U.S. Chemical Safety and Hazard Investigation Board

Flash Fire and Explosion at Sunoco Partners Nederland Terminal

Nederland, TX | *Incident Date: August 12, 2016* | **No. 2016-03-I-TX**

Investigation Report

Published: September 27, 2022

SAFETY ISSUE:

HOT WORK SAFETY

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Abbreviations

AST	Above Ground Storage Tank
CFR	Code of Federal Regulations
CSB	U.S. Chemical Safety and Hazard Investigation Board
LEL	Lower Explosive Limit
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline and Hazardous Materials Safety Administration
psig	pounds per square inch gauge

Executive Summary

Incident Overview

On August 12, 2016, at approximately 8:15 p.m. CDT, a flash fire and explosion occurred while a contractor (L-Con, Inc.) was welding a piping segment at the Sunoco Nederland crude oil terminal. The fire and explosion caused overpressure within the pipe segment, causing CARBER isolation tools, that had been installed as part of the project, and residual crude oil in the pipe to be ejected from the ends of the piping, resulting in impact and burn injuries to seven workers.

In April 2016, Sunoco's Nederland terminal began construction on the installation of new aboveground storage tanks, with associated piping, and modifying existing piping to facilitate transfer of crude oil to and from tanks within their terminal. To complete the required work for the installation, Sunoco hired L-Con, Inc. to complete the piping modifications, including proper fit and alignment, pipe cutting, and welding. The installation involved only a portion of the terminal's operation and therefore only required isolation of specific tanks and piping to complete the work.

To complete the work as planned, L-Con subcontracted CARBER to cut and isolate piping segments, as required. According to an agreement between Sunoco and L-Con, the area where work was to occur would not be clean or free of residual crude oil and would require the use of an isolation tool.

On August 11, 2016, the day prior to the incident, CARBER cut and isolated the piping section, which was 30 inches in diameter. CARBER used their company-specific isolation tools to isolate the pipe section, which contained residual crude oil, from workers and the hot work that would take place. Once the section of piping was cut and isolated, L-Con could weld the required piping sections in place.

Upon commencing welding during the night shift of August 12, 2016, the residual crude oil in the pipe ignited, causing a flash fire and explosion.

The Jefferson County Sherriff's Office and the Nederland Fire Department responded to the incident to assist in controlling the scene and transporting injured workers to receive medical attention.

Safety Issues

The CSB's limited scope investigation identified the safety issue below.

- **Hot Work Safety.** The piping section was not cleared of flammable material nor inerted prior to conducting hot work (welding), which are requirements per OSHA standards to prevent explosive atmospheres inside enclosed equipment. (Section 2.1)

Probable Cause

The CSB determined the probable cause of the incident was Sunoco approving, and L-Con conducting, hot work activities on equipment that contained an explosive atmosphere that when exposed to an ignition source, resulted in an explosion event. Contributing to the incident was the ineffective implementation and execution of policies and procedures by Sunoco, L-Con, and CARBER.

1 Factual Information

This section details the facts gathered by the U.S. Chemical Safety and Hazard Investigation Board (CSB) investigation team.

1.1 Incident Overview

A flash fire and explosion occurred at the Sunoco Nederland terminal on August 12, 2016, during on-going welding by L-Con, a contractor of Sunoco, on a section of piping that contained residual crude oil. The piping was plugged on both ends by CARBER, a subcontractor to L-Con. The incident resulted in injuries to seven contractor personnel. The flash fire and explosion were localized and had no impact offsite nor wide-spread impact to the site other than the immediate area of the incident.

1.2 The Sunoco Nederland Terminal

The Sunoco Partners Marketing and Terminals (SPMT) Nederland Terminal, located on the Sabine-Neches waterway between Beaumont and Port Arthur, Texas, is a large terminal providing storage and distribution services for refiners and other large transporters of crude oil, butane, and propane. The terminal receives (by pipeline, vessel, rail, and truck), stores, and distributes (by pipeline and vessel) crude oil, butane, and propane. The terminal has over 70 above ground storage tanks (ASTs) dedicated to crude oil. An overhead depiction of SPMT can be seen in **Figure 1** below, as outlined in yellow. The other storage tanks west of the SPMT facility are not owned/operated by SPMT.

Figure 1. Overhead view of Nederland terminal. (Credit: Google Earth; Adapted by CSB)

At the time of the incident, Sunoco Logistics Partners L.P. was a subsidiary of Sunoco, Inc. As of the time of this report, the Sunoco Nederland Terminal now does business as Energy Transfer Nederland Terminal, LLC (as of 01/01/2022) and is a subsidiary company of Energy Transfer. Throughout the report, the company will be referred to as Sunoco.

1.2.1 Crude Oil Terminal Process

The Nederland terminal is organized into zones of crude oil ASTs. Each of these zones has a piping manifold that contains valves for directing crude oil to and from the ASTs. From a central control room, operators transfer crude oil from pipelines to tanks (receiving crude oil), from tanks to pipelines (distributing crude oil), from tanks to other tanks (storing crude oil), or from rail or vessels to and from tanks. **Figure 2** below is a view of one of the piping manifolds in the facility, known as the central manifold.

The manifold where the incident occurred is referred to as the Central Manifold because it is physically located in the middle of the terminal. The Central Manifold is used to provide connections from pipelines to ASTs within the terminal and to transport oil between ASTs located in that region of the terminal.

Figure 2. View of central manifold (west facing view). (Credit: CSB)

1.2.2 Description of area surrounding the incident

Figure 3 shows the area surrounding the Sunoco Nederland Terminal. The area within the yellow circle is within a one-mile radius of the incident location. The Sunoco Nederland Terminal is in a primarily industrial area but is within approximately 0.5 miles (2640 feet) of a residential area.

Figure 3. Area surrounding the incident. Area within the circle is a three-mile radius from the Sunoco Nederland Terminal (Credit: Google Earth)

There are three cities that surround the Sunoco Nederland Terminal: Central Gardens, Nederland, and Port Neches, as seen in **Figure 4** below. The orange circle on the map indicates the location of the incident at the terminal.

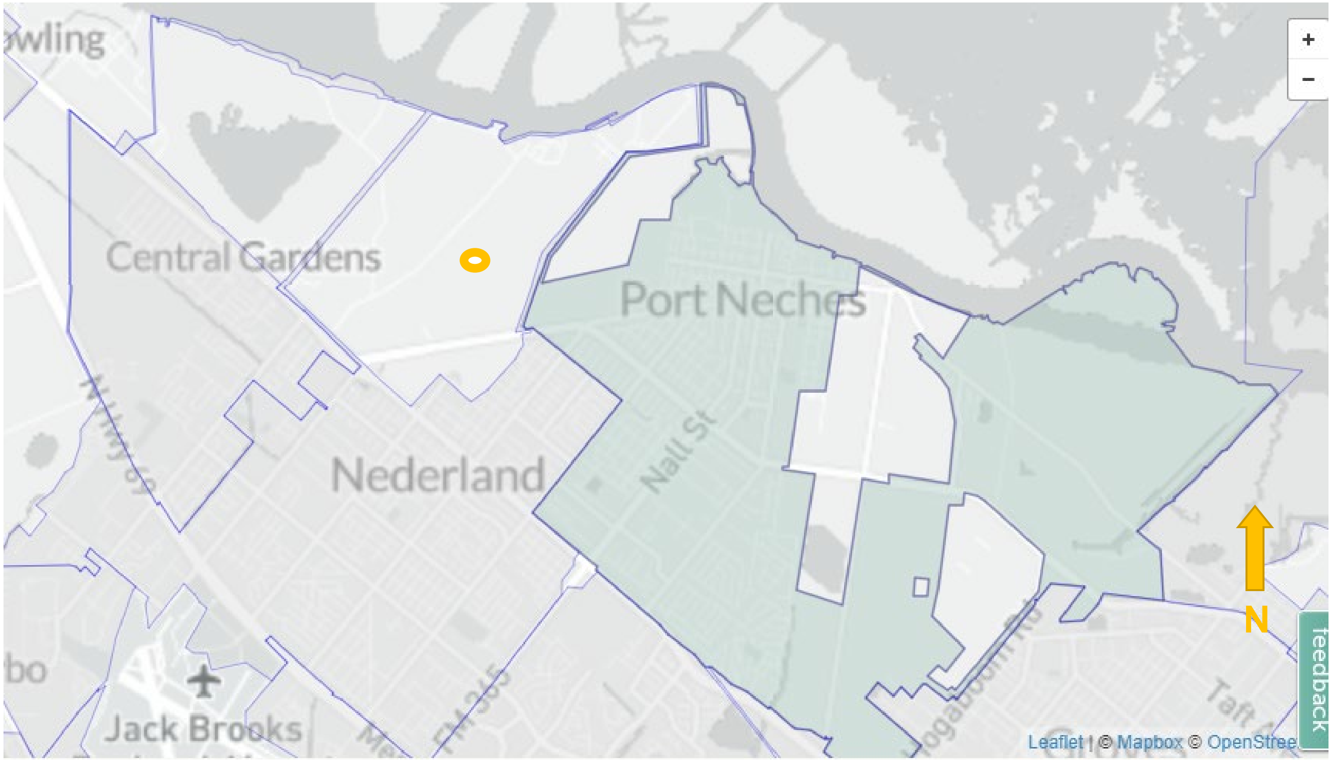

Figure 4. Cities that surround the Sunoco Nederland Terminal (Credit: Census Reporter, Adapted by the CSB)

Demographic information [1] [2] [3], about these three bordering cities, is in **Table 1** below.

