

CUSA uses various methods to assess process hazards associated with unit operation and prioritize actions that are needed to control these hazards. Two methods that are relevant to the threat of sulfidation corrosion are the Reliability Opportunity Identification/Intensive Process Review (ROI/IPR) and the Process Hazard Analysis (PHA).

The ROI/IPR is conducted as part of turnaround planning in order to identify opportunities or reliability threats that can be resolved during turnaround execution. The PHA is conducted on a five-year cycle and is used to broadly assess the safety and operability risks of plant operations.

The ROI/IPR for the 2011 4CU Turnaround was conducted in 2009 (prior to the release of the ETC Sulfidation Inspection Guidelines). Documentation related to the 2009 ROI/IPR references potential upgrades for some portions of the 4SC, but does not identify any specific circuits. It further suggests the need for additional information to evaluate potential upgrade recommendations. The final ROI/IPR report, however, does not include a recommendation for 100% component-by-component inspection or any other increased inspection of the 4SC circuits.

Causal Factor 4: The 2009 ROI/IPR recommendations did not include 100% component-by-component inspection.

The most recent PHA for the 4CU was conducted in 2009. It does not appear from the 2009 PHA or any of the previous PHAs that the various study teams recognized sulfidation corrosion as a specific hazard associated with the 4SC composition, operating temperature, and piping metallurgy.

Additional Consideration 6: The 4CU PHAs did not consider the potential for sulfidation corrosion.

6. Root Causes and Recommendations

The TapRooT® root cause analysis method defines Causal Factors as a "Mistake or failure that, if corrected, could have prevented the incident from occurring or would have significantly mitigated its consequences."[16]

After identifying the Causal Factors for an incident, the TapRooT® method calls for analyzing the Root Causes for each Causal Factor before developing Corrective Actions for each Root Cause. This is done using a structured methodology (TapRooT® Root Cause Tree®), which guides an investigation team in identifying Basic Cause categories (such as "Procedures" or "Communications") and then analyzing further to categorize the Root Cause. In the TapRooT® system, a Causal Factor may have multiple Root Causes. As an example, a Causal Factor may have the following root causes: "Communication" (Basic Cause Category), "Misunderstood Verbal Communication" (Near Root Cause Category), or "Standard Terminology Not Used" (Root Cause Category). The following analysis lists the TapRooT® Root Cause categories for each Causal Factor of the Incident.

<u>Causal Factor 1</u>: **The response and assessment after the discovery of the leak did not fully recognize the risk of piping rupture and the possibility of auto-ignition**, as covered in Sections 2.1 and 2.2 of this report.

The risk assessment performed upon leak discovery was informal and corresponded with the perception of a small, stable leak. There was not a single meeting where all parties could collectively consider the potential risks and outcomes. This gave rise to communication problems (e.g., some CFD personnel misunderstanding the line temperature in relationship to flash point). Additionally, not all pertinent information (e.g., an overall understanding of the potential corrosion mechanisms and their particular failure modes – see Section 2.2) was brought into the decision-making process. If all the relevant information had been included, it is likely that one or more parties would have decided not to proceed with the removal of the aluminum weather jacketing or the use of firefighting equipment to remove the insulation.

The Investigation Team identified four root causes for this Causal Factor. These were:

- Misunderstood oral communication.
- No communication or untimely communication.
- Standards, Policies or Administrative Controls were confusing or incomplete.
- There were no Standards, Policies or Administrative Control.

[16] TapRooT® Changing the Way the World Solves Problems by Mark Paradies & Linda Unger, 2008.

Recommendation:

- Revise Refinery policies and checklists to ensure appropriate information—including Process Safety and Inspection information—is considered when evaluating leaks and addressing the issue of whether to shut down or continue operation of equipment.

<u>Causal Factor 2</u>: **Documenting wall thickness information in a History Brief in Meridium without adding it to the Condition Manager limited the ability for future decision-makers to utilize the data,** as covered in Section 4.2.1 of this report.

The Meridium 2002 Inspection History Brief notes one-third wall loss downstream of CML #3 on the drawing of the P-1149/A suction piping. This is the area where the failure occurred. This was only noted as text in the History Brief and not elsewhere (see Section 4.2.1 of this report). As documented in Section 4.1 of this report, the Meridium tool does not use information entered as text in a History Brief for computations, predictions, or triggers.

The Investigation Team identified three root causes for this Causal Factor. These were:

- Standards, Policies or Administrative Controls were confusing or incomplete.
- Complex system – knowledge-based decision required.
- Complex system – monitoring too many items.

Recommendation:

- Enhance the Refinery's Mechanical Integrity program to ensure the Refinery properly identifies and monitors piping circuits for appropriate damage mechanisms using a standardized methodology and documentation system.

<u>Causal Factor 3</u>: **The inspection during the 2011 Turnaround did not include every component in the 4SC piping**, as covered in Section 4.2.3 of this report.

In 2006, a metallurgy review for the 4CU recommended increased inspection coverage of the 4SC piping to identify components that had a higher susceptibility to sulfidation corrosion. In September 2007, Richmond Refinery inspectors attended crude unit subject matter expert training that included a recommendation to inspect individual carbon steel components subject to sulfidation corrosion. The ETC Sulfidation Inspection Guidelines recommended that "*For Priority 1-3 piping circuits* inspect every component once to ensure none are corroding exceptionally fast or are near failure." Based on carbon steel operating above 600°F, the 4SC and the ABCR lines would be considered Priority 1. However, the recommendation to identify and inspect every component was not built into the inspection plans for these piping circuits. A 100% component-by-component inspection would have required inspection of the pipe component that failed in August 2012, which could have alerted the Refinery to the component's accelerated metal loss. Section 4.2.2 of this report covers the decision-making process in preparation for the 2011 Turnaround and the lack of any indication that the need to conduct a 100% component-by-component analysis of the 4SC piping was considered.

The Investigation Team identified three root causes for this Causal Factor. These were:

- Continuing training needs improvement.
- Work package/permit needs improvement.
- Communication of Standards, Policies, or Administrative Controls needs improvement.

