U.S. Chemical Safety and Hazard Investigation Board

Storage Tank Fire at Intercontinental Terminals Company, LLC (ITC) Terminal

Deer Park, Texas | *Incident Date: March 17, 2019* | **No. 2019-01-I-TX**

Investigation Report

Published: July 6, 2023

SAFETY ISSUES:

- **Pump Mechanical Integrity**
- **Flammable Gas Detection Systems**
- **Remotely Operated Emergency Isolation Valves**
- **Tank Farm Design**
- **PSM and RMP Applicability**

U.S. Chemical Safety and Hazard Investigation Board

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ABBREVIATIONS

ACC	American Chemistry Council
AIChE	American Institute of Chemical Engineers
ANSI	American National Standards Institute
CAA	Clean Air Act
API	American Petroleum Institute
BPH	barrels per hour
CCPS	Center for Chemical Process Safety
C.F.R.	Code of Federal Regulations
CCR	central control room
CIMA	Channel Industries Mutual Aid
CSB	U.S. Chemical Safety and Hazard Investigation Board
CTEH	Center for Toxicology and Environmental Health, LLC
DCS	distributed control system
EBV	emergency block valves
EPA	U.S. Environmental Protection Agency
ERT	Emergency Response Team
HSE	Health and Safety Executive
HCFMO	Harris County Fire Marshal's Office
IOM	Installation, Operation, and Maintenance
ISD	Independent School District
ITC	Intercontinental Terminals Company, LLC
LEL	lower explosive limit

LPG	liquified petroleum gas
MOC	management of change
MOV	Motor operated valve
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PM	Preventative Maintenance
PHA	Process Hazard Analysis
PSI	pounds per square inch
PSM	Process Safety Management
PSSR	pre-startup safety review
Pygas	pyrolysis gasoline
RBPS	Risk Based Process Safety
RAGAGEP	Recognized and Generally Accepted Good Engineering Practices
RMP	Risk Management Program
ROEIV	remotely operated emergency isolation valves
SDS	Safety Data Sheet
SPCC	Spill Prevention Control and Countermeasure Plan
TACB	Texas Air Control Board
TCEQ	Texas Commission on Environmental Quality
USCG	United States Coast Guard
VOCs	volatile organic compounds

Executive Summary

On Sunday, March 17, 2019, a large fire erupted at the Intercontinental Terminals Company, LLC (ITC) bulk liquid storage terminal located in Deer Park, Texas. The fire originated in the vicinity of Tank 80-8, an 80,000-barrel aboveground atmospheric storage tank that held a blend of naphtha and butane product, a flammable liquid. Once the fire erupted, ITC was unable to isolate or stop the release. As a result, the fire burned, intensified, and spread to the other 14 tanks located in the same containment area. The fire burned for three days, until it finally was extinguished on Wednesday, March 20, 2019. The fire caused substantial property damage at the ITC Deer Park terminal, including the destruction of fifteen (15) 80,000-barrel aboveground atmospheric storage tanks and their contents.

The incident also significantly impacted the environment. A containment wall around the tanks breached and released an estimated 470,000–523,000 barrels of hydrocarbon and petrochemical products, firefighting aqueous film forming foam, and contaminated water into Tucker Bayou and adjacent water, sediments, and habitats. From there, the released materials flowed into Buffalo Bayou and were carried out by streamflow and tides into the Houston Ship Channel and surrounding waters. A seven-mile stretch of the Houston Ship Channel adjacent to the ITC Deer Park terminal was closed, as were several waterfront parks in Harris County and the City of LaPorte, due to the contamination.

The incident did not result in any injuries or fatalities; however, the local community experienced serious disruptions, including several shelter-in-place orders because of benzene-related air quality concerns. A shelter-in-place was issued for the entire City of Deer Park at one point, and local schools and businesses either closed or operated under modified conditions. A portion of a major highway in the area also was closed. ITC estimated that property damage resulting from the loss of the First & Second 80's tank farm associated with the March 17, 2019, incident exceeded $150 million.

Safety Issues

The U.S. Chemical Safety and Hazard Investigation Board's (CSB's) investigation identified the safety issues below.

- **Pump Mechanical Integrity.** ITC did not have a formal mechanical integrity procedure in place that defined requirements for maintaining the mechanical integrity of Tank 80-8 and its associated equipment, including the Tank 80-8 circulation pump. A formal mechanical integrity program for pumps in highly hazardous chemical service could have prevented this incident by providing ITC with additional opportunities to identify pump issues prior to the incident. The mechanical seal on the pump failed on March 17, 2019, allowing butane-enriched naphtha product to release from the pump while it continued to operate. (Section 4.1)
- **Flammable Gas Detection Systems.** Tank 80-8 was not equipped with a flammable gas detection system to warn personnel of a hazardous atmosphere resulting from loss of containment from the tank or its associated equipment. In 2014, a hazard review team recommended the addition of flammable gas detection systems near Tank 80-8; however, ITC did not implement this recommendation, and did not document why it was not implemented. In the absence of a flammable gas detection system, there were

no alarms to alert personnel about the initial release of butane-enriched naphtha product around the Tank 80-8 piping manifold. Consequently, the butane-enriched naphtha product continued to release from the failed pump for approximately 30 minutes, completely undetected, before its flammable vapors eventually ignited. (Section 4.2)

- **Remotely Operated Emergency Isolation Valves.** Tank 80-8 and the other aboveground storage tanks located in the First & Second 80's tank farm were not equipped with remotely operated emergency isolation valves (ROEIVs) designed to mitigate process releases remotely from a safe location. The primary drivers for identifying the need for this type of equipment would have been through implementation of hazard assessments, such as those required by the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) standard and the U.S. Environmental Protection Agency (EPA) Risk Management Program (RMP) rule, as well as insurance company audits and/or corporate risk evaluations results. On the day of the incident, the large volume of butane-enriched naphtha product contained in Tank 80-8 could not be remotely or automatically isolated, and it continued to release, via the failed pump, fueling the fire that continued to intensify around the tank. As the Tank 80-8 fire intensified, flames from the fire spread to adjacent tank piping manifolds in the tank farm and eventually compromised the equipment, causing breaches in piping that allowed the hydrocarbon and petrochemical products contained in the storage tanks to release into the common containment area. (Section 4.3)

- **Tank Farm Design.** Although the First & Second 80's tank farm was designed largely in accordance with applicable National Fire Protection Association (NFPA) 30 requirements, elements of the tank farm design, including tank spacing, subdivisions, engineering controls for pumps located inside the containment area, and drainage systems, made it difficult for emergency responders to slow or prevent the spread of the initial fire and allowed the fire to spread to other tanks within the tank farm. While NFPA 30 defines minimum requirements for tank farm design, additional industry guidance documents provide more robust tank farm design recommendations. While ITC was not required to implement additional industry guidance recommendations, many of which were developed after construction of the First & Second 80's tank farm, implementation of such recommendations could have prevented the escalation of this incident. (Section 4.4)

- **PSM and RMP Applicability.** ITC did not apply a formal process safety management program to Tank 80-8 because neither the OSHA PSM standard nor the EPA RMP rule applied to Tank 80-8 and its associated equipment. Tank 80-8 was not covered by the OSHA PSM standard due to the atmospheric storage tank exemption in the standard, and the EPA RMP rule did not apply due to the flammability rating exemption in the rule for the butane-enriched naphtha mixture. Although ITC applied some process safety management elements across the terminal, the company did not apply other key elements, such as Mechanical Integrity and Process Hazard Analysis, to atmospheric storage tanks in highly hazardous chemical service. Applying these elements would have provided the company with additional opportunities to identify and control hazards through multiple layers of protection, including the examples of preventative and mitigative safeguards discussed in this report. Thus, had ITC developed and implemented a comprehensive process safety management program that effectively identified and controlled hazards for Tank 80-8 and its related equipment, the incident could have been prevented. (Section 4.5)

Cause

The CSB determined that the cause of the incident was the release of flammable butane-enriched naphtha vapor from the failed Tank 80-8 circulation pump, which accumulated in the area and ignited, resulting in a fire. Contributing to the severity of the incident were the absence of a flammable gas detection system to alert the operators to the flammable mixture before it ignited approximately 30 minutes after the release began, and the absence of remotely operated emergency isolation valves (ROEIVs) to safely secure the flammable liquids in Tank 80-8 and the surrounding tanks in the First & Second 80's tank farm.

Elements of the tank farm design, including tank spacing, subdivisions, engineering controls for pumps located inside the containment area, and drainage systems also contributed to the severity of the incident by allowing the fire to spread to other tanks within the tank farm. The resulting accumulation of hydrocarbon and petrochemical products, firefighting foam, and contaminated water in the secondary containment area ultimately contributed to a breach of the containment wall and a release of materials to the local waterways.

Finally, the CSB determined that because of the atmospheric storage tank exemption contained in the OSHA PSM standard and the flammability exemption contained in the EPA RMP rule, ITC was not required to develop and implement a formal PSM program for Tank 80-8 and its associated equipment that could have provided a process to identify and control the specific hazards that resulted in this incident, which also contributed to this incident.

Recommendations

To Intercontinental Terminals Company, LLC (ITC)

2019-01-I-TX-R1

Develop and implement a process safety management system for the ITC Deer Park terminal applicable to all atmospheric storage tanks and associated equipment in highly hazardous chemical service.[a] The program should follow industry guidance provided in publications such as the American Petroleum Industry's API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*.

2019-01-I-TX-R2

Develop and implement a condition monitoring program for all pumps in highly hazardous chemical service at the ITC Deer Park terminal. Ensure that condition monitoring equipment is programmed with control limits, including but not limited to vibration, consistent with ANSI/HI 9.6.9.-2018, that trigger alarms when control limits are exceeded, and that operating procedures and training reflect the appropriate actions to take when an alarm is triggered.

[a] The OSHA PSM standard defines "highly hazardous chemical" as "a substance possessing toxic, reactive, flammable, or explosive properties…" 29 C.F.R. § 1910.119(b).

2019-01-I-TX-R3

Install flammable gas detection systems with associated alarm functions in product storage and transfer areas at the ITC Deer Park terminal where flammable substance releases could occur. Develop and implement a response plan and operator training for actions to take when an alarm sounds.

2019-01-I-TX-R4

Install remotely operated emergency isolation valves configured to "Fail-Closed" for all atmospheric storage tanks that contain highly hazardous chemicals or liquids with a flammability rating of NFPA-3 or higher at the ITC Deer Park terminal.