City	Population	Median Age	Race and Ethnicity	Per Capita Income	Number of Housing Units	Types of Structures
Central Gardens	3,621	53.3	White: 90% Black: 0% Asian: 4% Hispanic 4% Two+: 3%	$40,494	1,866	Single unit: 72% Multi-unit: 16% Mobile home: 12% Boat/RV/Van/etc.: 1%
Nederland	17,334	36.5	White: 83% Black: 4% Asian: 2% Hispanic: 10% Two+: 2%	$36,316	7,650	Single unit: 85% Multi-unit: 11% Mobile home: 3% Boat/RV/Van/etc.: 0%
Port Neches	12,729	38.9	White: 81% Black: 2% Asian: 2% Hispanic: 9% Two+: 5%	$38,626	5,178	Single unit: 87% Multi-unit:10% Mobile home: 2% Boat/RV/Van/etc.: 0%

Table 1: Demographic information of area surrounding incident location (Credit: Census reporter, Adapted by CSB)

1.3 Other Crude Oil Terminals in the United States

Crude oil terminals are prevalent throughout the United States. There are many crude oil terminal facilities in the country, like the Sunoco Nederland Terminal. **Figure 5** maps the locations of the over 1,400 oil terminals across the U.S. [4]

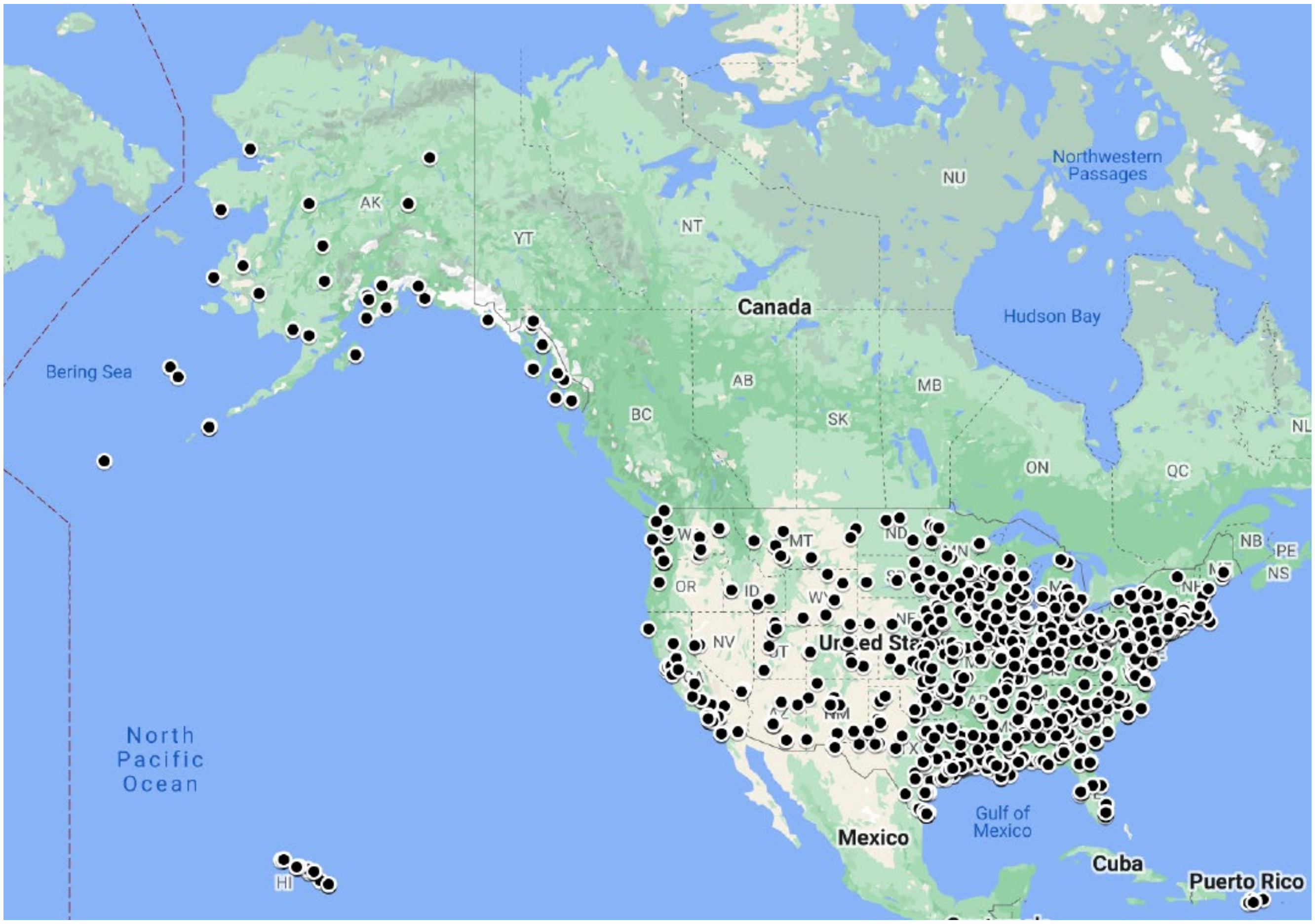

Figure 5: Locations of similar crude oil terminals throughout the United States. (Credit: U.S. Energy Information Administration)

1.4 Flammability Hazards of Crude Oil

Crude oil is a mixture of hydrocarbons that exist in liquid phase in natural underground reservoirs and remains liquid at atmospheric conditions after passing through surface separating facilities [5]. The characteristics of crude oil can vary based on where the crude oil originates. Crude oil can consist of varying amounts of hydrocarbons that are flammable and combustible, sulfur compounds, and various metals [5].

Figure 6 below shows the hazards identified on an SDS of some of the last contained material (crude oil) in the piping involved in the incident at the Nederland terminal.

2. HAZARDS IDENTIFICATION

Hazard Classification:

- Flammable Liquids – Category 1
- Acute Toxicity – Category 2
- Skin Irritation – Category 2
- Eye Irritation – Category 2A
- Toxic to Reproduction – Category 2
- Germ Cell Mutagenicity – Category 2
- Carcinogenicity – Category 1
- Specific Target Organ Toxicity
  - Single Exposure – Category 3
- Specific Target Organ Toxicity
  - Repeat Exposure – Category 2
- Aquatic Toxicant – Category 3

Emergency Overview: Danger. Extremely flammable liquid and vapour. Harmful if swallowed or inhaled. May cause respiratory and mild skin irritation. May cause serious eye irritation. May cause drowsiness or dizziness. May cause damage to organs (liver, kidneys, blood, nervous system and skin) through prolonged or repeated exposure. The benzene component of this material may cause cancer and is suspected of causing genetic effects. Harmful to aquatic life.
Sulfur compounds in this material may decompose to release hydrogen sulfide gas which may accumulate to potentially lethal concentrations in enclosed air spaces.

Prevention: Obtain special instructions before use. Do not handle until all safety precautions have been read and understood. Keep container tightly closed. Keep cool.
Keep away from heat, sparks, open flames and hot surfaces. No smoking.
Take precautionary measures against static discharge. Ground/bond container and receiving equipment. Use explosion-proof equipment and non-sparking tools where conditions may generate an explosive atmosphere.

Figure 6. Image of the SDS identified hazards associated with one of the last crude oils in the piping involved in the incident at the Nederland terminal. (Credit: Cenovus via Sunoco)

According to the identified hazards on the SDS, crude oil is a Category 1 flammable liquid, meaning the flashpoint of crude oil is below 73.4 °F [6, p. 3]. The flashpoint of a liquid is the minimum temperature at which a liquid gives off vapor…in sufficient concentration to form an ignitable mixture with air near the surface of the liquid [6, p. 2]. The SDS as shown in **Figure 7** below) also states that vapors can ignite rapidly when mixed with air and exposed to sources of ignition and can explode if the vapor/air mixture is confined when exposed to an ignition source. It also states that empty vessels that previously contained crude oil may contain explosive vapors, so it is cautioned not to cut, weld, or expose such vessels to sources of ignition.

5. FIREFIGHTING MEASURES

General Fire Hazards:
See Section 9 for Physical and Chemical Properties related to flammability.
Vapours may be ignited rapidly when exposed to heat, spark, open flame or other source of ignition. When mixed with air and exposed to an ignition source, flammable vapours can burn in the open or explode in confined spaces. Being heavier than air, vapours may travel long distances to an ignition source and flash back. Runoff to sewer may cause fire or explosion hazard.

Figure 7. SDS firefighting measures and handling & storage requirements. (Credit: Cenovus via Sunoco)

The ignitable concentration of flammable vapors in air is typically referred to as the range between the upper explosive limit (UEL) and the lower explosive limit (LEL). [4] According to the SDS (as depicted in **Figure 8** below) the LEL of the material in the pipe was estimated to be 0.8% by volume and the UEL was 8% by volume. This means that any concentration of flammable vapors between 0.8% and 8% by volume will ignite and subsequently explode when confined.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	Liquid	**Appearance:**	Brown/black liquid
Odour:	Hydrocarbon-like	**Odour Threshold (ppm):**	Not Available
Specific Gravity:	0.91-0.94	**pH:**	Not Available
Vapour Pressure (mmHg):	375-525@ 38°C	**RVP (kPa):**	50-70
Vapour Density (air=1):	2.5-5.0 (estimated)	**Evaporation Rate:**	Not Available
Boiling Range (°C):	-1-400+	**Initial Boiling Pt. (°C, D86):**	36
Flash Point (°C) & Method:	<-35 (PMCC)	**Freezing Pt. (°C):**	<-60
Upper Explosive Limit (% v/v):	8 (estimated)	**Lower Explosive Limit (% v/v):**	0.8 (estimated)
Auto-Ignition Temp. (°C):	250 (estimated)		
Sensitivity to Impact:	No	**Sensitivity to Static Discharge:**	Yes, at normal temperatures.
Octanol/Water Coefficient:	<0.1	**Solubility in Water:**	Negligible

Figure 8. Section 9 of SDS showing Physical and Chemical properties of crude oil (Credit: Cenovus via Sunoco)

1.5 Contractors

1.5.1 Cleveland Integrity Services

Cleveland Integrity Services (CIS) is a company that offers many services for pipeline, refinery, and power plant projects including construction management services [8]. CIS was hired by Sunoco to provide all materials, tools, equipment, labor, and supervision for Inspection Services for capital projects. CIS's primary function was to serve as a quality control function to Sunoco by ensuring that contractors were following quality control methods for their work (i.e., welding quality) and completing the work as designated by the scope of work. CIS also scheduled and coordinated the work planned and completed, while providing general oversight and management of the contractors on-site and keeping up with execution of scope of work for all the contractors. With the scheduling and coordination of work scope as their responsibility, CIS employees were also given the authority to issue work permits on behalf of Sunoco.