Recommendations:

- Review and enhance the requirements for inspector training and competency.
- Develop and implement a process for additional oversight of mechanical integrity-related recommendations and inspection plans, and the escalation of recommendations.
- Develop and implement a process to review and act upon mechanical integrity-related recommendations from industry alerts, ETC, and other subject-matter experts.
- Inspect 4CU piping that falls under the ETC Sulfidation Inspection Guidelines criteria for sulfidation corrosion prior to restarting the 4CU.
- Implement the ETC Sulfidation Inspection Guidelines for the remainder of the Refinery.

<u>Causal Factor 4</u>: **The 2009 ROI/IPR recommendations did not include a 100% component-by-component inspection**, as documented in Section 5 of this report.

Prior to the ROI/IPR study:

- In 2002, a thinning area was found downstream of CML #3 on the P-1149/A suction piping as documented in Section 4.2.1 of this report.
- A 4CU Metallurgical Review study completed in 2006 highlighted the need for increased inspection coverage of the 4SC piping and recommended the installation of Guided Wave sensors, but the data gathered by the Guided Wave technology was ultimately considered unreliable, as documented in Section 4.2.1 of this report.
- In 2007, piping downstream of P-1149/A was replaced with 9-chromium steel due to thinning, as documented in Section 4.2.1 of this report.
- In approximately 2007, CUSA training for crude unit inspectors was updated to include a recommendation to inspect individual components in carbon steel systems subject to sulfidation corrosion, as documented in Section 4.2.1 of this report.

While documentation related to the 2009 ROI/IPR references potential upgrades for some portions of the 4SC, it does not identify any specific circuits. It further suggests the need for additional information to evaluate potential upgrade recommendations. The final ROI/IPR report, however, does not include a recommendation for 100% component-by-component inspection or any other increased inspection of the 4SC circuits. Relevant information related to 100% component-by-component inspection was not transferred to the Refinery inspection management system.

The Investigation Team identified two root causes for this Causal Factor. These were:

- Corrective Action needs improvement.
- Standards, Policies, or Administrative Controls were confusing or incomplete.

Recommendation:

- Ensure relevant technical studies and inspection data are considered for the Refinery's equipment reliability plans and incorporated into the ROI/IPR process.

7. Additional Considerations

In the judgment of the Investigation Team, there are additional issues that did not directly cause the Incident, but represent an opportunity to prevent similar events. The Investigation Team identified six Additional Considerations, as follows:

Additional Consideration 1: **The CFD did not complete a Hazard Material Data Sheet and positioned Engine Foam 60 too close to the leak source when responding to the Incident**, as covered in Section 2.1 of this report.

Recommendation:

- See recommendation for Causal Factor 1.
- Review the Pre-Fire Plan to ensure sufficient guidance is provided on equipment positioning.

Additional Consideration 2: **The leaking line could not be isolated on the upstream side to mitigate loss of containment**, as described in Section 2.1 of this report.

Recommendation:

- Review company/industry loss history on large fractionating towers to determine if internal Engineering Standard FRS-DU-5267 (Emergency Isolation and Depressuring Valves) adequately addresses mitigation of accidental releases from these systems. Revise the standard as warranted by the findings of this review.

Additional Consideration 3: **The ETC Sulfidation Inspection Guidelines were not fully implemented and action items were not tracked to completion**, as discussed in Section 4.2.2 of this report.

Recommendation:

- See recommendation for Causal Factor 3.
- Ensure Refinery business plans provide for the appropriate implementation of Process Safety recommendations (such as the ETC Sulfidation Inspection Guidelines).

Additional Consideration 4: **The minimum thicknesses calculated for the 4SC washout spool piping (0.036 inches) did not include safety factors considered in the Refinery Piping Inspection Guideline and API RP 574, which may have triggered a Fitness for Service analysis and led to additional inspections and resulting data,** as described in Section 4.2.3 of this report.

Recommendation:

- Ensure sufficient organizational capacity and competency for minimum thickness Fitness for Service determinations.

<u>Additional Consideration 5</u>: **The June 2012 inspection of the P-1149/A suction piping was not entered into the Condition Manager**, as described in Section 4.2.3 of this report. The CMLs with out-of-tolerance readings should have been re-inspected, but were not.

Recommendation:

- See recommendation for Causal Factor 2.

- Consider additional training on expectations under the "Richmond Refinery Piping Inspection Guidelines" and "RFMS Piping Data Entry (Reliability Focused Maintenance System) and ACD (Add/Change/Delete) Guideline."

<u>Additional Consideration 6</u>: **The 4CU PHAs did not consider the potential for sulfidation corrosion**, as described in Section 5 of this report.

Recommendations:

- Review and modify the PHA procedures to ensure that teams consider known corrosion threats/mechanisms.

- Consider a project to evaluate the purpose and methods of various process safety management (PSM) reviews (PHA, ROI/IPR, AOA, COA, sRCM, RBI, etc.) to determine if these activities can be combined or better sequenced to improve risk understanding across the various functions and promote better process safety outcomes.

Investigation Team

Name	Discipline/Role	Current Position
Doug Pottenger	Team Lead	Technical Manager, El Segundo
Michael Baer	Team Facilitator	Senior Safety Specialist, Manufacturing OE/HES
Meaghan Horton	Trainee Facilitator	Safety Specialist – Incident Investigation & Reporting
Steve Bruce	Process Safety	ETC Risk Management & Fire Protection Team Lead
Chris Buehler	Technical	Exponent Thermal Sciences Practice
Bharat Chavda	Operations/Technical	Business Improvement Coordinator
Sean Clark	Operations	USW Health and Safety representative
Dave Cooke	Technical	ETC Consulting Materials Engineer
Carol-Ann Laughlin	Reliability	Reliability Consultant Manufacturing PSM, Reliability, and Energy
Dan Mattison	Technical	Exponent Thermal Sciences Practice
Dan Quinonez	Operations	Shift Team Leader
Mike Smith	Operations	USW Health and Safety representative

Appendix 1: Major Chemical Accidents or Releases Report[17]

ATTACHMENT C
Update to the 30 DAY FOLLOW-UP NOTIFICATION REPORT FORM
CONTRA COSTA HEALTH SERVICES
Page 1 of 8

For CCHS Use Only:
Received By: ____________
Date Received: ____________
Incident Number: ____________
Copied To: ____________
Event Classification Level: ____________