2019-01-I-TX-R5

Conduct an evaluation of the design of all new and existing tank farms at the ITC Deer Park terminal against the applicable sections of the Third Edition of API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and the 2021 Edition of NFPA 30, *Flammable and Combustible Liquids Code*. At a minimum the evaluation should include, but is not limited to the following sections of API STD 2610:

Section 4	Site Selection and Spacing Requirements
Section 7	Fire Prevention and Protection
Section 8.1	Aboveground Petroleum Storage Tanks
Section 9	Dikes and Berms
Section 10	Pipe, Valves, Pumps, and Piping Systems
Section 11	Loading, Unloading, and Product Transfer Facilities

and the following chapters of NFPA 30:

Chapter 21	Storage of Ignitible (Flammable or Combustible) Liquids in Tanks – Requirements for All Storage Tanks and
Chapter 22	Storage of Ignitible (Flammable or Combustible) Liquids in Tanks – Aboveground Storage Tanks

The evaluation should identify additional engineering controls needed to address minimal tank spacing, subdivisions between tanks, and placement of process equipment in containment areas. In addition, the evaluation should assess the adequacy of the containment wall and drainage system designs, accounting for the impact of firefighting activities, including the application of firewater and foam on these systems. Develop and implement recommendations based on findings from the evaluation.

To American Petroleum Institute (API)

2019-01-I-TX-R6

Update API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities,* or other appropriate products to include flammable gas detection systems within the leak detection section or where appropriate. The discussion of flammable gas and/or leak detection should address both engineering and administrative controls, including actions associated with responding to a catastrophic or emergency leak.

To Occupational Safety and Health Administration (OSHA)

2019-01-I-TX-R7

*(Supersedes **2001-05-I-DE-R1** from Motiva and **2010-02-I-PR-R4** from CAPECO)*[a]

Eliminate the atmospheric storage tank exemption from the PSM standard.

To Environmental Protection Agency (EPA)

2019-01-I-TX-R8

*(Supersedes **2010-02-I-PR-R1** from CAPECO)*

Modify 40 C.F.R. § 68.115(b)(2)(i) to expand coverage of the RMP rule to include all flammable liquids, including mixtures, with a flammability rating of NFPA-3 or higher.

[a] Previous CSB investigations: Motiva Enterprises Sulfuric Acid Tank Explosion [44] and CSB Caribbean Petroleum Refining Tank Explosion and Fire [46]

1 BACKGROUND

1.1 INTERCONTINENTAL TERMINALS COMPANY, LLC (ITC) COMPANY

At the time of the incident, Intercontinental Terminals Company, LLC (ITC), a subsidiary of Mitsui & Co. (U.S.A.), Inc., was a terminal and storage facility operator that had been servicing the petrochemical industry for over five decades [1]. ITC was founded on February 24, 1972, with the purpose of constructing, operating, maintaining, and growing terminal assets [2]. ITC currently owns and operates two terminals near Houston, Texas: the ITC Deer Park and ITC Pasadena terminals. ITC also operates one terminal near Baton Rouge, Louisiana (Exxon Anchorage terminal), which is owned by another company [1].[a] Outside of the United States, the company operates one terminal in Antwerp, Belgium: the ITC Antwerp terminal.

1.2 ITC DEER PARK TERMINAL OVERVIEW

The ITC Deer Park terminal is a bulk liquid storage terminal situated on the inlet of Tucker Bayou in the Houston Ship Channel (**Figure 1**) [1] [3]. On December 1, 1971, ITC began construction on the 11-acre parcel of land located on the inlet of Tucker Bayou that would become the ITC Deer Park terminal [1]. ITC acquired additional acreage and infrastructure between 1974 and 2013, which led to the expansion of the ITC Deer Park terminal's size, capability, and capacity [1]. At present, the ITC Deer Park terminal is a 265-acre facility equipped with 227 storage tanks, both rail car and tank truck access, six tanker berths, 10 barge docks, and multiple pipeline connections [3] [4].

[a] ITC participates in the American Chemistry Council (ACC) Responsible Care® program as a Responsible Care® Partner in the Terminal Operators Sector. The Responsible Care® Partner Program is open to companies that have direct, substantial involvement in the distribution, transportation, storage, use, treatment, disposal, or sales and marketing of chemicals. Responsible Care® Partners are expected to adhere to the same Responsible Care® requirements as ACC members. Partner companies are separated into different sectors based on their primary business operation. These companies strive to continually improve environmental, health, safety, and security performance for all their chemical operations. The ITC Deer Park terminal is both RC 14001 and ISO 9001 certified.

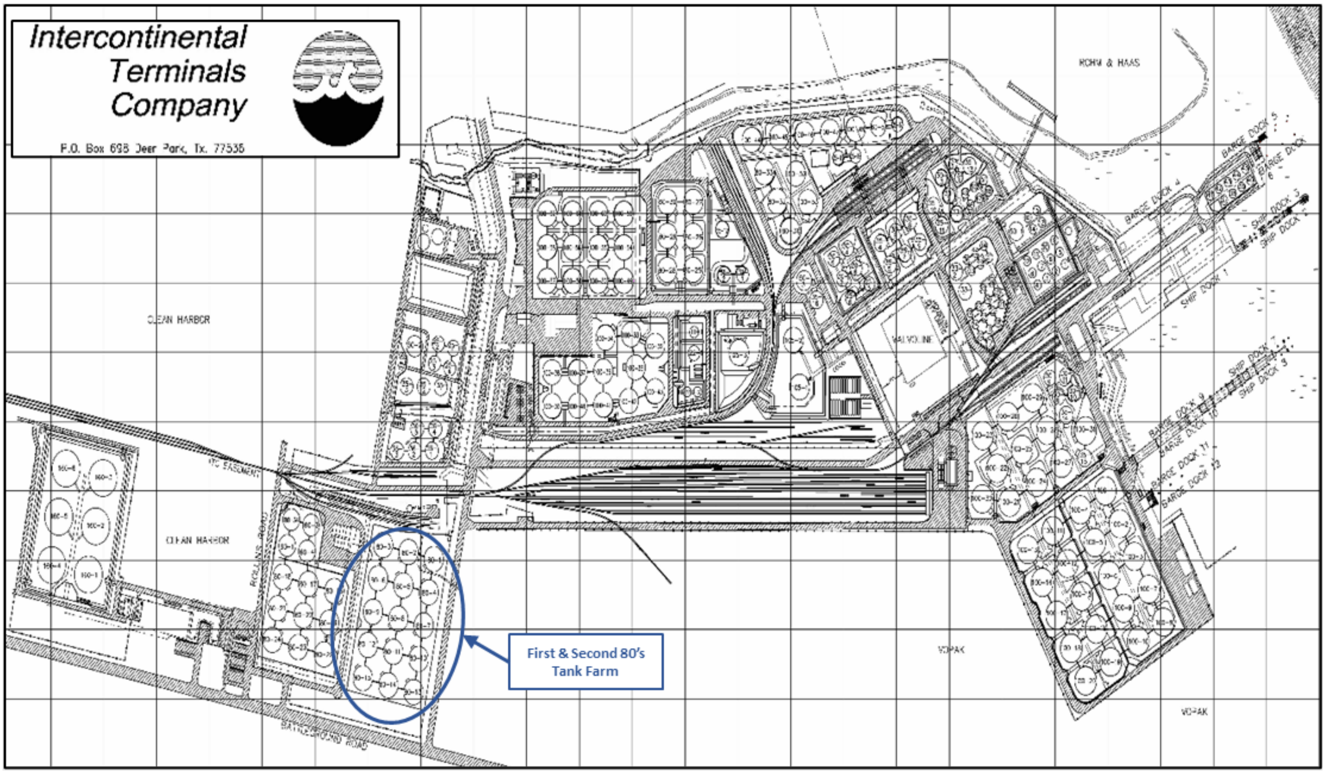

Figure 1. ITC Deer Park terminal overall plot plan. (Credit: ITC, annotations by CSB)

At the time of the incident, the ITC Deer Park terminal housed 242 fixed storage tanks, which ranged in size from 8,000- to 160,000-barrel capacities [3]. The terminal was separated into multiple tank farms, each comprised of multiple tanks within a common secondary containment area.[a] The tanks were used to store petrochemical liquids and gases, fuel oil, bunker oil, and distillates for various oil and chemical companies that leased the tanks from ITC [5]. The overall on-site storage capacity at ITC Deer Park was approximately 13.1 million barrels [3]. According to the company's website, the ITC Deer Park terminal handled approximately 770 ships, 3,700 barges, 12,000 rail tank cars, and 33,600 cargo tank trucks on an annual basis, with a total annual throughput of about 144 million barrels [2]. The terminal was staffed with approximately 270 employees at the time of the incident [1].

Records and other information provided by ITC indicate that portions of the ITC Deer Park terminal, including storage tanks containing butadiene, isoprene, liquified petroleum gas (LPG), and vinyl acetate monomer, were covered by both the U.S. Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) standard and the U.S. Environmental Protection Agency (EPA) Risk Management Program (RMP) rule. As will be discussed in Section 4.5, due to the atmospheric storage tank exemption contained in the OSHA PSM standard, the First & Second 80's tank farm was not covered by either regulation at the time of the incident.

[a] Secondary containment for aboveground storage tanks is defined as capturing the entire contents of the largest tank in the containment area in the event of a leak or spill. Doing so allows sufficient time for cleaning up the product before it moves beyond the secondary containment envelope and poses a more serious safety and environmental contamination hazard. Secondary containment usually consists of some combination of dikes, liners, ponds, impoundments, curbs, outer tanks, walls, or other equipment capable of containing the stored liquids. The most common forms are dikes and berms [86].

1.3 SURROUNDING AREA

Figure 2 shows the ITC Deer Park terminal and depicts the areas within roughly one, three, and five miles of the terminal. The area surrounding the ITC Deer Park terminal is mainly industrial, and no persons reside within a one-mile radius of the terminal. Nearby structures are primarily industrial facilities. Summarized demographic data for the area within a roughly three-mile radius of the ITC Deer Park terminal are shown below in **Table 1**. More detailed demographic information can be found in Appendix B.