1.5.2 L-Con, Inc.

L-Con, Inc. (L-Con) was a Houston, Texas-based engineering, construction, and construction management company that provided services to the petrochemical, refineries, gas processing, and steel industries [9]. L-Con (now known as "Lexicon Energy Services") remains a subsidiary company of the parent Lexicon Holding Company, which is headquartered in Little Rock, Arkansas. However, on January 2, 2017, Lexicon reorganized and ceased operating as L-Con, Inc.

L-Con supported the expansion project at the Nederland terminal since the beginning of the project, in April 2016.

According to the terms set in *Appendix A, Scope of Work* document of the executed Master Service Agreement, Sunoco contracted L-Con to perform the following activities related to the incident:

> Assist Sunoco operations and owner representative in draining of lines for multiple tie-ins[a] of various sizes
>
> When making welded tie-ins to existing piping that has been in service, the contractor will need to cold cut[b] the piping after it has been depressurized and drained.
>
> The contractor shall provide the necessary labor, equipment and materials for the complete installation of 2", 8", 12", 20", 26", 30" and 36" above ground piping, valves and fittings…
>
> The contractor shall provide continuous air monitoring and LEL[c] monitoring during all hot work activities.
>
> Additional labor shall include fire watch personnel at the site. Firewatch must remain at post, until 30 minutes after all welding has been completed. All contractor employees are required to obtain work permits and attend a pre-job safety meeting prior to commencing work each day…

1.5.3 CARBER

CARBER was a privately owned global specialty industrial service company based in Houston, Texas, and offered services including weld testing, pipe cutting, and line isolation [10]. In January 2019, CARBER was acquired by HydroChemPSC [8]. Additionally, in October 2021, Clean Harbors acquired HydroChemPSC [12]. Since the acquisitions happened after the August 12, 2016, incident, this report refers to the company as CARBER and its company specific isolation device, referred to in this report as the CARBER Isolation Tool.

Piping isolation devices are used to create a barrier between the hazards internal to the pipe and the external conditions, atmosphere, and/or people in the area. For the work at the Nederland Terminal, L-Con subcontracted CARBER to complete the cold cuts of the piping and the piping isolation using their own patented isolation tool to isolate sections of piping and create a physical barrier between workers and residual hydrocarbon contents in the pipe.

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[a] The term 'Tie-in' is generally used to describe the connection of a pipeline to a facility, to other pipeline systems or the connecting of different sections of a single pipeline. It also refers to additions or modifications to existing systems, for example to connect re-construction pipelines, insert Tees, spool pieces, valves etc. (Source: http://members.igu.org/html/wgc2006/pdf/paper/add11373.pdf)

[b] Cold cutting refers to cutting pipe without the use of heat, a flame, or producing sparks.

[c] LEL is defined as the minimum concentration of a particular combustible gas or vapor necessary to support its combustion in air. (Source: HSSE World https://hsseworld.com/what-is-meaning-of-lel-uel-pid/)

1.6 CARBER Isolation Tool

The CARBER isolation tool is a piping isolation device, designed and patented by CARBER. CARBER markets these devices as having the ability to isolate piping for hot work by creating a positive pressure vapor barrier against residual contents in the pipe. CARBER suggests, in addition to providing a barrier between the piping contents and the work external to the piping, it also has a means to ensure the seal's continued integrity by monitoring the system (**Figure 9** below shows an example schematic). According to CARBER, the ability to monitor the seal's integrity is essential to the CARBER isolation tool, especially since it intended to provide a barrier to hazardous conditions inside the pipe.

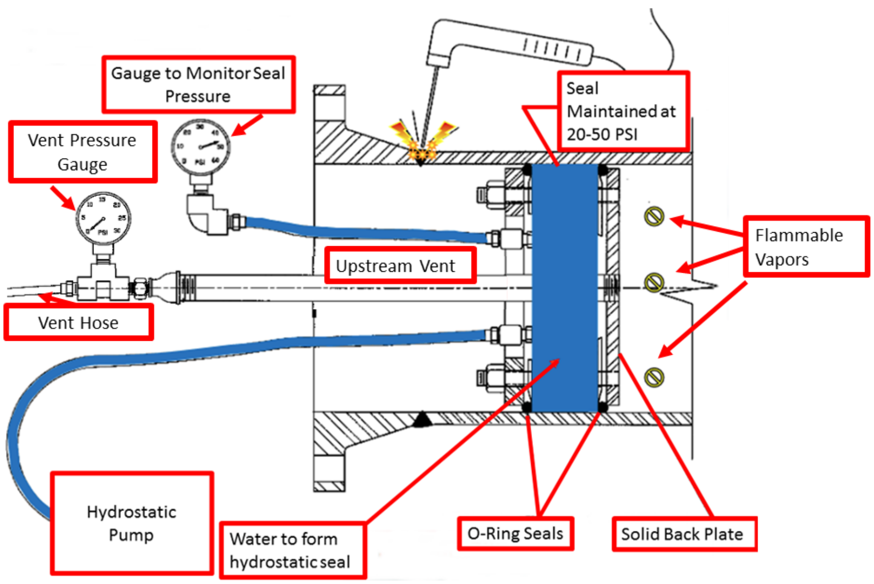


Figure 9. Depiction of CARBER Isolation Tool configuration per CARBER's procedures. (Credit: CARBER; Adapted by CSB)

For the piping work at the Nederland terminal, CARBER provided isolation devices for various piping sizes, from two-inch diameter piping up to 36-inch diameter piping.

The Isolation Tool provides a means to monitor the seal integrity using a pressure gauge attached to the water outlet. If no leaks are found and the water pressure holds steady, the isolation tool seals are proven (or verified).

Once the seals are proven, CARBER procedures call for installing a central vent pipe, fittings, a 0-15 psig vent gauge and vent hose to safely route vapors away (at a minimum 50 feet) from the hot work.

1.7 Incident Description

1.7.1 Preparing Seaway Header for Hot Work

To prepare for the spool piece installation, Sunoco operators ceased crude oil flow and drained the piping through that piping segment. Then, an L-Con worker inserted a piece of PVC piping through an existing two-inch vent to gauge how much crude oil remained in that section of piping. L-Con and Sunoco workers determined there was approximately one-and-a-half-inches to two-inches deep level of crude oil that remained.

L-Con workers began to open the pipe by removing bolts from a flange so that excess oil could drain from the system into a large, plastic containment pool. The crude oil, drained to the containment pool, was removed via vacuum truck to be reclaimed.

Once the crude oil was drained, CARBER was given permission to begin the cold cuts on the piping section. Cold cutting the piping was necessary to remove a section of piping safely, due to the crude oil that remained in the piping, so that the new required spool piece could be installed. The new spool piece was required to facilitate the movement of crude oil to the new tanks Sunoco was having installed.

After cold cutting the pipes, CARBER then installed their company's isolation tool to provide a barrier between the contents inside the piping segment and the external hot work activities.

1.7.2 Seaway Header Hot Work Permitting

Once the CARBER isolation tools were installed and the spool piece moved into position, hot work could commence.

Prior to starting the hot work the day of the incident, L-Con conducted a JHA (Job Hazard Analysis), seen in **Figure 10**.

L-CON, INC.

JOB HAZARD ANALYSIS

Location: Sunoco Logistics/ Nederland, Texas **Date:** 8-12-16 **Shift:** Nights **Time:** 6:30 AM PM

Work Area: Control manifold **Contact Person:** [redacted]

Job Description: Cut prep fit and weld 30" header slip on f/g flying spool bolt up/scaffold work

(Use Work Process and Task Breakdown Worksheet on reverse side of this form to help breakdown and analyze the job.)

Mobile Equipment #: Crane **Sunoco Permit #:** 886841

Use lists below to *help* identify hazards and controls for the job. Don't limit yourself to this list alone.