ATTENTION: Randall L. Sawyer
Hazardous Materials Program Director
Contra Costa Health Services Department
4333 Pacheco Boulevard
Martinez, CA 94553

INCIDENT DATE: August 6, 2012
INCIDENT TIME: 6:30 PM
FACILITY: Chevron U.S.A. Inc. Richmond Refinery

PERSON TO CONTACT FOR ADDITIONAL INFORMATION: Karen Draper
Phone Number: (510) 242-1547

PROVIDE ANY ADDITIONAL INFORMATION THAT WAS NOT INCLUDED IN THE 30-DAY REPORT WHEN THE 30-DAY REPORT WAS SUBMITTED, INCLUDING MATERIAL RELEASED AND ESTIMATED OR KNOWN QUANTITIES, COMMUNITY IMPACT, INJURIES, ETC.:

I. SUMMARY OF EVENT

On August 6, 2012, a piping rupture occurred in the #4 Crude Unit at the Chevron U.S.A. Inc. refinery in Richmond, CA, and subsequently a fire ignited in the area of the rupture. The rupture involved an 8" carbon-steel atmospheric gas-oil pipe line from the atmospheric distillation tower.

The primary location of the fire was near P-1149 (C-1100 Atmospheric Column No. 4 Sidecut pump). At the time of the fire, Operations personnel were in the process of evaluating a reported leak with the assistance of Chevron Fire Department personnel.

The #4 Crude Unit distills crude oil into various fractions of different boiling ranges, each of which is then processed further in the other refinery processing units. The #4 Crude Unit at Richmond Refinery has both an Atmospheric Distillation column and a Vacuum Distillation column. This incident involved equipment associated with the Atmospheric Distillation column.

[17] Sixth "Update to the 30 Day Follow-Up Notification Report Form" for the CWS Level 3 Event of August 6, 2012, dated March 29, 2013.

ATTACHMENT C
Update to the 30 DAY FOLLOW-UP NOTIFICATION REPORT FORM
CONTRA COSTA HEALTH SERVICES
Page 2 of 8

The company's investigation into this incident is on-going. Some of the information in this report is preliminary.

II. AGENCIES NOTIFIED, INCLUDING TIME OF NOTIFICATION

Primary: Community Warning System (CWS):

- Level 3 CWS (shelter in place) activated at approximately 6:35 PM (which served as the initial notification to most of the agencies below)
- The shelter in place was lifted by Contra Costa County Hazardous Materials Programs (CCHMP) at 11:30 PM

Secondary: Subsequent notifications via telephone to the agencies below:

State of Emergency Services	Bob McRae	800-852-7550 or 916-845-8911	6:53 PM
National Response Center (NRC)	Garther	800-424-8802	6:59 PM
Contra Costa Hazardous Materials Program (CCHMP)	Melissa Hagen	925-335-3200	7:28 PM
Bay Area Air Quality Management District (BAAQMD)	Mr. Scott	415-749-4979	7:33 PM
Richmond Fire/ Police Central Dispatch	Dispatch	510-620-6933	7:40 PM
California Division of Occupational Safety and Health (Cal/OSHA)	Clyde Trombettas	925-602-6517	10:09 PM

III. AGENCIES RESPONDING, INCLUDING CONTACT NAMES AND PHONE NUMBERS:

The list below does not include all representatives from the respective agencies

Cal/OSHA	Clyde Trombettas	925-602-2665
CCHMP	Trisha Asuncion	925-335-3200
BAAQMD	Jackie Huynh	415-749-4979
OSPR– Dept. Fish & Game	Bob Chedsey	707-864-4975
U.S. EPA	Scott Adair	415-947-4549
Richmond Police Department	Responding Officers	510-233-1214
U. S. Chemical Safety and Hazard Investigation Board (CSB)	Dan Tillema	303-236-8703

IV. EMERGENCY RESPONSE ACTION:

At or around 3:48 PM on August 6, 2012, an operator noticed a small leak from insulated piping on the C-1100 Atmospheric Distillation Column of the 4 Crude Unit. The operator immediately notified the Head Operator and Supervisor for the unit and initiated a dialogue regarding next steps and how to isolate the leak.

The standard practice of the Chevron Fire Department (CFD) is to respond to leaks, spills, and releases. In this instance, the CFD was notified at 4:02 PM that a leak had been discovered at the 4 Crude Unit. The CFD was asked to deploy a crew to the location as a precaution. The CFD arrived at the location between 4:07 PM and 4:09 PM and initiated air monitoring and assessment.

From 4:09 PM to 4:19 PM the rate of feed to the unit was reduced. Then, from 4:20 PM to 6:24 PM, Operations personnel, in conjunction with the CFD, investigated and assessed options. While the leak was being assessed, the CFD set up an engine and had two hose teams in place, one directed at the potential source of the leak and one directed at the personnel assessing the leak. At approximately 6:22PM, a small flash fire occurred on the insulated piping going to P-1149/A. The CFD and Plant Operators activated water spray and extinguished the small flash fire. At some point shortly before 6:25 PM, the size of the release abruptly increased. Between 6:25 PM and 6:28 PM, the order was given to shut down the unit. Around this time a white cloud was visible. At or around 6:32 PM, the fire that is the subject of this report and ongoing investigation ignited.

At 6:38 PM, a Community Warning System Level 3 alert was initiated by Chevron U.S.A. Inc. and the CWS alarm sounded. At or around this timeframe, both Petro-Chem Mutual Aid and Municipal Mutual Aid were called in for support. This included: Richmond Fire, El Cerrito Fire, Berkeley Fire, Contra Costa County Fire, Moraga/Orinda Fire, Hercules/Rodeo Fire, Phillips 66, Valero, Shell, Tesoro and Dow Fire. Also at or around this timeframe, a shelter-in-place order was issued for Richmond, San Pablo, and North Richmond. The shelter-in-place order advised residents to remain indoors until the fire was controlled. At 11:12 PM, the shelter-in-place order was lifted by CCHMP.