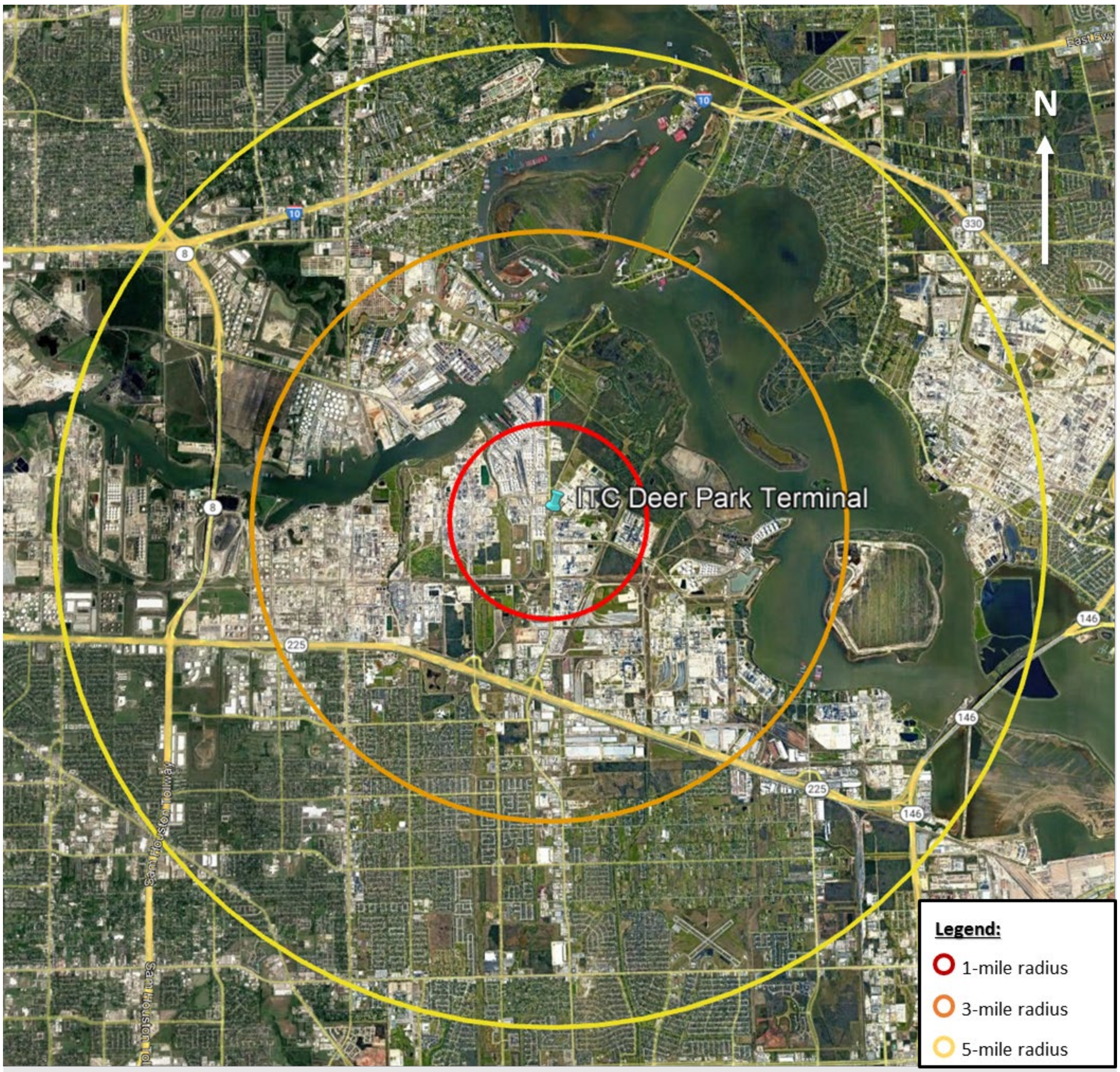

Figure 2. Overhead satellite image of ITC Deer Park terminal and the surrounding area. (Credit: Google Earth, annotations by CSB)

Table 1. Summarized demographic data of approximately 3-mile radius of ITC Deer Park terminal. (Credit: CSB)[a]

Population	Race & Ethnicity		Per Capita Income	Persons Below Poverty Line	Number of Housing Units	Types of Housing Units	
27,934	White	59%	$ 45,593	8%	9,921	Single Unit	88%
	Black	1%				Multi-Unit	8%
	Native	0%				Mobile Home	3%
	Asian	1%				Boat, RV, Van, etc	0%
	Islander	0%					
	Other	0%					
	Two+	2%					
	Hispanic	36%					

1.4 First & Second 80's Tank Farm

The incident occurred in what was commonly referred to as the First & Second 80's tank farm at the ITC Deer Park terminal (**Figure 3**). The First & Second 80's tank farm consisted of fifteen (15) 80,000-barrel (3,360,000-gallon) capacity aboveground atmospheric storage tanks situated within a common containment area that measured approximately 732 feet in length by 449 feet in width. The storage tanks measured 110 feet in diameter and 48 feet in height and were arranged in a 3 x 5 grid pattern, oriented in the east-west direction lengthwise. The aboveground atmospheric storage tank involved in the initial fire, Tank 80-8, was positioned in the center of the First & Second 80's tank farm (**Figure 4**).

[a]The Census Bureau reports that the overall per capita income for the United States from 2017-2021 was $37,638 [87].

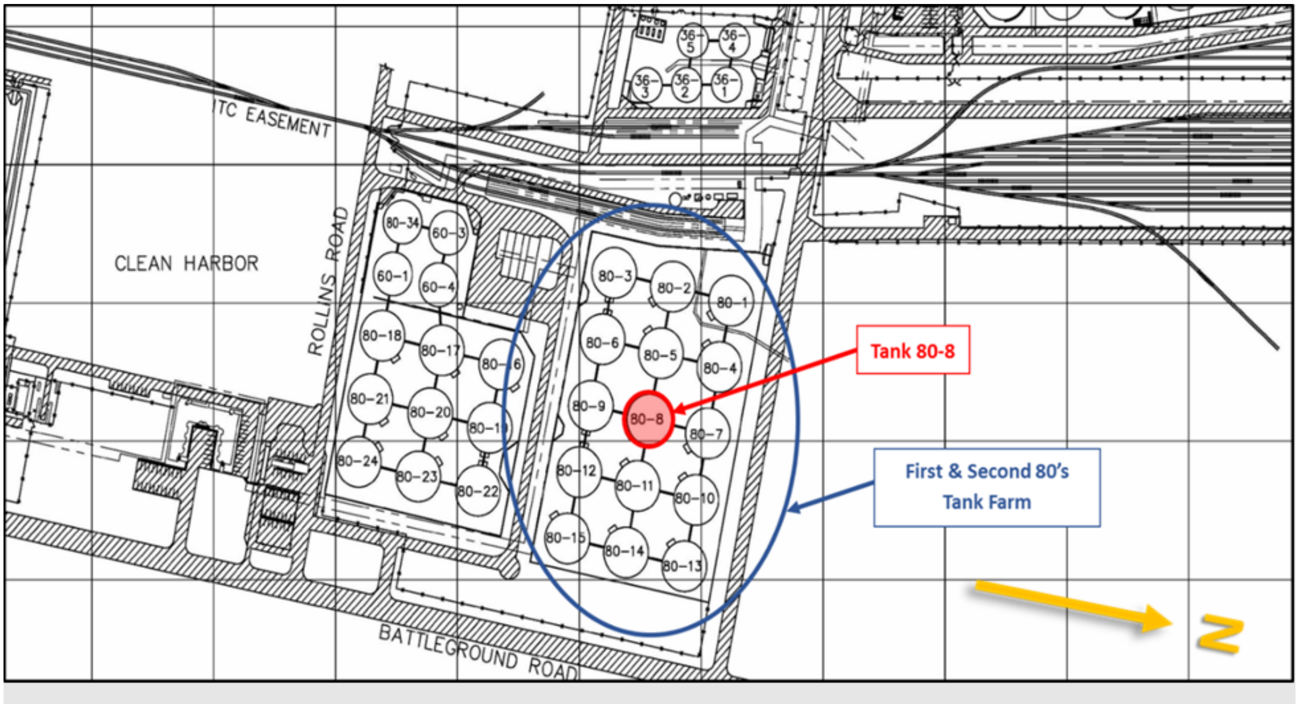

Figure 3. Plot plan of tank farm. Excerpt from overall plot plan for the ITC Deer Park terminal showing the location of the First & Second 80's Tank Farm. (Credit: ITC, annotations by CSB)

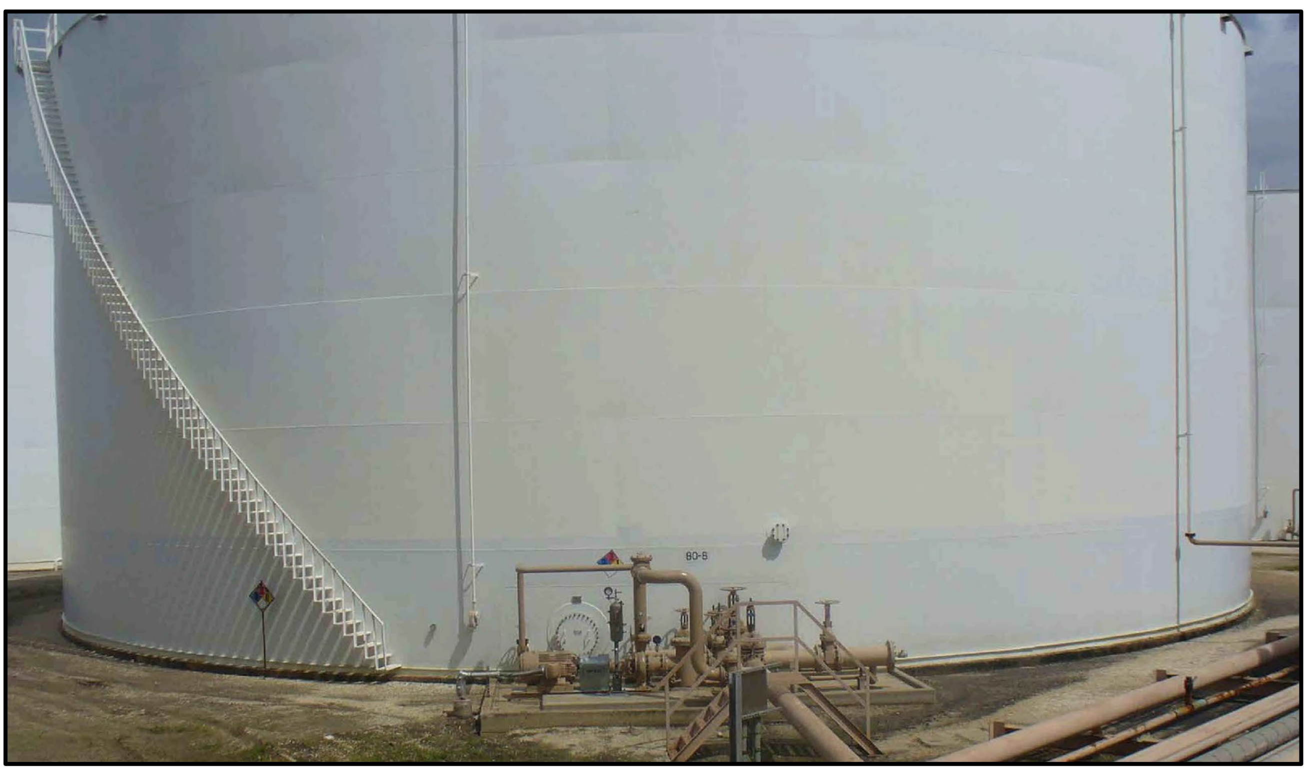

Figure 4. Tank 80-8, shown in 2007. (Credit: ITC)