Task-Associated Hazards	Work Area Hazards	Required Controls
☑ Fall hazards (existing or potential)	☑ Unstable, deteriorated or unsecured walking or working surface	☑ PPE – See below
☑ Overhead hazards (falling object potential)	☑ Uneven or slippery walking or work surface	☑ Permits – See below
☑ Demolition	☑ Moving equipment/materials above, below, or nearby	☑ Lockout / Tagout / Tryout
☑ Cranes (overhead or mobile)	☑ Other workers - above, below or nearby	☑ Task-specific training
☑ Rigging and rigging equipment	☑ Access problems (elevated, tight spots, etc.)	☑ Optional tools/equipment for the job
☑ Mobile equipment (aerial lift, forklift, loader)	☐ Confined space	☑ Material handling equipment
☑ Ladders or scaffold	☑ Inadequate lighting	☑ Additional lighting
☐ Potential energy sources	☑ ~~Poor ventilation,~~ dust, fumes, smoke, vapors	☐ Mechanical ventilation
☐ Tool hazards (hand, electric, mechanical)	☑ Electrical shock potential	☑ Barricades & barricade tape/signs
☑ Hot work (burns, fire, explosion)	☑ Process Safety (leaks, pressurized lines, etc.)	☐ Horizontal or vertical lifeline system
☑ Fumes from welding/cutting (copper, stainless, galvanized, etc.)	☑ Temperature extremes or weather concerns	☑ Communication with other parties
☑ Cutting/grinding/chipping (dust, flying debris, sparks)	☑ High noise levels	☑ Radio communication or hand signals
☑ Chemicals (solvents, cleaners, paints, etc.)	☑ Struck against hazards (hot, sharp or projecting objects)	☑ Fire extinguishers or blankets
☑ Pinch points (caught in)	☑ Excavations, pits or trenches	☑ Fire Watch
☑ Manual material handling(lift,carry,push, pull)	☑ Poor housekeeping (tripping or fire hazards)	☐ Barricade Watch
☑ Body position (stretch, bend, stoop)	☐ Other	☐ Confined Space Attendant
☐ Other		☐ Other

Mandatory PPE: ☒ Hard Hat ☒ Steel-toe, leather work boots ☒ Safety Glasses with Side Shields

Additional PPE: ☑ Hearing Protection ☑ Full Body Harness w/2 Lanyards ☐ Dust Mask / Respirator

☑ Grinding Shield ☑ Cutting Shield ☐ Tyvek Cover-all Suit ☐ Chemical Resistant Gloves

☑ Leather Work Gloves ☐ Welding Gloves ☐ Fire Retardant Clothing (Leathers or Greens) ☐ Fire Resistant Suit (Silver Suit)

Permits:

Permits Required for: ☐ Confined Space ☑ Hot Work ☐ Crane Interference ☒ Other Safety

Permits Signed by: ☑ Supervisor ☑ Affected Employees ☑ Excavator/Crane Operator ☒ Customer Supervisor

I have read & understood the JHA and agree to follow to all safety precautions and procedures to complete this job safely. All employees *MUST* sign before starting work.

Figure 10. L-Con JHA (Credit: L-Con)

L-Con identified a variety of hazards on the JHA checklist for the welding work planned at the Nederland terminal, including:

- Task-Associated Hazards:
  - Hot work (burns, fire, explosion)
  - Fumes from welding/cutting (copper, stainless, galvanized, etc.)
  - Cutting/grinding/chipping (dust, flying debris, sparks)

- Chemicals (solvents, cleaners, paints, etc.)

- Work Area Hazards:
  - Dust, fumes, smoke, vapors
  - Process safety (leaks, pressurized lines, etc.)
  - Poor housekeeping (tripping or fire hazards)
- Required Controls:
  - Permits (Hot work & Safety)
  - Lockout / Tagout / Tryout
  - Barricades & barricade tape/signs
  - Fire extinguishers or blankets
  - Fire watch

After identifying the hazards and required controls, the back of the form is to be used to identify the task steps of the job, associated hazards, and how to eliminate or manage those hazards. On the evening of the incident, L-Con employees completed this part of the JHA, which is shown in **Figure 11**.

Reminder: **Update / Revise JHA as job scope / hazards change**

Tasks Steps(Include tools)	Hazards	How will hazards be eliminated or managed? (Include add. PPE)
1 set up work area	pinch points/sharp obj	Watch your hand position wear
	over head Loads	proper ppe
2 gather all tools & material	uneven surfaces	stay out of the Line of Fire
	FAll Potentiall	Use good comunication with
3 bolt up & work / scaffold	FAlling Hazards	crane operador and co-workers
work	welding sparks/ and grinding	Stay 100% tie off and secure
4 cut prep fit and weld 30"	miss communication	all tools and material
slip on Flgs	blind spots	stay focus of your work
5 Flying spool into control	High pressure plug	TASK and Keep good communication
manifold/ Crane / ForkLift		

Area Hazards	How will hazards be eliminated or managed (Include add. PPE required)
Over head Loads	stay out of the line fire and use
pinch points / sharp obj	good communication with crane operador
uneven surfaces	Watch your step and stay focus be
blind spots	Alert
FAlling Hazards / Fall Potential	Stay 100% tie off and secure all tools and material.

Fall Protection required: Yes [✓] No [ ] Inspection tag signed for current shift? Yes [✓] No [ ]

If yes, specify tie off point(s): Scaffold

Scaffold required: [✓] yes [ ] no

If scaffold tag is YELLOW, list associated hazards: (IF SCAFFOLD HAS RED TAG OR NO TAG, DO NOT USE!)

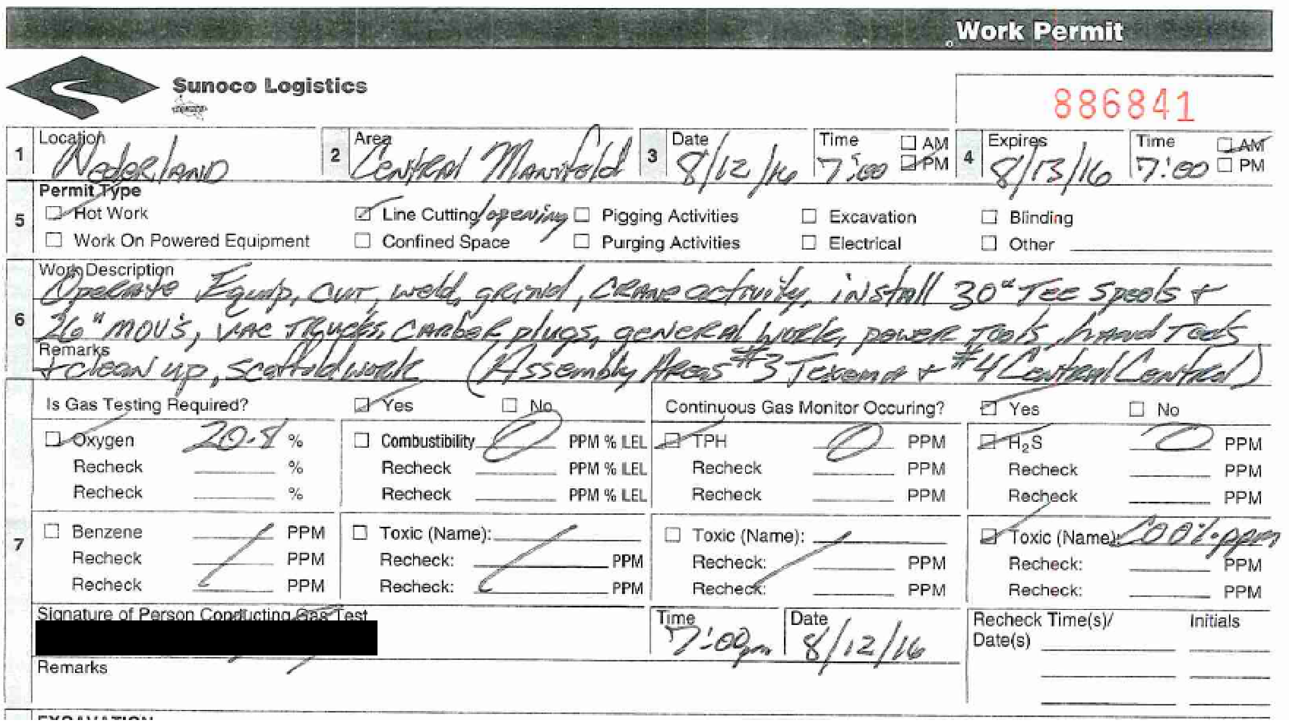
AT THE END OF SHIFT, TURN IN JHAs TO YOUR SUPERVISOR

Figure 11. L-Con JHA prior to conducting hot work (Credit: L-Con)

Note that L-Con identified “welding sparks/ and grinding” as a hazard associated with this job task.

A CIS employee, on behalf of Sunoco, then issued a hot work permit to L-Con, permitting them to start welding.

Figure 12 and **Figure 13** show the relevant portions (Sections 1-7 & 10-16) of the hot work permit that was issued the evening of the incident. Sections 8 & 9 of the hot work permit were labeled “Not Applicable” (N/A).



Work Permit

Sunoco Logistics

886841

1 Location: Nederland	2 Area: Central Manifold	3 Date: 8/12/16 Time: 7:00 ☐ AM ☑ PM	4 Expires: 8/13/16 Time: 7:00 ☑ AM ☐ PM

5 Permit Type
☑ Hot Work ☑ Line Cutting/opening ☐ Pigging Activities ☐ Excavation ☐ Blinding
☐ Work On Powered Equipment ☐ Confined Space ☐ Purging Activities ☐ Electrical ☐ Other

6 Work Description: Operate Equip, cut, weld, grind, crane activity, install 30" Tee spools & 26" MOV'S, vac trucks, carbon plugs, general work, power tools, hand tools
Remarks: + clean up, scaffold work (Assembly Areas #3 Terminal & #4 Central Control)