V. IDENTITY OF MATERIAL RELEASED AND ESTIMATED OR KNOWN QUANTITIES:

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-To-Know Act (EPCRA) require reporting when a facility releases more than a "reportable quantity" of a hazardous substance. The reportable release thresholds are based upon EPCRA & CERCLA reporting requirements. There was a reportable quantity of sulfur dioxide released from the fire and the flaring associated with the fire.

As a result of our continuing investigation, emission calculations from flaring associated with the event have been refined and summarized below.

Flare emissions (8/6 – 8/10)*	
Material Release	**Quantity Released**
Vent Gas Volume	8,021,389 SCF
Sulfur Dioxide (SO_2)	8,772 pounds
Methane	1,713 pounds
Non-Methane Hydrocarbon	3,794 pounds
Hydrogen Sulfide (H2S)	46 pounds
Nitric Oxides (NOx)	270 pounds

* Flare emission data includes emissions from the initial release and from depressuring the unit through August 10, 2012

As a result of our continuing investigation, emissions calculations from the fire that were in excess of a reportable quantity have been refined and summarized below:

Fire Emissions		
Material Released	**Quantity Released**	**Reportable Release Thresholds**
Sulfur Dioxide (SO_2)	2,017 pounds	500 pounds

Emission estimates herein are based on currently available data and are subject to change based on further investigation and analysis.

VI. METEROLOGICAL CONDITIONS AT TIME OF EVENT:

Wind Speed	11.5 MPH
Wind Direction	134° (SE)
Precipitation	None
Temperature (F)	75°

VII. DESCRIPTION OF INJURIES:

The following employee injuries were associated with this incident (all were part of the emergency response):

1) Employee received minor burn to small area of the left ear
2) Employee received minor burn to left wrist
3) Employee suffered abdominal discomfort
4) Employee suffered respiratory irritation
5) Employee suffered blister to lower leg from boot wear
6) Employee suffered bruise to a finger

All employees received first aid onsite by the Chevron Fire Department and/or the onsite clinic. All employees returned to work on the same shift. There were no injuries to contractor personnel associated with this incident.

VIII. COMMUNITY IMPACT:

A shelter-in-place order was issued for Richmond, San Pablo, and North Richmond, which advised residents to remain indoors until the fire was controlled. According to the Contra Costa Health Services website, a large number of people sought medical attention at local emergency rooms (three individuals were admitted to the hospital). Most cases have been minor complaints of nose, throat or eye irritation or respiratory issues.

a) Chevron U.S.A. Inc. established a claims process to compensate community members for medical and property expenses incurred as a result of the incident. As of January 21, 2013, approximately 23,900 claims have been initiated, and Chevron U.S.A. Inc. has spent approximately $10 million to compensate area hospitals, affected community members with valid claims, and local government agencies in Richmond and West Contra Costa County.

b) On August 6, 2012, seventeen (17) direct-reading samples were taken using an Industrial Scientific MX6 iBrid multi-gas monitor. The data from these samples confirms that concentrations for Hydrogen Sulfide (H2S), Sulfur Dioxide (SO2) and Carbon Monoxide (CO) were below detectable limits (<0.1ppm, <0.1ppm, and <1ppm respectively). Additionally, nineteen (19) grab samples were collected in Tedlar bags in various downwind locations in Richmond, California, El Sobrante, California, and El Cerrito, California. These samples were sent for analysis of sulfur compounds and hydrocarbons to Air Toxics Ltd., a laboratory specializing in the analysis of air using a wide variety of methods. All results from these samples were well below both the California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA) Reference Exposure Levels and California Occupational Safety and Health Administration (Cal/OSHA) Permissible Exposure Limits.

Follow-up community monitoring was conducted by Chevron U.S.A. Inc. at various locations throughout Richmond, California on August 7-8, 2012. Twenty (20) direct-reading air samples were taken during this timeframe using an Industrial Scientific MX6 iBrid multi-gas monitor. The data from these samples also confirms that concentrations of Hydrogen Sulfide (H2S), Sulfur Dioxide (SO2) and Carbon Monoxide (CO) were below detection limits (<0.1ppm, <0.1ppm, and <1ppm respectively). In addition, six (6) grab samples were collected in Tedlar bags during this timeframe at various locations in Richmond, California and were sent to Air Toxics Ltd Laboratory for analysis of sulfur compounds and hydrocarbons. Consistent with the above-referenced findings, all results from these samples were well below the OEHHA Reference Exposure Levels and Cal/OSHA Permissible Exposure Limits. Please note, however, that the laboratory detection limit for Acrolein is higher than the OEHHA Reference Exposure Limit.

c) Fence-line monitoring: Continuous monitoring data is gathered around the clock from instrumentation located at Chevron's Office Hill, Castro Street and Gertrude Street monitoring stations. A data point, close to or prior to the incident, is employed as a reference. The following maximum readings were recorded between the times the fire ignited and the time all-clear was called by CCHMP (between 6:30 PM and 11:31 PM on August 6, 2012). As reflected in the table below, none of the maximum readings exceeded Cal/OSHA's Permissible Exposure Limits (PELs).

Permissible Exposure Limits (PELs). Maximum Concentration Readings

	Cal/OSHA PEL	Castro Street	Office Hill	Gertrude Street
H2S (ppb) Background at 3:00 PM	10,000 ppb	3.04 ppb	3.99 ppb	2.09 ppb
H2S (ppb) Max.	10,000 ppb	3.27 ppb	5.41 ppb	2.51 ppb
SO2 (ppm) Background at 3:00 PM	2 ppm	0.006 ppm	0.003 ppm	0.002 ppm
SO2 (ppm) Max.	2 ppm	0.007 ppm	0.006 ppm	0.002 ppm

Note: The Cal/OSHA PEL are concentrations averaged over an 8-hour period.

IX. INCIDENT INVESTIGATION RESULTS:

Chevron U.S.A. Inc. promptly initiated an investigation of the incident using the TapRooT® methodology. The investigation team is composed of Subject Matter Experts (SMEs) as well as operations personnel, management personnel and representatives of the United Steel Workers. The investigation Team Leader and the investigation Facilitator are Chevron U.S.A. Inc. personnel external to the Richmond Refinery. The investigation is on-going.