The First & Second 80's tank farm was constructed in two phases, the first of which included Tanks 80-1 through 80-12. On June 17, 1976, the Texas Air Control Board (TACB) authorized the construction of twelve (12) 80,000-barrel cylindrical storage tanks at the ITC Deer Park terminal.[a] On September 1, 1977, the TACB authorized the construction of an additional twelve (12) 80,000-barrel cylindrical storage tanks, including Tanks 80-13 through 80-15. The TACB issued an operating permit for Tanks 80-1 through 80-12 in 1978, and another for Tanks 80-13 through 80-24 several years later. The original operating permits included a list of approved products for storage, including gasoline, benzene, cyclohexane, sodium sulfide solution, and fuel oil. Over the years, ITC requested amendments to these permits for storage of other products including ethylene dichloride, ethanol, isopropyl alcohol, and toluene. The operating permits were also periodically amended by the TACB's successor agency, the Texas Commission on Environmental Quality (TCEQ) [6]. The terminal currently operates pursuant to TCEQ Air Quality Permit No. 1078 and Federal Operating Permit No. O1061. At the time of the incident, Tanks 80-1 through 80-15 contained various hydrocarbon and petrochemical products, including naphtha, xylene, toluene, pyrolysis gasoline (Pygas), base oil, and gasoline blendstock.

1.5 TANK 80-8 BUTANE INJECTION SYSTEM DESCRIPTION

According to the original operating permit issued for Tank 80-8 on February 14, 1978, the atmospheric storage tank was initially approved for the loading and storage of gasoline, benzene, or cyclohexane; all of which are flammable liquid hydrocarbon compounds or mixtures.[b] ITC indicated that, since that time, Tank 80-8 had been used to load and store various liquid hydrocarbon products in accordance with the terms of the applicable versions of its Title V Federal Operating Permit and TCEQ Air Quality Permit.[c] Most recently, Tank 80-8 was under lease by a local company for loading and storage of naphtha. Pursuant to TCEQ Air Quality Permit No. 1078, ITC was authorized to store naphtha in internal floating roof tanks, which included Tank 80-8.

In 2014, Tank 80-8's lessee requested the addition of butane injection capability to the tank to boost the octane level of product stored in the tank, a practice commonly used by midstream companies to prepare the product for use as a gasoline blendstock [7, p. 1]. Butane is a colorless, liquified petroleum gas that is typically less expensive than naphtha [7, p. 1]. Blending butane with naphtha increases the overall naphtha product volume. However, since butane has a higher vapor pressure than naphtha, only a limited amount may be added to ensure that the final butane-enriched naphtha product remains within established Reid Vapor Pressure (RVP)[d] or True Vapor Pressure (TVP)[e] limits. ITC evaluated the tank lessee's request and designed the Tank 80-8 Truck Butane Injection System based on what ITC referred to as the "best known process for butanizing."

The Tank 80-8 Truck Butane Injection System originated at the 80's truck rack, located southwest of the tank farm (**Figure 5**), and terminated at an injection point in Tank 80-8's circulation line (**Figure 6**). The system was

[a] The tanks measured 110 feet in diameter and 48 feet in height, and were fabricated by the Southwest Tank & Treater Manufacturing Company, Henderson, Texas, in accordance with API Standard 650, *Welded Tanks for Oil Storage* (API STD 650), between 1976 and 1977.

[b] Hydrocarbons are organic chemical compounds composed only of carbon (C) and hydrogen (H) atoms. Hydrocarbons are the principal constituents of petroleum and natural gas [80].

[c] In 1992, ITC consolidated the individual TACB permits into one TCEQ air quality permit (No. 1078) that covers all of the permitted tanks at the ITC Deer Park terminal. ITC operated Tank 80-8 in accordance with the terms of the permit.

[d] RVP is the absolute vapor pressure of volatile crude oil and volatile nonviscous petroleum liquids, except liquified petroleum gases, as determined by ASTM D323-82 or 94. 40 C.F.R. § 60.111(l).

[e] TVP is the equilibrium partial pressure exerted by a petroleum liquid as determined in accordance with methods described in API Bulletin 2517, *Evaporation Loss from External Floating-Roof Tanks*, Second Edition, February 1980. 40 C.F.R. § 60.111(i).

designed so that the butane unloading operation could not begin unless the Tank 80-8 circulation pump was turned on, to ensure that butane-enriched naphtha product was circulating in the line. Once this condition was met, an ITC operator positioned at the 80's truck rack could then open the butane injection control valve to commence butane unloading operations. Nitrogen was used to unload the butane from the truck, and through two-inch piping to the Tank 80-8 circulation line, at which point the butane combined with the existing butane-enriched naphtha product in the tank. The Tank 80-8 circulation pump remained on throughout the unloading activity, and for several hours afterward, in order to facilitate the mixing of the naphtha and butane.

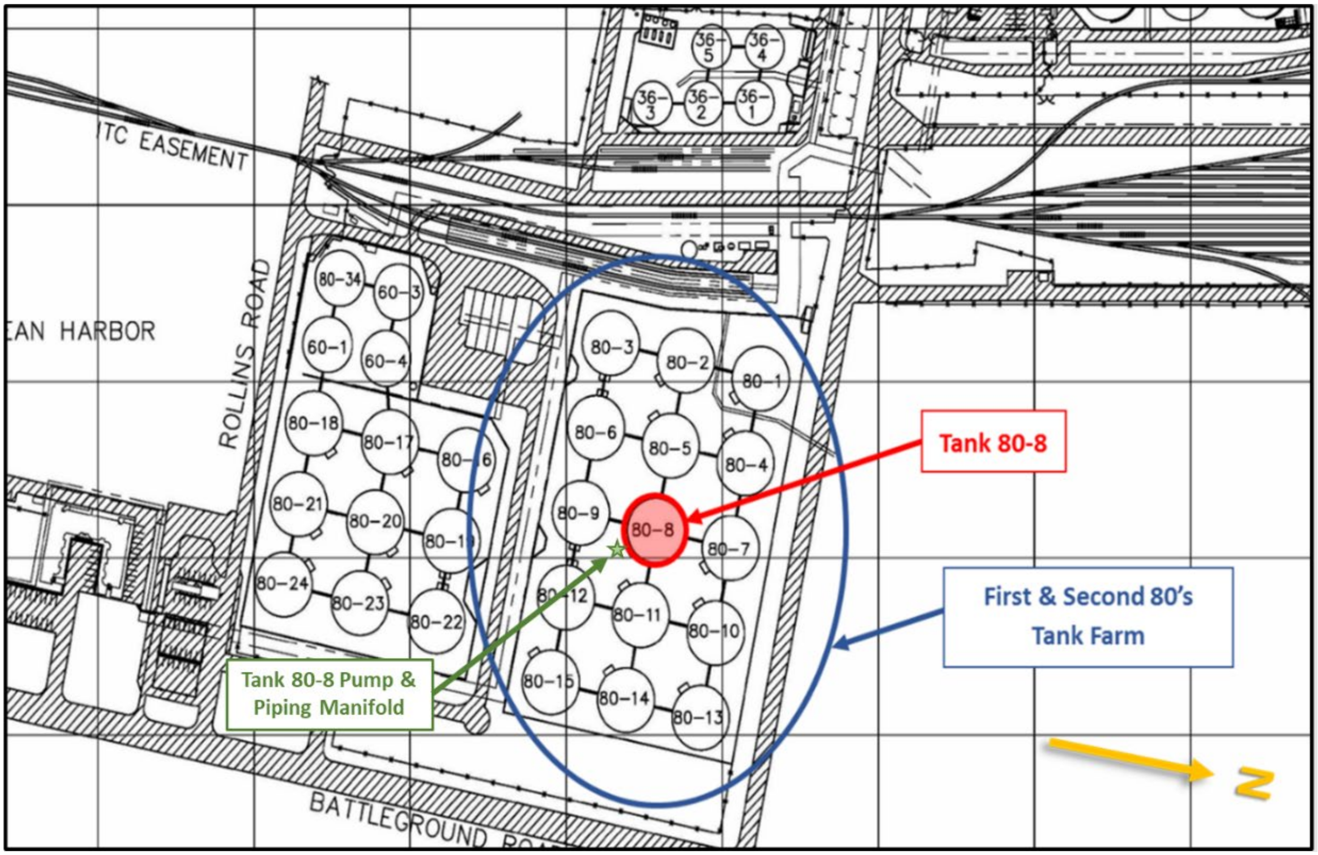

Figure 5. Plot plan of 80's truck rack. Excerpt from overall plot plan for the ITC Deer Park terminal showing the location of the 80's truck rack and First & Second 80's tank farm. (Credit: ITC, annotations by CSB).