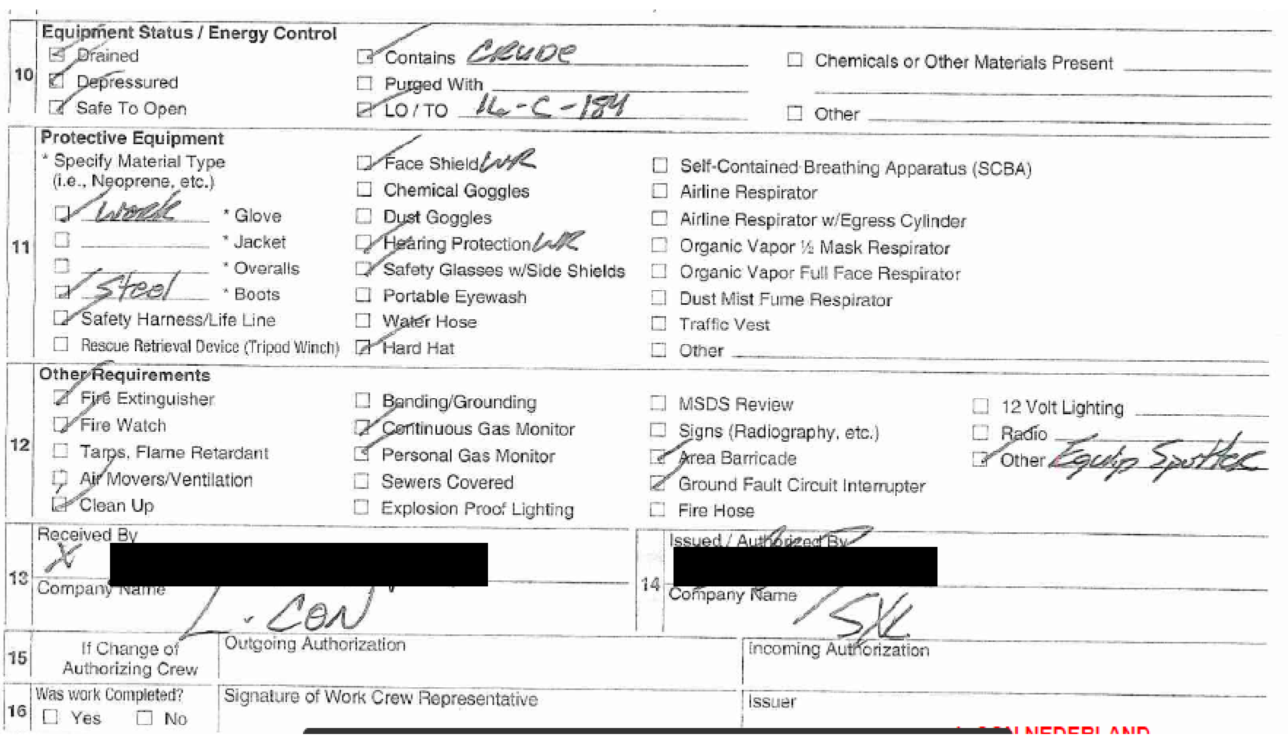
7 Is Gas Testing Required? ☑ Yes ☐ No — Continuous Gas Monitor Occuring? ☑ Yes ☐ No

☑ Oxygen 20.9 %	☐ Combustibility 0 PPM % LEL	☑ TPH 0 PPM	☑ H_2S 0 PPM
Recheck ___ %	Recheck ___ PPM % LEL	Recheck ___ PPM	Recheck ___ PPM
Recheck ___ %	Recheck ___ PPM % LEL	Recheck ___ PPM	Recheck ___ PPM
☐ Benzene ___ PPM	☐ Toxic (Name): ___	☐ Toxic (Name): ___	☑ Toxic (Name): 100% ppm PPM
Recheck ___ PPM	Recheck: ___ PPM	Recheck: ___ PPM	Recheck: ___ PPM
Recheck ___ PPM	Recheck: ___ PPM	Recheck: ___ PPM	Recheck: ___ PPM

Signature of Person Conducting Gas Test [redacted] — Time 7:00pm — Date 8/12/16 — Recheck Time(s)/Date(s) — Initials

Remarks

Figure 12. Top portion of hot work permit issued by Sunoco (Credit: Sunoco)



10 Equipment Status / Energy Control
☑ Drained ☑ Contains CRUDE ☐ Chemicals or Other Materials Present
☑ Depressured ☐ Purged With
☑ Safe To Open ☑ LO / TO 16-C-184 ☐ Other

11 Protective Equipment
* Specify Material Type (i.e., Neoprene, etc.)
☑ Work * Glove ☑ Face Shield WR ☐ Self-Contained Breathing Apparatus (SCBA)
☐ * Jacket ☐ Chemical Goggles ☐ Airline Respirator
☐ * Overalls ☐ Dust Goggles ☐ Airline Respirator w/Egress Cylinder
☑ Steel * Boots ☑ Hearing Protection WR ☐ Organic Vapor ½ Mask Respirator
☑ Safety Harness/Life Line ☑ Safety Glasses w/Side Shields ☐ Organic Vapor Full Face Respirator
☐ Rescue Retrieval Device (Tripod Winch) ☐ Portable Eyewash ☐ Dust Mist Fume Respirator
☐ Water Hose ☐ Traffic Vest
☑ Hard Hat ☐ Other

12 Other Requirements
☑ Fire Extinguisher ☐ Bonding/Grounding ☐ MSDS Review ☐ 12 Volt Lighting
☑ Fire Watch ☑ Continuous Gas Monitor ☐ Signs (Radiography, etc.) ☐ Radio
☐ Tarps, Flame Retardant ☑ Personal Gas Monitor ☑ Area Barricade ☑ Other Equip Spotter
☑ Air Movers/Ventilation ☐ Sewers Covered ☑ Ground Fault Circuit Interrupter
☑ Clean Up ☐ Explosion Proof Lighting ☐ Fire Hose

13 Received By [redacted] Company Name L-CON
14 Issued / Authorized By [redacted] Company Name SXL

15 If Change of Authorizing Crew — Outgoing Authorization — Incoming Authorization

16 Was work Completed? ☐ Yes ☐ No — Signature of Work Crew Representative — Issuer

Figure 13. Bottom portion of hot work permit issued by Sunoco (Credit: Sunoco)

The issued hot work permit required a fire watch, fire extinguisher, and a continuous flammable gas monitor for the job. A continuous monitor was mounted on the railing close to where welding was occurring. **Figure 14** shows the location of the continuous monitor at the time of the incident. There were no accounts from the welders that the continuous monitor alarmed at any time during welding activities, which would be indicative of flammable vapors in the area.

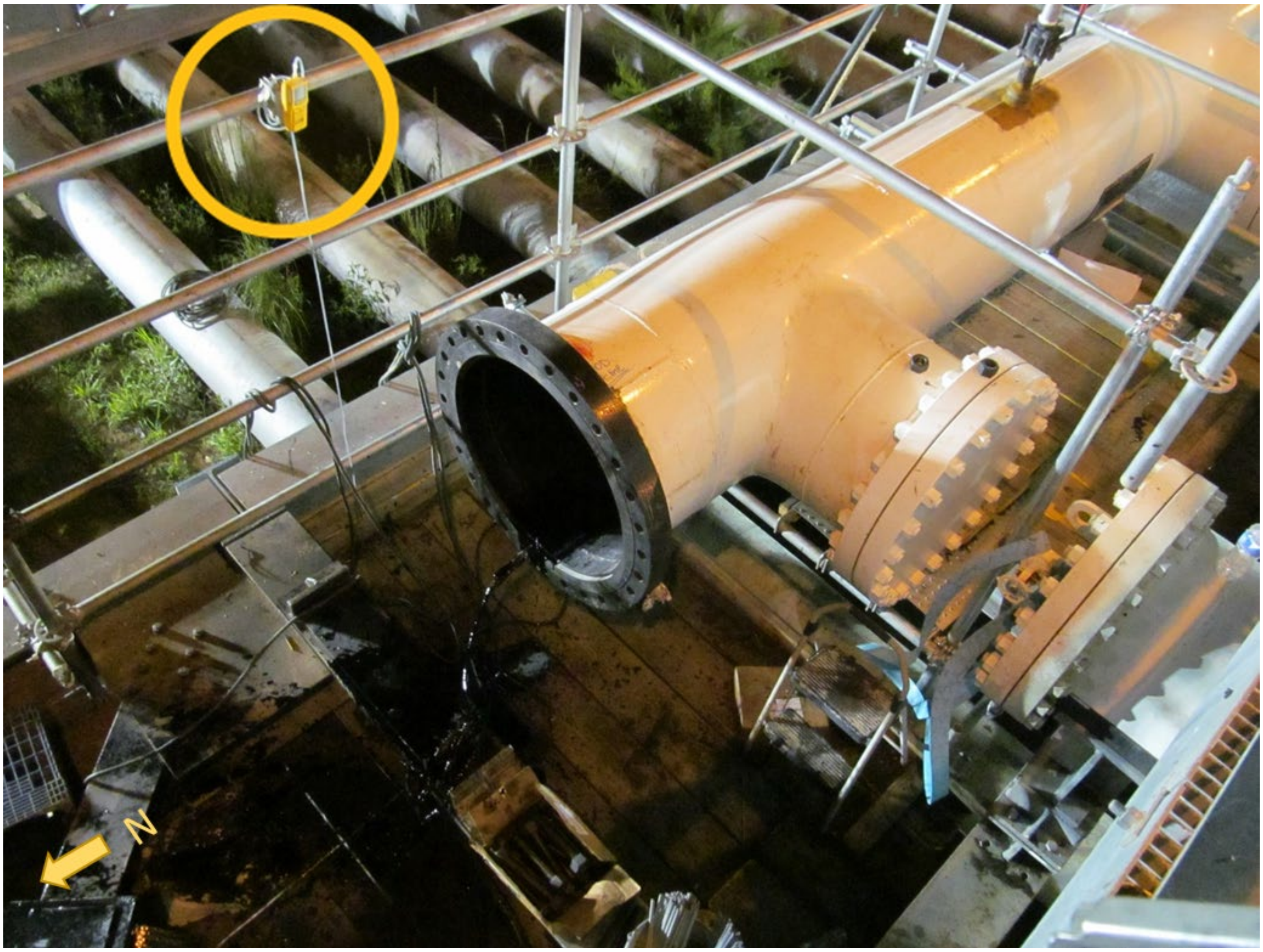


Figure 14. Location of continuous atmospheric monitor (inside yellow circle) at the location of on-going welding. (Credit: CSB)

According to the work permit issued the night of the incident, atmospheric testing was conducted at 7:00 p.m. and did not detect any flammable vapors. There were no accounts of the specifics on the exact location(s) of where atmospheric testing was conducted.

1.7.3 Welding the Pipe

During the day shift on Friday, August 12, 2016, L-Con contractors began welding flanges, using a welding process called arc welding[a], onto the piping. Flanges were required to connect the spool piece to the existing piping that had been cut. Connecting the flanges to the cut ends of the piping requires two full welds, one on the outside and one on the inside of the flange. **Figure 15** shows the flanges (in red) that were added, where the spool piece was being added in the line, where the pipe was vented through the hose on top of the pipe, and where the CARBER isolation tools were installed (orange).