X. SUMMARIZE INVESTIGATION RESULTS BELOW OR ATTACH COPY OF REPORT:

The investigation is not complete. Chevron U.S.A. Inc. worked with multiple governmental agencies, including the CSB and Cal/OSHA with respect to evidence identification and collection. Protocols for the removal and testing of relevant evidence have been agreed upon and subsequently, a five foot section of the affected piping system was sent for metallurgical analysis on September 10, 2012. Although the test laboratory has issued a preliminary report, the final report is not yet available. The final results of the testing are among the information necessary for the investigation team to complete its work. Chevron U.S.A. Inc. will provide updates to CCHMP as required until the investigation is concluded.

XI. SUMMARIZE PREVENTABLE MEASURES TO BE TAKEN TO PREVENT RECURRENCE INCLUDING MILESTONE AND COMPLETION DATES FOR IMPLEMENTATION

Since the company's investigation is ongoing, the company is currently unable to identify or summarize all measures to prevent a recurrence. The company has implemented or will implement the following measures.

Industry Alert

On September 26, 2012, Chevron U.S.A. Inc. shared some potentially significant preliminary information regarding the incident through issuance of an Industry Alert. The Alert noted that an area-of-interest in Chevron U.S.A. Inc.'s investigation of the incident is whether the pipe failure resulted from general thinning of the five-foot piping component.

Corrective Actions

The refinery has begun to develop and implement the following corrective actions based on preliminary observations from the investigation team. We have met with governmental agencies, including the CSB, Cal/OSHA, and the County to discuss these efforts. Additional actions may be identified upon completion of the investigation, but the following efforts are already underway:

Low Silicon Carbon Steel and Piping Component Inspections

- As stated in the above-referenced Industry Alert, carbon steel piping with low-silicon content is susceptible to accelerated corrosion when exposed to high-temperature sulfidation (HTS) conditions. Based on preliminary information from the test laboratory, the pipe component that ruptured had low-silicon content and general thinning. This thinning was not readily detected by existing corrosion monitoring locations. To address this issue, the company is inspecting all components potentially susceptible to accelerated HTS corrosion and will complete inspection of all such components in the No.

4 Crude Unit before restarting the unit. If we do locate any components that are not suitable for service they will be replaced.

Mechanical Integrity Program

- The refinery is implementing a process to review, prioritize, and act upon mechanical integrity-related recommendations from internal and external technical experts, including industry standards and alerts.
- The refinery is enhancing its mechanical integrity program to ensure that the proper identification and monitoring of piping circuits for all potential damage mechanisms, not just HTS corrosion. Our goal is to enhance and standardize our inspection method and documentation system.

Assessment, Decision-Making, and Oversight

- The refinery is implementing a process for additional oversight of mechanical integrity-related recommendations and inspection plans. We also are taking steps to make certain that relevant technical studies and inspection data are considered for equipment reliability plans and other processes used to ensure process safety.
- The refinery is reviewing and strengthening its procedures for analyzing process hazards to ensure that work teams consider known failure threats/mechanisms. We also are considering a project to evaluate the purpose and methods of various process safety-related reviews to determine if these activities can be combined or better sequenced to improve risk understanding and promote better process safety outcomes.
- The refinery is reviewing and improving its requirements for training and competency for leaders, inspectors, and engineers. We also are making certain that we have the appropriate technical resources to assist in any evaluation of the fitness of equipment for service.

Leak Response

- The refinery is revising internal policies and checklists to ensure appropriate information—including process safety information and inspection history and data—is considered when evaluating leaks and addressing whether to shut down or continue operation of equipment. We intend to share the resulting leak response protocol with other Bay Area refineries.
- We are looking at the industry's experience with major losses of containment to determine if we should change our standards for fire protection or loss prevention.

Safety Focus

- We are reemphasizing our expectations around process safety to clarify our responsibility for process safety performance and the importance of incorporating process safety into decision-making.

XII. ADDITIONAL INFORMATION. DETAILED EVENT TIMELINE, CORRESPONDENCE, RELEVANT HISTORY OF INCIDENTS WITH SIMILAR EQUIPMENT OR PROCEDURES:

The detailed event timeline is still under development as part of the incident investigation. All required information will be provided upon completion and submittal of the investigation report.

Appendix 2: Timeline of Key Events

Date/Time	Description of Events
1976	The 4CU is put into service.
2002	Inspection of the 4SC piping noted one-third wall loss downstream of CML #3.
February 2006	The 4CU Metallurgy Review noted that operating conditions for the 4SC made the carbon steel piping in the 4CU susceptible to sulfidation corrosion and recommended inspection of the line using Guided Wave UT.
1st QTR 2007	Piping downstream of P-1149/A was replaced and 16 Guided Wave UT sensors were installed (none were installed on the failed component).
June 2009	ROI/IPR did not specifically mention sulfidation corrosion in the 4SC as an issue to be addressed in the 2011 Turnaround for the 4CU.
August 31, 2009 – November 17, 2009	The study teams on the 2009 PHA for the 4CU did not appear to recognize sulfidation corrosion as a specific possible hazard associated with the 4SC.
September 2009	ETC Sulfidation Inspection Guidelines were issued, which recommended 100% component-by-component inspection for certain carbon steel piping circuits operating above 500°F.
End of 2009	The 4CU Inspector continued traditional UT and RT techniques for measuring wall thickness because the data captured by the Guided Wave sensors was considered unreliable.
June 2010	An overview of the ETC Sulfidation Inspection Guidelines was presented to the RSC. It does not appear that there was a specific understanding on a path forward.
End of 2010	During 2010/2011 planning for the 4CU Turnaround, the Turnaround Core Team concluded that the 4SC piping should be inspected rather than replaced.
4th QTR 2011	During the fourth quarter 2011 Turnaround for the 4CU, the 4SC piping was inspected at CMLs 1-19, but not at every component.
February and June 2012	Inspections of the 4SC continued at CMLs 1-19, with no significant decrease in thicknesses recorded.
March 2012	Fabrication of replacement washout spool.
Day of Incident: August 6, 2012	
~1548 hours	The Plant Operator (PO) observed a leak on the 4SC piping and notified the Head Operator (HO).
1553 hours	The Shift Team Leader was notified and went to the 4CU.
1602 hours	The Chevron Fire Department (CFD) was called and went to the 4CU with two monitor trucks and Engine Foam 60.
~1608 hours	The CFD performed gas testing and determined the atmosphere around leak was not flammable, based on an LEL reading of 2%.