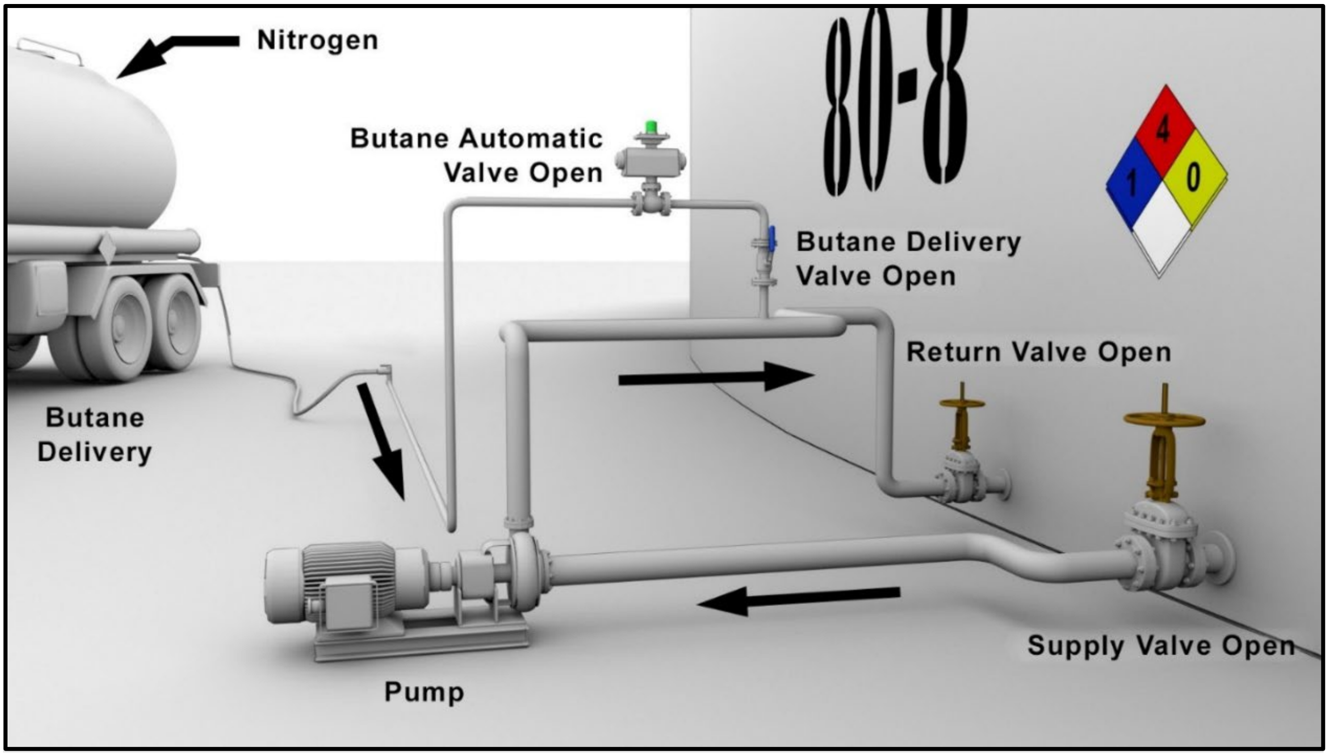

Figure 6. Simplified schematic showing ITC's butane injection system prior to 2016. The arrows in the figure show the butane flow direction and the naphtha product circulation path through the piping. Note: schematic not to scale. (Credit: CSB)

Although the OSHA PSM standard and EPA RMP rule did not apply to Tank 80-8, ITC used its management of change (MOC) process to document the Tank 80-8 Truck Butane Injection System project.[a] As part of this MOC, ITC completed a pre-startup safety review (PSSR) for the project on August 18, 2014. About a year and a half later, in January 2016, the company revised the Tank 80-8 Truck Butane Injection System to replace the majority of two-inch piping with four-inch piping in an effort to reduce the amount of time required to unload butane from the cargo tank trucks.[b]

1.6 Naphtha and Butane Characteristics

According to the Safety Data Sheet (SDS)[c] provided by Midcoast Energy, LLC (Tank 80-8 lessee), naphtha is a colorless to light yellow, flammable liquid with a characteristic hydrocarbon-like odor. It is a complex mixture of petroleum hydrocarbons in the C4-C10 range, and one of the more volatile forms of petroleum [8]. Naphtha is typically used as a feedstock for producing ethylene and propylene, or a gasoline blending component. It has a flash point of -7.1°F and lower explosive limit (LEL) of 1.2%. Naphtha has a higher vapor density than air; thus,

[a] Although parts of the Deer Park terminal were not covered under OSHA's PSM standard, ITC applied some elements of PSM, including MOC, to the entire terminal.

[b] Note: The figures show the Tank 80-8 piping manifold before the January 2016 revision, when ITC replaced the majority of the two-inch piping with four-inch piping.

[c] *Midcoast Energy, LLC* provided ITC the SDS for the naphtha stored in Tank 80-8. The components and characteristics of the naphtha product may vary within anticipated ranges between shipments.

if released from containment and exposed to atmospheric conditions, its flammable vapors typically collect along the ground or in low-lying areas.[a] In its liquid form, naphtha is lighter than water and has only negligible water solubility; thus, it will float on water.[b,c] The SDS indicates that "suitable extinguishing media" for fires involving naphtha include water spray, alcohol-resistant foam, dry chemical, or carbon dioxide; a solid water stream should not be used, as it may scatter and spread the fire. In the case of large fires involving naphtha, the SDS indicates that water spray, fog, or firefighting foam should be utilized to fight the fire, while water spray should be used to cool fire-exposed containers. Naphtha is a Class I liquid—a liquid with a flash point below 100°F—per National Fire Protection Association (NFPA) classifications [9, p. 12].

Butane is a Category 1 flammable gas (per 29 CFR §1910.1200) and is a substance covered by the EPA RMP rule at quantities exceeding 10,000 pounds.[d] Butane is highly flammable and can be easily ignited by heat, sparks, or flames [10].

2 Incident Description

The sections below detail the incident sequence. Appendix C contains a summarized timeline of events.

2.1 Tank 80-8 Butane Deliveries

On the evening of March 16, 2019, two butane truck deliveries were scheduled for Tank 80-8. At approximately 6:45 p.m., the area operator who was assigned to the First & Second 80's tank farm (Operator 1) received a call from the operator stationed at the truck loading rack (Operator 2) requesting that he get Tank 80-8 ready for the first butane delivery. Operator 1 arrived at the Tank 80-8 piping manifold shortly thereafter and took a level gauge reading on the tank to confirm that there was enough room in the tank to accommodate the planned butane deliveries. At 6:54 p.m., Operator 1 started the Tank 80-8 circulation pump and verified that the circulation valve was fully open. He then manually adjusted the pressure on the circulation line to 40 pounds per square inch (psi) using the chainwheel operated valve. Once the circulation pressure was set, Operator 1 informed Operator 2 that he could start offloading the butane truck. At approximately 7:23 p.m., Operator 2 initiated the unloading process at the truck loading rack. The first scheduled delivery was completed at 8:15 p.m. Approximately 170 barrels of butane were added to Tank 80-8.

Later that evening, Operator 1 received a call for the second butane truck delivery. He proceeded to the Tank 80-8 piping manifold and confirmed that there was room in the tank, the pump was still turned on, and that the valves were still properly aligned. At approximately 9:30 p.m., he notified Operator 2 that he could begin unloading the second truck. Operator 2 started unloading the butane truck shortly thereafter, and the second scheduled delivery of roughly 193 barrels of butane was completed at approximately 10:29 p.m. that evening. Following completion of the two butane truck deliveries, the Tank 80-8 circulation pump remained on overnight to circulate the roughly 70,300 barrels of butane-enriched naphtha product contained in the tank. Operator 1 told

[a] The SDS indicates that naphtha has a vapor density of 3.5, compared with that of air, which is 1.0.

[b] The SDS indicates that naphtha has a specific gravity of 0.77, compared with that of water, which is 1.0.

[c] According to the Certificate of Analysis (COA) for a sample taken from Tank 80-8 on March 12, 2019, the specific gravity of the butane-enriched naphtha product in Tank 80-8 was around 0.68, as opposed to the 0.77 referenced on the SDS.

[d] The EPA's List of Regulated Substances (per 40 CFR § 68.130 – Tables 3 and 4 with a threshold quantity of 10,000 pounds).

investigators that during the butane deliveries, the Tank 80-8 circulation pump appeared to be operating normally.

A chemical tanker, *Stena Performance,* was scheduled to arrive at 12:00 p.m. on March 17, 2019. The entire contents of Tank 80-8 were intended to be transferred to the ship at that time.

2.2 Initial Butane-Enriched Naphtha Product Release

On the morning of March 17, 2019, as the Tank 80-8 circulation pump continued to operate, distributed control system (DCS) data for the tank indicated a series of unanticipated changes in the monitored operating pressures, flow rate, and tank volume. Beginning at approximately 7:25 a.m., the pump discharge pressure began to increase with no change in operation having occurred (**Figure 7**). By 8:45 a.m., the pump discharge pressure had gradually increased from 80 psi to 84 psi. At approximately 9:30 a.m., when the mechanical seal on the pump failed and butane-enriched naphtha product began to release to the atmosphere, the recorded tank level began to decrease, and recorded average flow rate[a] for the tank, automatically calculated from changes in tank level measurements, began to increase (**Figure 8**). At approximately 9:35 a.m., the pump discharge pressure abruptly dropped to 80 psi, and within the next 10 minutes dropped further to 75 psi. At the same time, the recorded average flow rate of material from the tank had increased to about 158 barrels per hour (bph), and by 9:44 a.m. had increased to over 388 bph.

[a]The flow rate, or "BPH Rate," is calculated in barrels per hour (bph). Logic configured in the SCADA system calculates the flow rate for each tank. The rate is based on the difference in the gross tank volume in a time span of 60 seconds. This difference in volume is fed into a moving average calculation function block containing 15 samples of the gross volume difference value. Every 60 seconds a new difference value is fed into the moving average calculation, replacing the oldest value, and a new average is derived. This calculation is only activated if the tank is in **Inbound or Outbound mode**; otherwise, the rate will be zero if the tank is in **Idle mode**.