During the remainder of the day shift, L-Con contractors worked to weld the flanges onto the piping. The flanges require two full welds, one on the outside and one on the inside of the flange. By the start of the night shift, an internal and external weld was completed on Flange "C", and welders began working at both flange "B" and flange "A" to complete the rest of the welds (**Figure 15**). A few hours into the Friday night shift, external welds for all three flanges had been completed. Around 6:20 p.m., the welding work on flanges "A" and "B" was nearly complete and only finishing touches remained for the night shift to complete. At approximately 8:00 p.m., a supervisor went to check on the work being done around flange "A." The supervisor saw the hot work was nearly complete and workers were performing some grinding finishing work around the external weld.

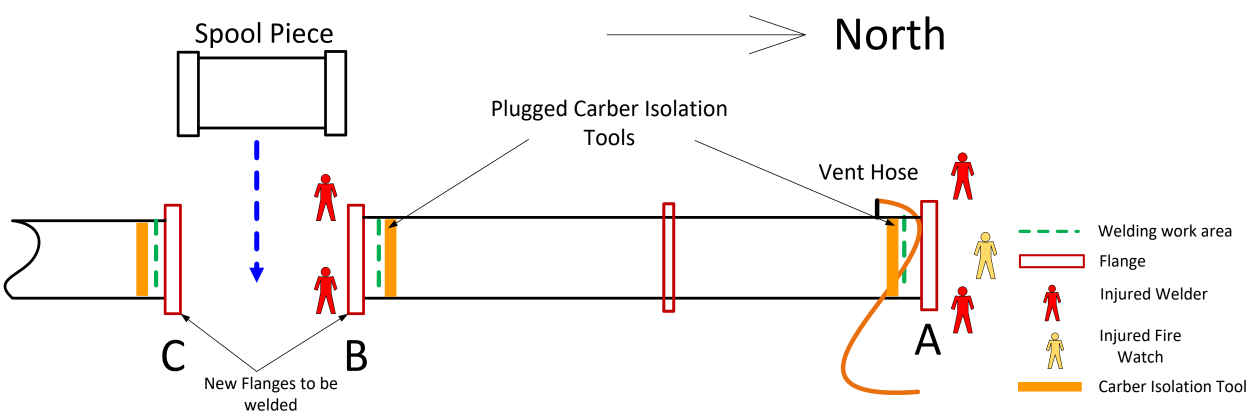


Figure 15. Depiction of pipeline work and location of some workers. (Credit: CSB)

1.7.4 Flash Fire and Explosion

After completing external welding on the spool piece, the L-Con welders began working on the internal welds of the A flange during the night shift on Friday, August 12, 2016.

After approximately three to four inches of welding the inside surface of the flange, vapor inside the piping, between two of the installed CARBER isolation tools, ignited. The ignition initiated a pressure spike that, in

[a] Arc welding is defined here: https://www.twi-global.com/technical-knowledge/faqs/what-is-arc-welding

turn, caused the isolation tools at flanges A and B (**Figure 15**), to blow out of the open pipe at the north and south ends.

The forced ejection of the isolation tools and the flash fire from the pipe section injured seven contractors, including four welders, one fire watch, and two other contractors.

The four of the seven injured were transported to the hospital (via helicopter and ambulance) and treated for burns, bone fractures, and other blast related injuries. Three of the seven injured were treated for minor injuries and released.

Figure 16 below shows the piping segment where the flash fire and explosion occurred. **Figure 17** below also shows black soot on the side of the building where the crude oil and flash fire impacted the building at the time of the incident.

Figure 16. Piping segment where flash fire and explosion occurred. (Credit: CSB)

Figure 17. West-facing view of the section of piping where welding work was ongoing (on the north end) at the time of the incident. (Credit: CSB)

1.7.5 Weather at Time of Incident

Data from the Jack Brooks Regional Airport Station indicate that on August 12, 2016, at 7:53 p.m. CST, the temperature was 84° F with and an 8-mile-per- hour (mph) wind blowing from the south-southwest (SSW) [12].

1.7.6 Incident Responders

L-Con and CIS employees called 911 at approximately 8:40pm CST and dispatched the Nederland fire and police departments, the Jefferson County Emergency Response Sheriff's office, and the USCG.

Jefferson County Sherriff's Office responded to the scene to control the site and scene. They arrived on scene at approximately 8:52pm.

Nederland Fire Department also arrived at approximately 8:54pm. While heading to Sunoco, they contacted Acadian, an EMS service, and Air Rescue, a life flight service, to transport injured workers. The fire department team established a triage area to begin monitoring and caring for the injured workers until the EMS services reached the site.

1.8 Post-Incident Actions

In February 2017, L-Con was cited and issued fines by OSHA for multiple violations of OSHA regulations, including not utilizing their company's procedures to control potentially hazardous energy, lack of training of employees on recognizing and controlling hazardous energy sources, not confining the heat, sparks, and slag from welding activities, and for welding in the presence of explosive atmospheres such as uncleaned or improperly prepared equipment that previously contained flammable material [13].

L-Con and OSHA reached a Settlement Agreement, where L-Con received one other than serious violation of 29 CFR 1910.147(d)(5)(ii) for failing to ensure its subcontractor continuously monitored the isolation devices the subcontractor installed until the servicing work was completed or until the possibility of such accumulation no longer existed.

CARBER was also issued a serious citation from OSHA in February 2017 [14] for violation of 29 CFR 1910.147(c)(4)(1).

OSHA did not issue citations to Sunoco. The Sunoco Nederland terminal is regulated by the Pipeline and Hazardous Materials Safety Administration (PHMSA). At the time of the 2016 incident, SPMT considered the area of the incident to be exempt from the jurisdiction of PHMSA. However, PHMSA (Pipeline and Hazardous Materials Safety Administration) cited Sunoco with failure to report the incident, according to the agency's regulatory requirements [15]. Since the incident, however, SPMT has reevaluated the jurisdiction of this area and determined that it is subject to PHMSA regulation.

1.9 Hot Work Policies and Procedures

Sunoco and L-Con had policies and procedures in place to provide direction to employees on how to mitigate the hazards of hot work.

1.9.1 Sunoco's Policies and Procedures

Sunoco provided the CSB with their Master Service Agreement (MSA) with L-Con, which outlined the duties and responsibilities of both Sunoco and L-Con as it related to completion of the piping work at the Nederland terminal. The MSA has multiple exhibits that provide additional detail on scope of work, health and safety requirements, and other business-related details. Sunoco provided the CSB with the defined "Scope of Work" document presented to L-Con in their signed agreement and purchase order.

Per the "Scope of Work" document, Sunoco required the following:

> When making tie-ins to existing piping that has been in service, the contractor will need to cold cut piping after it has been depressurized and drained. Lines will be drained but not hydrocarbon free therefore a "CARBER plug" will need to be utilized to allow welding of the first flange… Contractor to supply necessary "CARBER plugs" and all necessary materials to make tie-ins.

Sunoco also had an *Overview of Work Permits* procedure that required the issuance of work permits for hot work activities. Specific requirements for basic fire protection precautions prior to conducting hot work included:

- Equipment that has been in flammable or combustible service or may be contaminated with hazardous materials shall be purged, made safe, or decontaminated prior to conducting hot work on the equipment.
- Hot work activities that may produce sparks or hot slag, such as welding and cutting, shall be permitted only after taking precautions to ensure that sparks and slag will not ignite combustible materials or flammable vapors.

- If the object to be welded or cut cannot be moved, and if all fire hazards in the vicinity cannot be eliminated, then guards or shielding shall be installed to contain the sparks and slag.
- Approved instrumentation shall be used to monitor flammable and combustible gases in areas surrounding hot work activities and in piping and equipment. A hot work / work permit must not be issued if the instrumentation indicates the presence of flammable or combustible gas greater than 10% of the LEL for the flammable material, or if the concentration of oxygen is greater than 22.5%.
- Continuous monitoring for flammable gases is preferred to ensure safe hot work operations. If it is not practical to conduct continuous monitoring for flammable gases, then monitoring shall be conducted frequently enough to assure safe hot work activities and shall be conducted prior to re-starting hot work activities following work breaks.
- If the above precautions cannot be met, then the hot work operations shall not be performed without further evaluation, an alternate means of protection, and approval by the facility manager or supervisor and a Health and Safety representative.

Sunoco's *Hot Work* procedure also specified how to manage piping that previously contained flammable materials, saying:

> Piping, storage tanks, or associated equipment that have contained… flammable or combustible materials shall be properly isolated and decontaminated (by purging or flushing) prior to approval of any hot work activity on the equipment. …The permitting authority prior to permit approval shall verify isolation and/or decontamination measures taken to assure safety of the operation.

It also stated:

> In situations where piping systems or other process equipment cannot be isolated or fully decontaminated, alternative precautions, such as purging with inert gases, must be established to ensure that welding and cutting can be conducted safely. When inert purge gases are used, precautions shall be taken to ensure employees are not exposed to the purge gases.

1.9.2 L-Con's Policies and Procedures

L-Con provided the CSB with its safety manual, the *Health, Safety, & Environmental (HS&E) Manual*. The manual contains all of L-Con's HS&E policies and procedures, including:

- Welding and Cutting Safety
- Pipe Mechanical Seal Guideline

L-Con's *Welding and Cutting Safety* procedure stated:

> A JHA shall be used to identify and communicate the potential hazards and required safety controls associated with all welding and cutting operations. Special attention shall be given to identification and control of hazards associated with hazardous fumes,

> gases, or dust in the work area. The JHA will be reviewed prior to beginning the work and signed by the Supervisor and all employees working in the area.