Date/Time	Description of Events
1609 hours	The Control Board Operator (CBO) began reducing the 4CU feed rate per routine shutdown procedures.
1619 hours	Operations determined that the section of leaking pipe could not be isolated.
	Assembled personnel concluded that the weather jacketing and piping insulation needed to be removed to allow visual assessment of leak.
	A plan was devised to erect scaffolding near the leaking pipe so that the insulation around the leak could be removed to better determine whether an online repair was feasible.
~1650 hours	While the scaffolding was being erected (~1 hour), a plan was developed for removing the weather jacketing and insulation from the leaking pipe, which entailed: two firefighters using hand tools to remove jacketing and insulation from the leaking pipe.
~1700 hours	Operations and CFD personnel arriving for the Night Shift conducted field turnovers with the Day Shift.
1810 – 1821 hours	Two firefighters cut the bands on the horizontal piping and the first two bands on the sloping portion of the pipe, and began removing the weather jacketing.
1822 hours	A small flash fire ignited when the second sheet of weather jacketing was removed.
	The fire was quickly extinguished. The two firefighters descended from the scaffolding and set up a Blitz monitor to provide additional firewater coverage on the leaking pipe.
	CFD hose teams switched from power cone to a straight stream nozzle pattern to knock away oil-soaked piping insulation.
	CFD hose teams briefly shut off the water to assess the insulation removal, revealing an increase in volume of material from the leak. At or around this time, the released material began to smoke.
1827 hours	The order for emergency shutdown of the 4CU was given at which time supporting field personnel began to evacuate the area.
1828 hours	The RSL was informed that the 4CU was being shut down.
~1829 hours	The CBO activated hand switches for emergency shutdown of the 4CU.
~1830 hours	The leak rapidly worsened and a large white cloud formed and enveloped the 4CU and downwind processing plants.
	The CFD hose teams shut off nozzles and withdrew from the area.
~1832 hours	A black smoke plume formed.
1838 hours	A shelter-in-place order was issued for the cities of Richmond, San Pablo, and North Richmond.
2215 hours	The CFD, with assistance from Petrochemical Mutual Aid Organization and Municipal Mutual Aid, brought the fire under control.
2312 hours	The shelter-in-place was lifted.
August 7, 2012	The Investigation Team met for the first time and began the investigation.

Appendix 3: MSDS for LGO

Material Safety Data Sheet

SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

GAS OIL, LIGHT

Product Use: Refinery stream
Company Identification
Chevron Products Company
Marketing, MSDS Coordinator
6001 Bollinger Canyon Road
San Ramon, CA 94583
United States of America

Transportation Emergency Response
CHEMTREC: (800) 424-9300 or (800) 424-9300 or (703) 527-3887
Health Emergency
Chevron Emergency Information Center: Located in the USA. International collect calls accepted. (800) 231-0623 or (510) 231-0623
Product Information
MSDS Requests: (800) 689-3998

SECTION 2 COMPOSITION/ INFORMATION ON INGREDIENTS

COMPONENTS	CAS NUMBER	AMOUNT
Distillates, straight run middle (gas oil, light)	64741-44-2	100 %weight

SECTION 3 HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

- COMBUSTIBLE LIQUID AND VAPOR
- CAUSES SKIN IRRITATION
- MAY BE HARMFUL OR FATAL IF INHALED
- MAY CAUSE RESPIRATORY TRACT IRRITATION IF INHALED
- MAY CAUSE LUNG DAMAGE IF SWALLOWED
- MAY CAUSE DIZZINESS, DROWSINESS AND REDUCED ALERTNESS
- CONTAINS MATERIAL THAT MAY CAUSE DAMAGE TO:
- LIVER
- BLOOD/BLOOD FORMING ORGANS
- TOXIC TO AQUATIC ORGANISMS. MAY CAUSE LONG-TERM ADVERSE EFFECTS IN THE AQUATIC ENVIRONMENT

IMMEDIATE HEALTH EFFECTS
Eye: Not expected to cause prolonged or significant eye irritation.
Skin: Contact with the skin causes irritation. Skin contact may cause drying or defatting of the skin. Symptoms may include pain, itching, discoloration, swelling, and blistering. Contact with the skin is not expected to cause an allergic skin response. Not expected to be harmful to internal organs if absorbed through the skin.
Ingestion: Because of its low viscosity, this material can directly enter the lungs, if swallowed, or if subsequently vomited. Once in the lungs it is very difficult to remove and can cause severe injury or death. May be irritating to mouth, throat, and stomach. Symptoms may include pain, nausea, vomiting, and diarrhea.
Inhalation: Toxic; may be harmful or fatal if inhaled. The vapor or fumes from this material may cause respiratory irritation. Symptoms of respiratory irritation may include coughing and difficulty breathing. Excessive or prolonged breathing of this material may cause central nervous system effects. Central nervous system effects may include headache, dizziness, nausea, vomiting, weakness, loss of coordination, blurred vision, drowsiness, confusion, or disorientation. At extreme exposures, central nervous system effects may include respiratory depression, tremors or convulsions, loss of consciousness, coma or death.

DELAYED OR OTHER HEALTH EFFECTS:
Target Organs: Contains material that may cause damage to the following organ(s) following repeated skin contact based on animal data: Liver Blood/Blood Forming Organs
See Section 11 for additional information. Risk depends on duration and level of exposure.

SECTION 4 FIRST AID MEASURES

Eye: No specific first aid measures are required. As a precaution, remove contact lenses, if worn, and flush eyes with water.
Skin: Wash skin with water immediately and remove contaminated clothing and shoes. Get medical attention if any symptoms develop. To remove the material from skin, use soap and water. Discard contaminated clothing and shoes or thoroughly clean before reuse.
Ingestion: If swallowed, get medical attention. Do not induce vomiting. Never give anything by mouth to an unconscious person.
Inhalation: During an emergency, wear an approved, positive pressure air-supplying respirator. Move the exposed person to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention.
Note to Physicians: Ingestion of this product or subsequent vomiting may result in aspiration of light hydrocarbon liquid, which may cause pneumonitis.