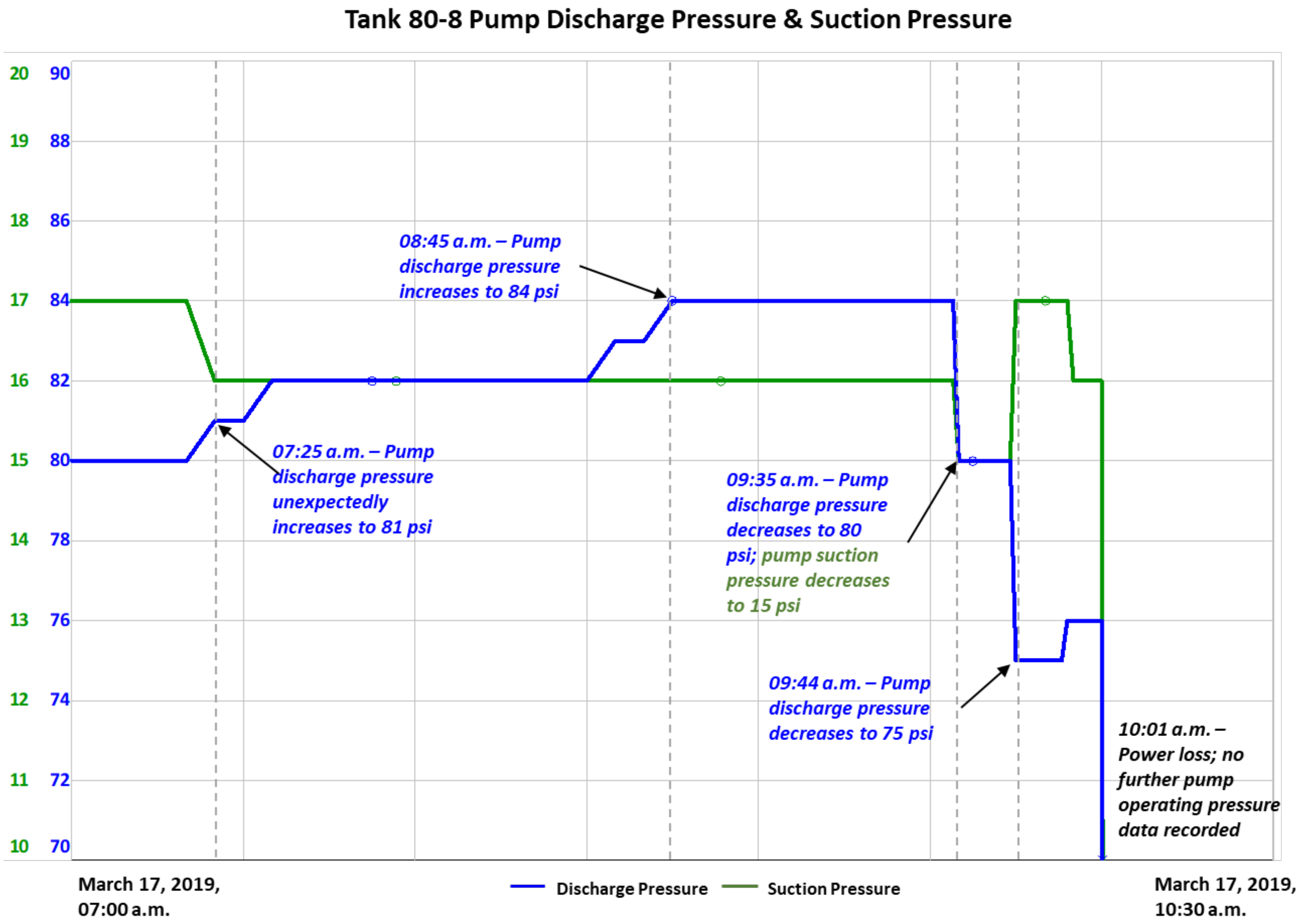

Figure 7. Recorded data historian trends showing recorded pump operating pressure data for Tank 80-8. (Credit: CSB)

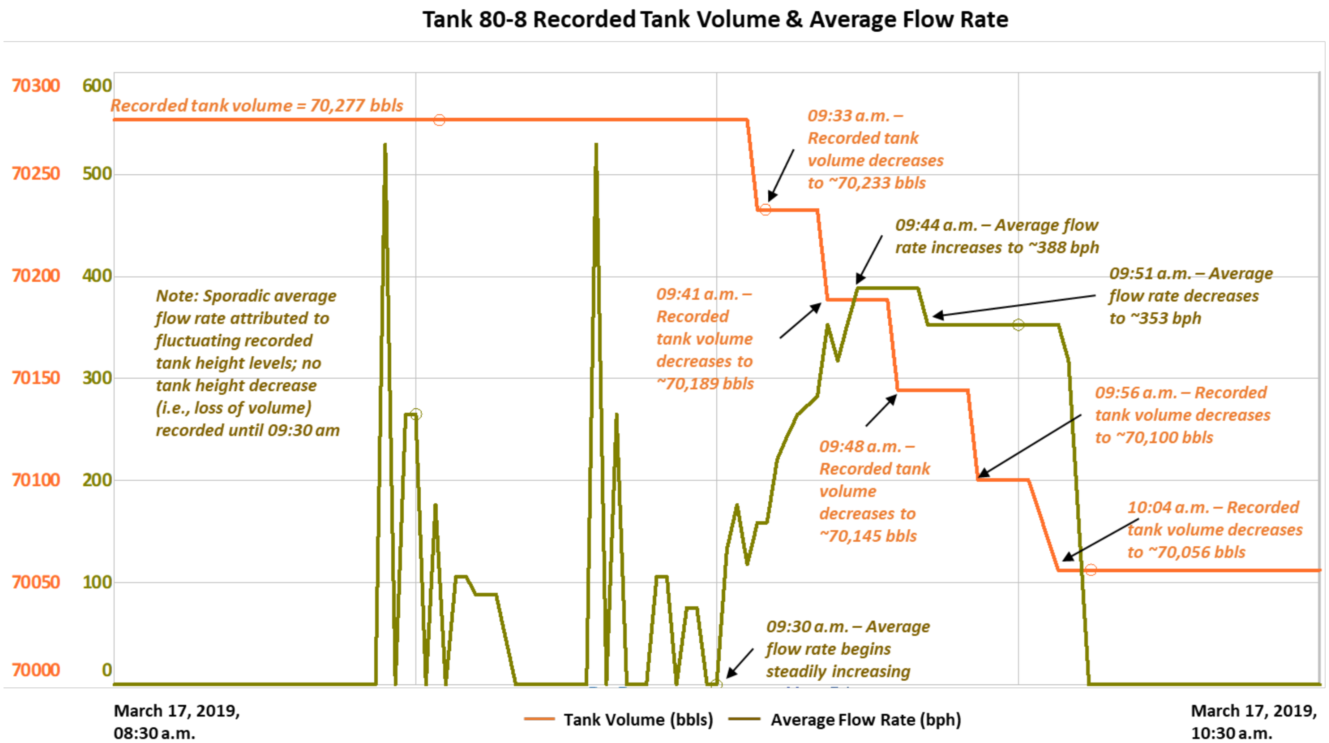

Figure 8. Recorded data historian trends showing recorded average flow rate and tank volume data for Tank 80-8. (Credit: CSB)

Between 9:30 and 10:00 a.m., the recorded tank volume[a] in Tank 80-8 decreased by more than 177 barrels as the naphtha product continued to release from the failed pump.[b] At 10:00:46 a.m., approximately 30 minutes after the release began, the butane-enriched naphtha product releasing from the Tank 80-8 piping manifold ignited (**Figure 9**). No operators were working outside in the First & Second 80's tank farm during this time frame. The acting shift manager was working in the adjacent Third 80's tank farm that morning and an operator was working in the nearby 100's tank farm. However, neither of them heard, saw, or smelled anything out of the ordinary during the time of the release. The First & Second 80's tank farm was not equipped with a gas detection system.

The unanticipated changes in the computer control system data did not trigger any alarms in the central control room (CCR) since the changes did not reach any applicable alarm setpoints.[c] The Hi and Lo alarm setpoints for the Tank 80-8 pump discharge pressure were 130 and 0 psi, respectively. The CCR operator on duty was not

[a] The tank volume, or "Gross BBLS," is calculated using the ITC tank strapping tables, which correlate a level in inches to a corresponding volume within a specific tank. Calibration is performed by third-party vendors for product management purposes. This volume is calculated as gross barrels (42 U.S. gallons) with no correction factors applied. The strapping table is converted into a data table format compatible with the SCADA system. The converted table is placed into the control system logic function block for each specific tank. The SCADA system polls the tank gauging system, which for Tank 80-8 was a Saab Radar Gauge, to receive a product level in 16ths of an inch. This value is multiplied by 16 to derive inches of level. This level value is fed into the logic function block to derive the tank gross volume based on the level reading from the tank gauge. If the level value is between two table entries, the logic function block interpolates the volume.

[b] The DCS records "Gross BBLS" changes in increments of 40 barrels; thus, the actual amount of product lost from Tank 80-8 at this time was likely more than 206 barrels, as opposed to the 177 barrels indicated on the recorded data.

c The Hi and Lo alarm setpoints for the Tank 80-8 pump discharge pressure were 130 and 0 psi, respectively.

actively monitoring Tank 80-8 because no loading or unloading activity was ongoing at the time. As a result, the CCR operator did not identify the ongoing reduction in tank volume and took no measures to secure the butane-enriched naphtha product release.

At 10:01 a.m., control system event logs indicated an uncommanded stop for the Tank 80-8 circulation pump. Subsequently, the Tank 80-8 circulation pump lost communication with the DCS as the sensors responsible for taking tank height readings lost connectivity with the system, likely as a result of power loss from the fire. No further control system data for Tank 80-8 or the pump were available after this time. That afternoon, at 12:09 p.m., DCS data stopped recording for all tanks located in the First & Second 80's tank farm as a result of power loss from the fire.

Figure 9. ITC Deer Park terminal security camera footage showing fireball over First & Second 80's Tank Farm at 10:00:46 a.m. on March 17, 2019. (Credit: ITC, annotations by CSB)

2.3 Incident Response and Fire Progression

When the fire erupted shortly after 10:00 a.m.[a] on March 17, 2019, the acting shift manager was finishing up work in the adjacent tank farm, about 600 feet away from Tank 80-8. He was walking north, between Tanks 80-17 and 80-20 (**Figure 3**), toward his truck when he heard an unexpected noise that he described as sounding like two railcars coupling. A few seconds later he looked up and saw fire between Tanks 80-8 and 80-11.

[a] 10:00:46 a.m. from ITC surveillance camera footage.

The acting shift manager hopped over the containment wall to exit the tank farm and immediately reported the fire via his handheld radio and instructed members of ITC's Emergency Response Team (ERT)[a] to respond to the First & Second 80's tank farm. He then called the facility's Security Office and instructed security personnel to activate the plant-wide alarm to alert all on-site personnel of the incident. Between approximately 10:03 a.m. and 10:10 a.m., the security officer sounded the fire alarm, made an announcement over the all-call system, and sent out a notification over the computer system, followed by an e-notify message. The acting shift manager continued to make notifications, including a call to the Vice President of Safety, Health, Environmental, Security, Regulatory Compliance, and Operations (VP of Safety) to inform him of the tank farm fire.

Members of the ERT reported to the fire house and prepared to fight the fire. The onsite fire truck arrived at the First & Second 80's tank farm within minutes. The first responding member of the ERT entered the tank farm near Tank 80-12 and attempted to activate the fixed fire monitor[b] located in the center of Tanks 80-8, 80-9, 80-11, and 80-12. However, the fire monitor was engulfed in flames, and he was unable to access or activate it (**Figure 10**). He then approached the fixed fire monitor between Tanks 80-7, 80-8, 80-10, and 80-11, directed it towards the fire at the Tank 80-8 piping manifold, and opened the valve to start the flow of water. The acting shift manager described the flow of water coming out of this monitor as a "trickle" not capable of reaching the fire. Later, another operator in the area activated a fixed fire monitor located on the tank farm containment wall near Tank 80-9. However, the positions of these fixed fire monitors did not allow for them to be aimed directly at the fire engulfing the Tank 80-8 piping manifold, as they were not designed to reach that area. In the meantime, the fire shifted toward Tank 80-11, causing the insulation surrounding the tank to ignite, according to an emergency responder.

[a] The ERT consisted of a total of 60 ITC employees. During any given shift, roughly 8-10 members of the ERT were typically on duty. All members of the ERT attend the Texas A&M or Calcasieu firefighter training schools annually and participate in quarterly ERT training in-house (i.e., medical, spill, fire, and hazardous materials response).