L-Con's *Welding and Cutting Safety* procedure also had a section on "Isolating Hot Work on Existing Piping Systems" that stated:

> Special engineering controls are required to eliminate hot work hazards when there is a fire or explosion exposure to the interior of existing piping systems or containers that have contained flammable gases or liquids that cannot be eliminated because the piping system or container cannot be fully opened, removed to a fab yard or thoroughly cleaned.
>
> In these cases, alternative engineering methods for controlling the exposure will be used. Those controls may include a nitrogen or argon blanket to inert the space or a high-pressure plug to isolate the hot work from the interior of the space.
>
> A third-party vendor, approved by the Project Manager and or the customer will be used to implement and monitor both of these types of controls.
>
> A high pressure plug system uses a controlled venting system. The "vent line" controls referenced below must be met when considering the securing of vent lines to the plug and placement of the exhaust end of the vent lines.

L-Con included an addendum, Attachment A: Pipe Mechanical Seal Guideline, to their *Maintenance Safety Procedure*, to define the requirements and limitations of using pipe mechanical seals to ensure safe work practices.

As L-Con defined it, a piping mechanical seal is "a mechanical device used to seal the end of an open pipe."

Attachment A stated:

> A formal JHA will be performed each time a piping mechanical seal device is to be applied. A Reliability Inspector and/or the Pipefitter/Welder Supervisor must participate in the JHA to provide input on appropriateness of the proposed application.
>
> Only CARBER testing services, or equivalent, or better methods may be considered for situations when the line to be sealed normally contains or might reasonably have contained free hydrocarbon with a flash temperature below 140 °F during the last 48 hours of operation prior to removal from service.
>
> A piping mechanical seal device may be used only in the following situations for lines which have contained hydrocarbons or other flammable materials:
>
> - An open end cannot be cleared of flammables for hot work; and
> - Available means of removal of vapors (steam out, water purge, inert purge) has (have) been used before the piping mechanical seal is installed; and

- Liquid is not present in the line within six (6) feet of the hot work to be performed, lest it vaporize from the heat and generate pressure behind the piping mechanical seal device; and
- No other adequate means of vapor isolation exists

1.10 Similar Industry Incidents

1.10.1 Sunoco

On August 17, 2021, Sunoco experienced an incident involving an accidental release that was similar to the subject incident of this report. A contract crew was removing a section of piping to install a new flanged spool piece. The line was opened, vacuumed, and drained of crude oil to prepare for cold cutting the pipe. A blind flange was installed on the south end of the pipe section, and an inflatable isolation plug was installed on the north end of the piping, where the cold cut was made.

A crew member checked the seal with a gas monitor to verify the absence of flammable vapors. When the conclusion was drawn that the pipe was properly sealed, a pipefitter began to prepare the weld area by using an electric portable angle grinder. Shortly after starting the preparation work, the isolation plug failed, and a flash fire occurred at approximately 3:15pm. The incident resulted in one injury of a contractor.

According to Sunoco's internal investigation, the incorrect isolation tool was utilized and failed due to improper installation and incompatibility with petroleum, and allowed flammable vapors to enter the hot work area, leading to ignition.

1.10.2 L-Con

On the morning of June 2, 2012, L-Con was involved in a hot work incident at an Oiltanking Houston facility in Houston, Texas, where a device similar to the isolation tool used in the August 12, 2016, incident was used in a section of piping to isolate crude oil flammable vapor from hot work conducted on a piping segment. The hot work ignited the flammable vapors, causing the isolation tool to blow out of the open end of the pipe. The incident resulted in a worker fatality and OSHA citations to L-Con [16]. **Figure 18** is a picture of the pipe segment that experienced the flash fire and blow out of the isolation tool at the Oiltanking Houston facility in June 2012 (left) and a depiction of the isolation tool as it would have been installed at the time of the June 2012 incident (right).

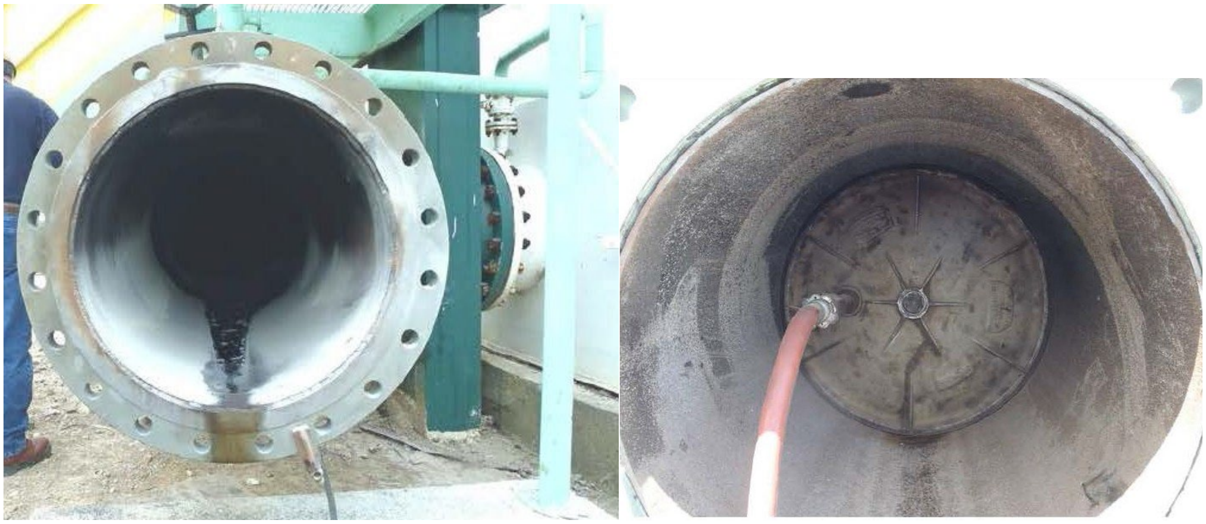


Figure 18. (Left) Crude oil inside pipe post-incident in June 2012. (Right) Isolation tool as it would have been installed in June 2012 incident. (Credit: OSHA)

1.11 Current Sunoco (Energy Transfer) Procedures

In August 2021, the CSB requested information from Energy Transfer for their current SMS structure to compare against the SMS in place at the time of the incident.

Energy Transfer provided the CSB with the following documents:

- Job Plan Procedure
- Preparing Equipment for Maintenance and Repair Procedure
- Work Permits Procedure

1.11.1 Job Plan Procedure

The *Job Plan Procedure* defines the process of creating a job plan for the execution of maintenance or construction work at Energy Transfer facilities.

The procedure requires the development of a job plan for all projects that require the use of isolation devices, as defined in their *Liquid Isolation Devices – Non-Pressure Systems* Standard Operating Procedure, in preparation for hot work. All job plans must include the contact information for all parties involved in the work, all applicable procedures (safety, maintenance, etc.) that will be used throughout the job, and a sequential list of work tasks for the job along with the responsible parties for those tasks.

Energy Transfer requires that all job plans must be reviewed by all necessary personnel (including contractors who have activities associated with the plan) and submitted in advance for approval up to the Division VP or their designee, based on job complexity.

1.11.2 Preparing Equipment for Maintenance and Repair Procedure

The *Preparing Equipment for Maintenance and Repair* procedure defines the requirements for preparing equipment prior to any maintenance or repair activities and provides guidance on isolation, depressurizing, cleaning/purging, and atmospheric monitoring of equipment that contains or has contained hydrocarbons.

The procedure states:

> Once the piping and equipment are isolated and depressured, purge any remaining hydrocarbon vapors and/or liquids from the equipment before any maintenance or repair activity can begin. Note: The most common purging materials for hydrocarbons are nitrogen, air, or water.
>
> Check the piping/equipment with a portable gas detector to verify the equipment is clear of hydrocarbons before maintenance or repairs begin.

1.11.3 Work Permits Procedure

The *Work Permits* procedure defines requirements for the issuance of Hot Work permits. The procedure requires a Hot Work permit to be issued for all activities that produce a source of ignition from flame, spark, or heat in a hot work permit required area, as defined in the procedure.

The *Work Permits* procedure requires atmospheric testing be conducted "on valves, piping, flanges, and other equipment around the area where hot work is being conducted." It also states:

> Test the area where a spark or heat source may ignite flammable gases or vapors, i.e., the area as near a vessel opening or fuel source as practical to ensure safety but not inside a vessel where a safe working atmosphere may not be obtained (unless the inside of the vessel may be directly impacted by cutting, welding, or other activities).

2 Incident Analysis

The following sections discuss the safety issue the CSB identified in its investigation, which include: *Hot Work Safety*:

2.1 Hot Work Safety

Both Sunoco and L-Con developed plans and procedures to provide employees with guidance on how to safely conduct hot work operations. However, the plans and procedures were inadequate to prevent the fire and explosion that occurred at the Nederland terminal. Sunoco, and subsequently L-Con, did not ensure adequate mitigation strategies were implemented to prevent a fire/explosion during hot work activities.

While the CSB was not able to determine the specific causal scenario, the CSB concludes that there had to be a fuel source in the presence of an ignition source and oxygen for the incident to occur.

As discussed below, the CSB identified problems with hot work hazard recognition.

2.1.1 Regulatory Requirements

Sunoco and L-Con are subject to OSHA regulations for Welding, Cutting, and Brazing (29 CFR 1910.252) [17], also referred to as "hot work." L-Con is also subject to OSHA regulations 29 CFR 1926 Construction Standards [18].

OSHA's Welding, Cutting, and Brazing standard 1910.252(a)(1), *Basic precautions,* states "Fire hazards. If the object to be welded or cut cannot readily be moved, all movable fire hazards in the vicinity shall be taken to a safe place" (1910.252(a)(1)(i)) and "Guards. If the object to be welded or cut cannot be moved and if all the fire hazards cannot be removed, then guards shall be used to confine the heat, sparks, and slag, and to protect the immovable fire hazards" (1910.252(a)(1)(ii)). Associated Section 1910.252(a)(1)(iii) states "Restrictions. If the requirements stated in paragraphs(a)(1)(i) and (a)(1)(ii) of this section cannot be followed, then welding and cutting shall not be performed."