SECTION 5 FIRE FIGHTING MEASURES

See Section 7 for proper handling and storage.

FIRE CLASSIFICATION:
OSHA Classification (29 CFR 1910.1200): Combustible liquid.

NFPA RATINGS: Health: 2 Flammability: 2 Reactivity: 0

FLAMMABLE PROPERTIES:
Flashpoint: < 93 °C (< 200 °F)
Autoignition: 338 °C (640 °F) NFPA 325M
Flammability (Explosive) Limits (% by volume in air): Lower: 0.5 Upper: 5

EXTINGUISHING MEDIA: Use water fog, foam, dry chemical or carbon dioxide ($CO2$) to extinguish flames.

PROTECTION OF FIRE FIGHTERS:
Fire Fighting Instructions: For fires involving this material, do not enter any enclosed or confined fire space without proper protective equipment, including self-contained breathing apparatus.
Combustion Products: Highly dependent on combustion conditions. A complex mixture of airborne solids, liquids, and gases including carbon monoxide, carbon dioxide, and unidentified organic compounds will be evolved when this material undergoes combustion.

SECTION 6 ACCIDENTAL RELEASE MEASURES

Protective Measures: Eliminate all sources of ignition in the vicinity of the spill or released vapor. If this material is released into the work area, evacuate the area immediately. Monitor area with combustible gas indicator.
Spill Management: Stop the source of the release if you can do it without risk. Contain release to prevent further contamination of soil, surface water or groundwater. Clean up spill as soon as possible, observing precautions in Exposure Controls/Personal Protection. Use appropriate techniques such as applying non-combustible absorbent materials or pumping. All equipment used when handling the product must be grounded. A vapor suppressing foam may be used to reduce vapors. Use clean non-sparking tools to collect absorbed material. Where feasible and appropriate, remove contaminated soil. Place contaminated materials in disposable containers and dispose of in a manner consistent with applicable regulations.
Reporting: Report spills to local authorities and/or the U.S. Coast Guard's National Response Center at (800) 424-8802 as appropriate or required.

SECTION 7 HANDLING AND STORAGE

Precautionary Measures: Liquid evaporates and forms vapor (fumes) which can catch fire and burn with explosive force. Invisible vapor spreads easily and can be set on fire by many sources such as pilot lights, welding equipment, and electrical motors and switches. Fire hazard is greater as liquid temperature rises above 29C (85F).
Do not get in eyes, on skin, or on clothing. Do not taste or swallow. Do not breathe vapor or fumes. Wash thoroughly after handling.
General Handling Information: Avoid contaminating soil or releasing this material into sewage and drainage systems and bodies of water.
Static Hazard: Electrostatic charge may accumulate and create a hazardous condition when handling this material. To minimize this hazard, bonding and grounding may be necessary but may not, by themselves, be sufficient. Review all operations which have the potential of generating and accumulating an electrostatic charge and/or a flammable atmosphere (including tank and container filling, splash filling, tank cleaning, sampling, gauging, switch loading, filtering, mixing, agitation, and vacuum truck operations) and use appropriate mitigating procedures. For more information, refer to OSHA Standard 29 CFR 1910.106, 'Flammable and Combustible Liquids', National Fire Protection Association (NFPA 77, 'Recommended Practice on Static Electricity', and/or the American Petroleum Institute (API) Recommended Practice 2003, 'Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents'.
General Storage Information: DO NOT USE OR STORE near heat, sparks, flames, or hot surfaces. USE AND STORE ONLY IN WELL VENTILATED AREA. Keep container closed when not in use.
Container Warnings: Container is not designed to contain pressure. Do not use pressure to empty container or it may rupture with explosive force. Empty containers retain product residue (solid, liquid, and/or vapor) and can be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, static electricity, or other sources of ignition. They may explode and cause injury or death. Empty containers should be completely drained, properly closed, and promptly returned to a drum reconditioner or disposed of properly.

SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

GENERAL CONSIDERATIONS:
Consider the potential hazards of this material (see Section 3), applicable exposure limits, job activities, and other substances in the work place when designing engineering controls and selecting personal protective equipment. If engineering controls or work practices are not adequate to prevent exposure to harmful levels of this material, the personal protective equipment listed below is recommended. The user should read and understand all instructions and limitations supplied with the equipment since protection is usually provided for a limited time or under certain circumstances.

ENGINEERING CONTROLS:
If user operations generate airborne material, use process enclosures, local exhaust ventilation, or other engineering controls to control exposure.

PERSONAL PROTECTIVE EQUIPMENT
Eye/Face Protection: No special eye protection is normally required. Where splashing is possible, wear safety glasses with side shields as a good safety practice.
Skin Protection: Wear protective clothing to prevent skin contact. Selection of protective clothing may include gloves, apron, boots, and complete facial protection depending on operations conducted. Suggested materials for protective gloves include: Chlorinated Polyethylene (or Chlorosulfonated Polyethylene), Nitrile Rubber, Polyurethane, Viton.
Respiratory Protection: If exposure to harmful levels of airborne material may occur when working with this material, wear an approved respirator that provides protection, such as: Air-Purifying Respirator for Organic Vapors.

Use a positive pressure air-supplying respirator in circumstances where air-purifying respirators may not provide adequate protection.
No applicable occupational exposure limits exist for this material or its components.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Attention: the data below are typical values and do not constitute a specification.