[b] Fixed fire monitors are fixed master stream devices, manually or remotely controlled, or both, capable of discharging large volumes of water or foam. [NFPA 1964, Standard for Spray Nozzles and Appliances]

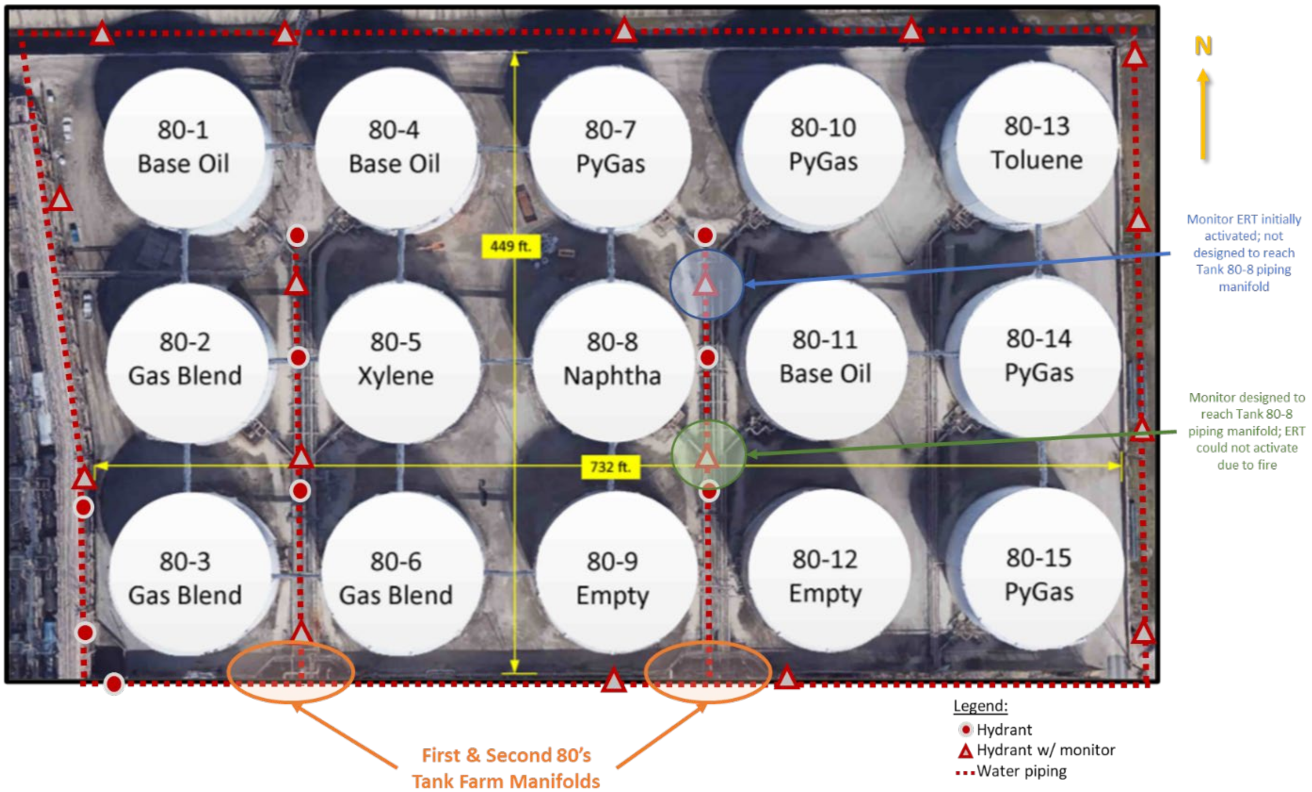

Figure 10. First & Second 80's tank farm layout, including products contained in the tanks at the time of the incident and positions of fire water equipment. (Credit: ITC, annotations by CSB)

While en route to the facility, the VP of Safety, who also led the ERT, was in radio contact with ERT members to ensure that fire pumps were being activated and that on-site personnel were being accounted for by facility management. He also asked the Security Office to notify the Channel Industries Mutual Aid (CIMA) organization of the fire and request that resources be deployed to assist with the response. CIMA is a non-profit group that combines the firefighting, rescue, hazardous materials handling, and emergency response capabilities of the refining and petrochemical industry in the greater Houston metropolitan area [11]. Participating members of the CIMA organization agree to provide emergency response resources and support, including firefighting personnel, equipment, trucks, foam, and supplies to assist with response efforts at other member facilities on a voluntary basis.

When the VP of Safety arrived, his initial observation of the scene was a three-dimensional fire[a] involving the Tank 80-8 piping manifold (**Figure 11**). A liquid pool fire at ground level fully engulfed the Tank 80-8 piping manifold located on the southeast side of the tank, and a pressure fire shot flames horizontally from piping or a flange located roughly six feet above ground level in the same area. Flames from the fire extended up along the side of the tank toward the rim.

[a] According to a training module from TRANSCAER (Transportation Community Awareness and Emergency Response), an outreach program covering North America: "A three-dimensional fire is defined as a liquid-fuel fire in which the fuel is being discharged from an elevated or pressurized source, creating a pool of fuel on a lower surface. Foam is not effective at controlling three-dimensional flowing fires. It is recommended that firefighters control a three-dimensional flowing fire by first controlling the spill fire; then they may extinguish the flowing fire using a dry chemical agent" [70].

Figure 11. Initial ITC tank fire that ignited at Tank 80-8 on March 17, 2019. (Credit: HCFMO, annotations by CSB)

Given that Tank 80-8 was situated in the center of the First & Second 80's tank farm, the initial response efforts focused on using water to cool the tanks, control the fire, and prevent it from spreading. Since Tanks 80-9 and 80-12 were both empty, resources were not focused on cooling these tanks; however, a wind shift caused the fire to inundate the Second 80's tank farm manifold located in this area, which connected to process piping from other locations in the facility.[a] As a result, the ERT positioned a portable fire monitor between Tanks 80-11 and 80-12 to assist with cooling efforts and prevent the combustible insulation surrounding Tank 80-11 from reigniting. At this time, fire was visible near the rim of Tank 80-8, with flames being expelled through the roof vents (**Figure 12**).

[a] There were two tank farm manifolds (piping connections) located on the south side of the First & Second 80's tank farm. The tank farm manifolds connected loading piping from other locations in the facility to the piping systems serving individual tanks ("transverse piping"). The piping serving Tanks 80-7 through 80-12 ran north-south between Tanks 80-7 through 80-9 and Tanks 80-10 through 80-12. The piping for Tanks 80-13 through 80-15 ran north-south between Tanks 80-10 through 80-12 and Tanks 80-13 through 80-15.

Figure 12. ITC fire involving Tank 80-8 on the morning of March 17, 2019. (Credit: ABC13 Houston, annotations by CSB)

Additional emergency responders began to arrive at the facility with firefighting equipment and resources, including the Deer Park Fire Department and other members of CIMA, at which time a formal Unified Command was established to oversee the coordinated response. The Unified Command included representatives from ITC, CIMA, the Harris County Fire Marshal's Office (HCFMO), the Harris County Office of Emergency Management, the EPA, the U.S. Coast Guard (USCG), and TCEQ. The response also included support from other federal, state, and local agencies.

Early response efforts focused on life safety[a] and directing water sources at Tank 80-8 and the ground-level fire that engulfed its piping manifold (**Figure 13**). As the fire grew, additional water supply was needed; so, efforts were also underway to establish water supply from neighboring facilities and the Houston Ship Channel via fire boats. Emergency responders continued to work to control the fire; however, it was "growing faster than [they] could do anything."

[a] Per NFPA, life safety is defined as the protection of human life, including all persons within structure, civilians, and firefighting personnel [71].

Figure 13. The quick attack truck (circled in red) staged between Tanks 80-11 and 80-12 on March 17, 2019. (Credit: Associated Press, annotations by CSB.)

Tank 80-8 was equipped with a fixed foam system that injected foam into the tank to cover the flammable liquid, to suppress the flammable vapors and cut off oxygen supply necessary to support combustion. The fixed foam system on Tank 80-8 was a manually activated system, with supply coming from fire trucks. The hose connection point was located at the Second 80's piping manifold by Tanks 80-9 and 80-12, which was inundated with fire. This made the area inaccessible to responders. Additionally, the tank level was estimated to be about 80% and the tank level indicator was not functioning, so there was no way to confirm the actual tank product height. Without having level indication, there was concern by the VP of Safety and Unified Command that adding foam and water to the tank would potentially cause the tank to overflow and release butane-enriched naphtha product into the containment area. Based on these two significant safety concerns, the Unified Command decided not to activate Tank 80-8's fixed foam system.

Tank 80-8 was not equipped with a remotely operated emergency isolation valve (ROEIV) therefore, the Unified Command discussed trying to manually isolate the main valves on the tank. However, because flames engulfed the entire Tank 80-8 piping manifold, so the area could not be safely accessed, allowing the continued release of butane-enriched naphtha product from Tank 80-8. At approximately 3:00 p.m., the Unified Command sent a team inside the containment area to close the main valves on some of the other tanks in the tank farm. While the team was inside the tank farm, flammable xylene vapors at the roofline of a second storage tank (Tank 80-5) ignited. Concerned for the team's safety, the Unified Command directed the responders to exit the tank farm before they could successfully close any valves. The fire eventually compromised the Tank 80-5 piping manifold, causing xylene to release into the containment area.

Responders continued to fight the fire in defensive mode[a] throughout the evening, applying water and foam to prevent the fire from spreading further.[b,c,d] However, the large amount of water in the tank farm containment area and gaps in the foam blanket allowed the fire to spread. Both naphtha and xylene are lighter than water,[e] therefore, the released flammable products floated on top of the water in the containment area, ignited, and caused several small fires to burn on the water surface where gaps in the foam existed.

The fire continued, and winds continued to shift overnight. By 1:30 a.m. the next morning, Monday, March 18, 2019, five additional storage tanks in the tank farm had caught fire, bringing the total of involved tanks to eight.[f] As responders continued to fight the fires, temporary reductions in water pressure the following afternoon and later that night hindered progress and allowed additional tanks storing flammable substances to catch on fire.[g]

Realizing a need for additional resources to relieve CIMA responders, at approximately 5:00 p.m. that afternoon, ITC reached out to a third-party emergency response services provider, US Fire Pump, located in Holden, Louisiana for assistance in extinguishing the fire. ITC and US Fire Pump signed a formal Emergency Response Agreement by 12:13 a.m. on Tuesday, March 19, 2019. US Fire Pump arrived on scene at approximately 6:48 a.m. with additional response resources including large volume pumps, submersible pumps, large-flow monitors, and truckloads of firefighting foam.