In addition, 1910.252(a)(2), *Special precautions*, states "When the nature of the work to be performed falls within the scope of paragraph (a)(1)(ii) of this section certain additional precautions may be necessary:" The additional precautions include a set of "prohibited areas" listed in 1910.252(a)(2)(vi) where "Cutting or welding shall not be permitted", including 1910.252(a)(2)(vi)(C), "In the presence of explosive atmospheres (mixtures of flammable gases, vapors, liquids…), or explosive atmospheres that may develop inside uncleaned or improperly prepared tanks or equipment which have previously contained such materials..."

29 CFR 1910.252(a)(1) also requires "welders and cutters, their supervisors (including outside contractors) and those in management on whose property cutting and welding is to be performed" [17] to follow the National Fire Protection Association's (NFPA) Standard 51B, 1962, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work* (incorporated by reference per 1910.6(t)(9)).

The NFPA states their organization is a leading information and knowledge resource on fire, electrical, and related hazards [19] and provides codes and standards for multiple industries to identify, mitigate, and reduce the risk of fire and explosion hazards. These standards and codes can be accessed on their website.

The NFPA's *Standard for Fire Prevention in Use of Cutting and Welding Processes*, Standard 51B, outlines guidance to prevent injuries and loss of life and property from fires and explosions due to hot work activities, including welding.

The incorporated by reference version of NFPA 51B (1962) [20] states, "41. Cutting or welding shall not be permitted in the following situations: …In the presence of explosive atmospheres (mixtures of flammable gases, vapors, liquids, or dusts with air), or explosive atmospheres that may develop inside uncleaned or improperly prepared tanks or equipment which have previously contained such materials, or that may develop in areas with an accumulation of combustible dusts".

Based on the verbiage of the applicable OSHA regulations and NFPA 51B (as incorporated by reference in the OSHA standard), the CSB concludes that welding on equipment that contains a flammable and/or explosive atmosphere is not permitted by OSHA or NFPA 51B.

2.1.2 Fuel Source Management

2.1.2.1 Pipe Not Cleaned

As planned, Sunoco left residual crude oil (which was previously established as being flammable) in the pipe, as specified in the *Scope of Work* document developed by Sunoco four months prior to this incident occurring and agreed to by L-Con.

As outlined in Section 2.1.1, an isolation approach for residual crude oil in a pipe undergoing hot work is not permitted by 29 CFR 1910.252(a)(1)(i)-(ii), which state that "…all movable fire hazards in the vicinity shall be taken to a safe place" and "…if all the fire hazards cannot be removed, then guards shall be used…" In this case, the fire hazard could have been physically removed or inerted, and thus the option of providing a guard function via an isolation device such as the CARBER tool would not be allowed per 1910.252(a)(1)(iii), which states "If the requirements stated in paragraphs(a)(1)(i) and (a)(1)(ii) of this section cannot be followed then welding and cutting shall not be performed." Such operations are also not permitted per NFPA 51B (1962).

Sunoco was unable to provide a specific policy or procedure for how to clean pipelines that contain, or previously contained, flammable material before conducting hot work. However, the company's *Hot Work* procedure outlined their requirements to prepare such piping for hot work, stating

> "Equipment that has been in flammable or combustible service or may be contaminated with hazardous materials shall be purged, made safe, or decontaminated prior to conducting hot work on the equipment."

The "made safe" provision was interpreted by Sunoco staff as allowing the use of the CARBER isolation tool, however Sunoco's *Hot Work* procedure further stated:

> Piping, storage tanks, or associated equipment that have contained… flammable or combustible materials shall be properly isolated and decontaminated (by purging or flushing) prior to approval of any hot work activity on the equipment…The permitting authority prior to permit approval shall verify isolation and/or decontamination measures taken to assure safety of the operation.

The procedure stated that equipment shall be isolated and decontaminated by purging or flushing. In this instance, Sunoco did not take measures to decontaminate the equipment prior to conducting hot work. However, the procedure is unclear since subsequent direction states that the permitting authority shall verify the isolation and/or decontamination, which allows for isolation, decontamination, or a combination of the two.

The CSB concludes that Sunoco's *Hot Work* procedure did not adequately state that hot work on equipment that contained or previously contained flammable material, was not permitted by OSHA or NFPA 51B, nor did the procedure clearly explain how to ensure equipment shall be cleaned or decontaminated to safely conduct hot work.

2.1.2.2 Residual Flammable Material at or Above Flashpoint

Ambient conditions at the time of the incident at the Nederland terminal were around 84°F, as mentioned in Section 1.2. According to the SDS, the flashpoint of crude oil is below 73.4 °F. Therefore, the crude oil that remained in the pipe at the time of the incident was at a temperature above its flashpoint, meaning the crude oil was emitting flammable vapors.

The CSB concludes that the weather at the time of the incident contributed to the existence of flammable vapors inside the pipe.

2.1.2.3 Explosive Atmosphere Inside the Pipe

The crude oil SDS (as shown in **Figure 7** above) stated that vapors can ignite rapidly, when mixed with air, and exposed to sources of ignition and can explode if the vapor/air mixture is confined when exposed to an ignition source.

The previous section established the existence of flammable vapors inside the pipe. Those vapors were mixed with the air inside the pipe since the pipe was previously open to atmosphere. The exact concentration of flammable vapor in air inside the pipe at the time of the incident is unknown. However, given the contents inside the pipe ignited, the CSB concludes the vapor/air mixture inside the pipe was flammable.

The flammable atmosphere inside the pipe was confined due to plugging both ends with CARBER isolation tools (with only the vent hose on top of the pipe providing limited pressure relief). This created a closed volume that could explode if exposed to an ignition source.

The CSB concludes that the atmosphere inside the pipe at the time of the incident was explosive, due to confinement of the flammable atmosphere by the CARBER isolation tools and ignited when exposed to an ignition source.

2.1.2.4 Pipe Not Inerted

As established in the previous section, the atmosphere inside the pipe at the time of the incident was explosive, due to flammable vapors mixed with air in a confined space.

Sunoco's decision was not to decontaminate the pipe, but to isolate the flammable material inside by using the CARBER isolation tools. However, Sunoco's *Hot Work* procedure provided guidance on how to prepare equipment that could not be isolated or fully decontaminated, and stated:

> In situations where piping systems or other process equipment cannot be isolated or fully decontaminated, alternative precautions, such as purging with inert gases, must be established to ensure that welding and cutting can be conducted safely. When inert purge gases are used, precautions shall be taken to ensure employees are not exposed to the purge gases.

Purging with an inert gas, such as nitrogen, would have reduced the levels of flammable vapors and air inside the pipe, rendering the atmosphere inside the pipe non-flammable.

Therefore, the CSB concludes that purging the pipe with an inert gas, such as nitrogen, would have prevented the incident from occurring by eliminating the flammable atmosphere inside the pipe.

As stated in Section 1.11, Sunoco's procedures were updated after the 2016 incident to reflect that hot work on equipment that contains a flammable atmosphere is prohibited. Equipment must be purged with inert gas, such as nitrogen and the inside of the equipment tested to ensure it is free of hydrocarbon vapors.

3 Conclusions

3.1 Findings

1. Sunoco's *Hot Work* procedure did not adequately state that hot work on equipment that contained or previously contained flammable material, was not permitted by OSHA or NFPA 51B, nor did the procedure clearly explain how to ensure equipment shall be cleaned or decontaminated to safely conduct hot work. (Section 2.1.2.1)
2. The weather at the time of the incident contributed to the existence of flammable vapors inside the pipe. (Section 2.1.2.2)
3. The vapor/air mixture inside the pipe was flammable. (Section 2.1.2.3)
4. The atmosphere inside the pipe at the time of the incident was explosive, due to confinement of the flammable atmosphere by the CARBER isolation tools and ignited when exposed to an ignition source. (Section 2.1.2.3)
5. Purging the pipe with an inert gas, such as nitrogen, would have prevented the incident from occurring by eliminating the flammable atmosphere inside the pipe. (Section 2.1.2.4)

3.2 Probable Cause

The CSB determined the probable cause of the incident was Sunoco approving and L-Con conducting hot work activities on equipment that contained an explosive atmosphere that, when exposed to an ignition source, resulted in an explosion event. Contributing to the incident was the ineffective implementation and execution of policies and procedures by Sunoco, L-Con, and CARBER.

4 Key Lessons for the Industry

To prevent chemical incidents, and in the interest of driving chemical safety change to protect people and the environment, the CSB urges companies that conduct hot work in facilities with flammable materials to review these key lessons:

1. When isolating equipment in preparation for hot work, ensure the internal atmosphere is not flammable. OSHA's regulatory requirement and NFPA's industry guidance both state that hot work shall not occur on equipment that contains flammable material. Cleaning the equipment, purging with inert gas such as nitrogen, or filling the equipment with water prior to conducting hot work are all viable solutions to mitigating the risk of fire and/or explosion.

2. Thorough identification and assessment of the locations all flammables and combustibles in hot work zones must be completed to develop a robust mitigation plan to prevent fires and explosions. It is important to assess all possible fuel sources (flammable vapors, flammable liquids, combustible materials) when performing hot work to adequately assess the risks and implement sufficient mitigation strategies to prevent incidents.

3. As stated in the CSB Hot Work Safety Bulletin [21], released February 2010, keys to preventing hot work incidents are using alternative methods to hot work, analyzing and controlling the hazards of the job, conducting effective atmospheric monitoring, testing the general area (even adjacent areas/equipment to hot work) for potential flammable conditions, using written permits that specify the hazards and required precautions, training the workforce thoroughly on hot work policies and procedures, and providing adequate contractor supervision.

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