Color: No data available
Physical State: Liquid
Odor: Petroleum odor
pH: Not Applicable
Vapor Pressure: 0.4 kPa (Estimated) @ 40 °C (104 °F)
Vapor Density (Air = 1): >1 (Estimated)
Boiling Point: 205°C (401°F) - 345°C (653°F)
Solubility: Soluble in hydrocarbon solvents; insoluble in water.
Freezing Point: Not Applicable
Melting Point: Not Applicable
Specific Gravity: <1 NFPA 325M
Density: 0.844 g/ml
Viscosity: 4.16 cSt @ 40°C (104°F)

SECTION 10 STABILITY AND REACTIVITY

Chemical Stability: This material is considered stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.
Incompatibility With Other Materials: May react with strong acids or strong oxidizing agents, such as

chlorates, nitrates, peroxides, etc.
Hazardous Decomposition Products: None known (None expected)
Hazardous Polymerization: Hazardous polymerization will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

IMMEDIATE HEALTH EFFECTS
Eye Irritation: The Draize eye irritation mean score in rabbits for a 24-hour exposure was: 1.0/110.
Skin Irritation: For a 24-hour exposure, the Primary Irritation Score (PIS) in rabbits is: 3.2/8.0.
Skin Sensitization: This material did not cause skin sensitization reactions in a Buehler guinea pig test. This material did not cause sensitization reactions in a Modified Buehler guinea pig test.
Acute Dermal Toxicity: LD50: >2g/kg (rabbit).

Acute Oral Toxicity: LD50: > 5 g/kg (rat)

Acute Inhalation Toxicity: 4 hour(s) LC50: 1.78mg/l (rat).
Genetic Toxicity: This product gave positive results in the following mutagenicity assays: <Mouse Lymphoma Gene Mutation Assay> This product gave negative results in the following mutagenicity assays: <In Vivo Mouse Micronucleus Test>
ADDITIONAL TOXICOLOGY INFORMATION:
This product may contain significant amounts of Polynuclear Aromatic Hydrocarbons (PAH's) which have been shown to cause skin cancer after prolonged and frequent contact with the skin of test animals. Brief or intermittent skin contact with this product is not expected to have serious effects if it is washed from the skin. While skin cancer is unlikely to occur in human beings following use of this product, skin contact and breathing, of mists, vapors or dusts should be reduced to a minimum.

SECTION 12 ECOLOGICAL INFORMATION

ECOTOXICITY
This material is expected to be toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment.

ENVIRONMENTAL FATE
This material is not expected to be readily biodegradable. The biodegradability of this material is based on data for the components.

SECTION 13 DISPOSAL CONSIDERATIONS

Use material for its intended purpose or recycle if possible. This material, if it must be discarded, may meet the criteria of a hazardous waste as defined by US EPA under RCRA (40 CFR 261) or other State and local regulations. Measurement of certain physical properties and analysis for regulated components may be necessary to make a correct determination. If this material is classified as a hazardous waste, federal law requires disposal at a licensed hazardous waste disposal facility.

SECTION 14 TRANSPORT INFORMATION

The description shown may not apply to all shipping situations. Consult 49CFR, or appropriate Dangerous Goods Regulations, for additional description requirements (e.g., technical name) and mode-specific or quantity-specific shipping requirements.

DOT Shipping Description: UN2810, TOXIC, LIQUIDS, ORGANIC, N.O.S. (STRAIGHT RUN MIDDLE DISTILLATE), 6.1, III

IMO/IMDG Shipping Description: UN2810, TOXIC, LIQUIDS, ORGANIC, N.O.S. (STRAIGHT RUN MIDDLE DISTILLATE), 6.1, III, MARINE POLLUTANT (STRAIGHT RUN MIDDLE DISTILLATE)

ICAO/IATA Shipping Description: UN2810, TOXIC, LIQUIDS, ORGANIC, N.O.S. (STRAIGHT RUN MIDDLE DISTILLATE), 6.1, III

SECTION 15 REGULATORY INFORMATION

EPCRA 311/312 CATEGORIES:

1. Immediate (Acute) Health Effects: YES
2. Delayed (Chronic) Health Effects: YES
3. Fire Hazard: YES
4. Sudden Release of Pressure Hazard: NO
5. Reactivity Hazard: NO

REGULATORY LISTS SEARCHED:

01-1=IARC Group 1	03=EPCRA 313
01-2A=IARC Group 2A	04=CA Proposition 65
01-2B=IARC Group 2B	05=MA RTK
02=NTP Carcinogen	06=NJ RTK
	07=PA RTK

The following components of this material are found on the regulatory lists indicated.
Distillates, straight run middle (gas oil, light) 06

CHEMICAL INVENTORIES:
All components comply with the following chemical inventory requirements: AICS (Australia), DSL (Canada), EINECS (European Union), IECSC (China), KECI (Korea), PICCS (Philippines), TSCA (United States).

SECTION 16 OTHER INFORMATION

NFPA RATINGS: Health: 2 Flammability: 2 Reactivity: 0

HMIS RATINGS: Health: 2* Flammability: 2 Reactivity: 0
(0-Least, 1-Slight, 2-Moderate, 3-High, 4-Extreme, PPE:- Personal Protection Equipment Index recommendation, *- Chronic Effect Indicator). These values are obtained using the guidelines or published evaluations prepared by the National Fire Protection Association (NFPA) or the National Paint and Coating Association (for HMIS ratings).

REVISION STATEMENT: This revision updates the following sections of this Material Safety Data Sheet: 3, 5, 12, 14, 16
Revision Date: APRIL 11, 2011

ABBREVIATIONS THAT MAY HAVE BEEN USED IN THIS DOCUMENT:

TLV - Threshold Limit Value	TWA - Time Weighted Average
STEL - Short-term Exposure Limit	PEL - Permissible Exposure Limit

	CAS - Chemical Abstract Service Number
ACGIH - American Conference of Government Industrial Hygienists	IMO/IMDG - International Maritime Dangerous Goods Code
API - American Petroleum Institute	MSDS - Material Safety Data Sheet
CVX - Chevron	NFPA - National Fire Protection Association (USA)
DOT - Department of Transportation (USA)	NTP - National Toxicology Program (USA)
IARC - International Agency for Research on Cancer	OSHA - Occupational Safety and Health Administration

Prepared according to the OSHA Hazard Communication Standard (29 CFR 1910.1200) and the ANSI MSDS Standard (Z400.1) by the Chevron Energy Technology Company, 100 Chevron Way, Richmond, California 94802.

The above information is based on the data of which we are aware and is believed to be correct as of the date hereof. Since this information may be applied under conditions beyond our control and with which we may be unfamiliar and since data made available subsequent to the date hereof may suggest modifications of the information, we do not assume any responsibility for the results of its use. This information is furnished upon condition that the person receiving it shall make his own determination of the suitability of the material for his particular purpose.