By 1:00 p.m., US Fire Pump resources were fully integrated with local emergency responders already on scene. Firefighters continued response efforts throughout the evening and into the early morning, applying thick blankets of foam and water to suppress the remaining fires.

The fire at the ITC Deer Park terminal was extinguished by approximately 3:00 a.m. on Wednesday, March 20, 2019 (**Figure 14**).[h] Later that evening, at approximately 5:20 p.m., a flare-up occurred at Tank 80-5 (**Figure 15**). Emergency responders were able to contain the fire quickly.

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[a] Defensive firefighting is defined as the mode of manual fire control in which the only fire suppression activities taken are limited to those required to keep a fire from extending from one area to another (NFPA 600 and NFPA 1081).

[b] Emergency responders continued to work on controlling the fire using water and foam to prevent it from spreading, and employed various fire apparatus, including foam engines and foam aerials.

[c] Foam engine, also known as a Foam Pumper – fire apparatus with a permanently mounted fire pump of at least 750 gpm capacity, water tank, and hose body, whose primary purpose is to combat structural and associated fires; in this case, with foam capabilities (adapted from NFPA 1901 and NFPA 1912).

[d] Foam aerial – a piece of fire apparatus with a permanently mounted, power-operated elevating device, including aerial ladders, aerial ladder platforms, telescoping aerial platforms, articulating aerial platforms, and elevating water delivery systems; in this case, with foam capabilities (adapted from NFPA 1002).

[e] Xylene has a specific gravity of 0.87, compared with that of water, which is 1.0.

[f] These five additional tanks included Tanks 80-2, 80-3, 80-6, 80-9, and 80-11, which contained gasoline blendstock and base oil. Flammable vapors ignited along the rooflines of Tanks 80-2, 80-3, 80-6, and 80-9, causing fire to expel from the vents located near the top of the tanks. At this time, the fire involving Tank 80-11 burned at ground level in the area of the piping manifold. Sometime before 5:30 a.m., an additional tank containing toluene, Tank 80-13, became involved in the fire at ground level but was quickly extinguished (Figure 10).

[g] For example, Tanks 80-14 and 80-15, which caught fire in the early hours of March 19, were located in the southeast corner of the tank farm (Figure 10) and contained Pygas, a highly flammable liquid.

[h] Emergency responders continued to spray foam and water on the tanks to keep them cool, prevent vapors from escaping, and prevent any of the remaining material in the containment area from reigniting.

Figure 14. First & Second 80's tank farm on fire on Tuesday, March 19, 2019, and fully extinguished on Wednesday, March 20, 2019. (Credit: KHOU 11 News)

Figure 15. Tank 80-5 flare-up that occurred on March 20, 2019. (Credit: "Raw video ITC fire reignites in Deer Park", annotations by CSB)

Beginning on the morning of Thursday, March 21, 2019, ITC commenced efforts to move product out of the compromised tanks.[a] On June 19, 2019, the EPA Federal On-Scene Coordinator transitioned the incident from the emergency response phase to the long-term remediation phase. By July 29, 2019, the deconstruction and cleaning of all 15 tanks were complete.

2.4 Containment Wall Failure and Remediation

On Friday, March 22, 2019, at around 12:15 p.m., the secondary containment wall surrounding the First & Second 80's tank farm partially collapsed near Tank 80-7. The containment wall displaced laterally due to excessive lateral soil and hydrostatic pressures.[b] The containment wall failure allowed the mixture of released hydrocarbon products, firefighting foam, and contaminated water previously confined to the tank farm to exit the containment area and enter the ditch running adjacent to Tidal Road on the north side of the tank farm

[a] At around 3:40 p.m., on Friday, March 22, 2019, three tanks, Tanks 80-2, 80-3, and 80-5, re-ignited on the west side of the tank farm. Emergency responders applied foam and were able to fully extinguish the fire in roughly one hour. The product removal and transfer process continued over the course of the next several weeks, during which time emergency responders continued to apply foam to the tank farm to prevent potential flare-ups by maintaining a sufficient level of foam across the tank farm. No additional flare-ups were reported after this event.

[b] Additional detail related to the containment wall failure can be found in Section 4.4.4.

(**Figure 16**). The release also resulted in the potential for elevated levels of volatile organic compounds (VOCs)[a] in the immediate industrial area. As a result, ITC notified its industrial neighbors and local state parks of the potential exposure and recommended that they shelter in place. The breach in the containment wall measured roughly 10 feet in width (**Figure 17**).

Figure 16. Overhead view of the First & Second 80's tank farm containment wall failure that allowed materials to enter the surrounding waterways on Friday, March 22, 2019. (Credit: ITC, annotations by CSB)

[a] VOCs are compounds that have a high vapor pressure and low water solubility. VOCs are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects [81].

Figure 17. Close-up view of the First & Second 80’s tank farm containment wall breach that occurred on Friday, March 22, 2019. (Credit: HCFMO).

The released contaminants eventually entered the Houston Ship Channel via Tucker Bayou. As a result of the breach and subsequent release of materials, the USCG closed a seven-mile stretch of the Houston Ship Channel adjacent to the ITC Deer Park terminal extending from Tucker Bayou and the San Jacinto Monument to Crystal Bay (**Figure 18**) [13]. Additionally, Harris County Precinct 2 temporarily closed eight of the county’s waterfront parks [14] The City of La Porte closed all its waterfront parks as well.[a] By 4:00 a.m. the next day, the containment area was secured.

[a] La Porte waterfront parks remained closed until April 16, 2019.

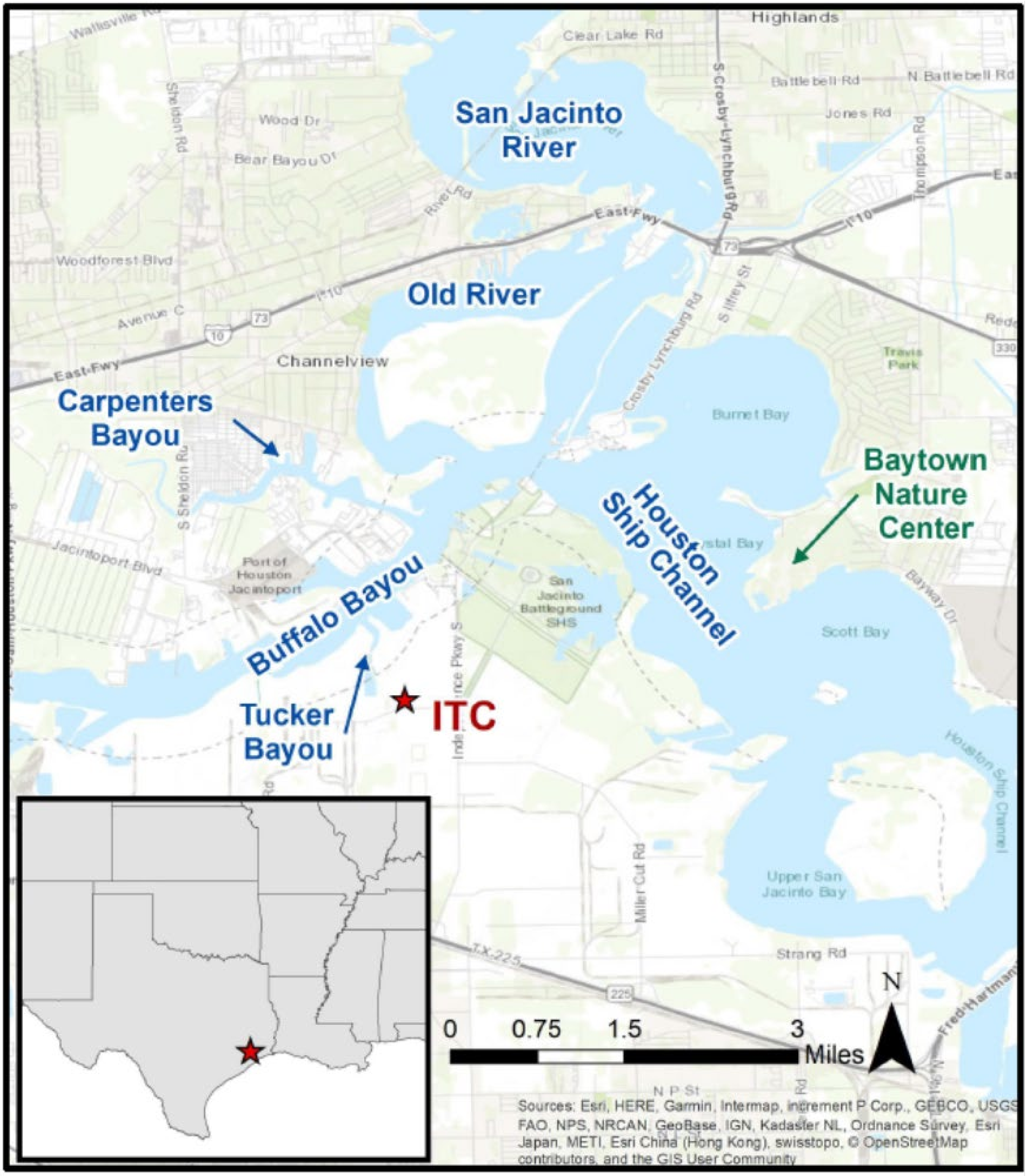

Figure 18. Houston Ship Channel closure. This map shows the general area where response activities associated with product recovery occurred, with the red star indicating the location of the ITC Deer Park terminal. (Credit: DOI) [15]

On Saturday, March 23, 2019, vacuum trucks and hoses were used to begin recovery of the released hydrocarbon and petrochemical products, foam, and water from the First & Second 80's tank farm and the adjacent drainage ditch. Recovery operations continued until Monday, April 1, 2019, when ITC issued a public statement indicating that the tank farm was stable. ITC stated that crews had recovered 92,222 barrels of hydrocarbon and petrochemical product mixed with foam and water from the area over the past 10 days and that the tank farm contained minimal liquid level covered with foam at this time.

Spill containment and cleanup operations to remove the released products from Tucker Bayou and the Houston Ship Channel also commenced on Saturday, March 23, 2019. Tucker Bayou and the adjacent ITC docks were determined to be the primary impacted locations.[a] Crews deployed boom[b] and response vessels to contain the materials and conduct clean-up operations in these areas, in addition to Patrick Bayou, Old River, Carpenter Bayou, Battleship Texas, Santa Ana Bayou, and the San Jacinto River (**Figure 19**).[c,d] As of Monday, April 1, 2019, ITC reported that crews had deployed more than 130,000 feet of boom and recovered over 61,000 barrels of oily water mix from area waterways to date.

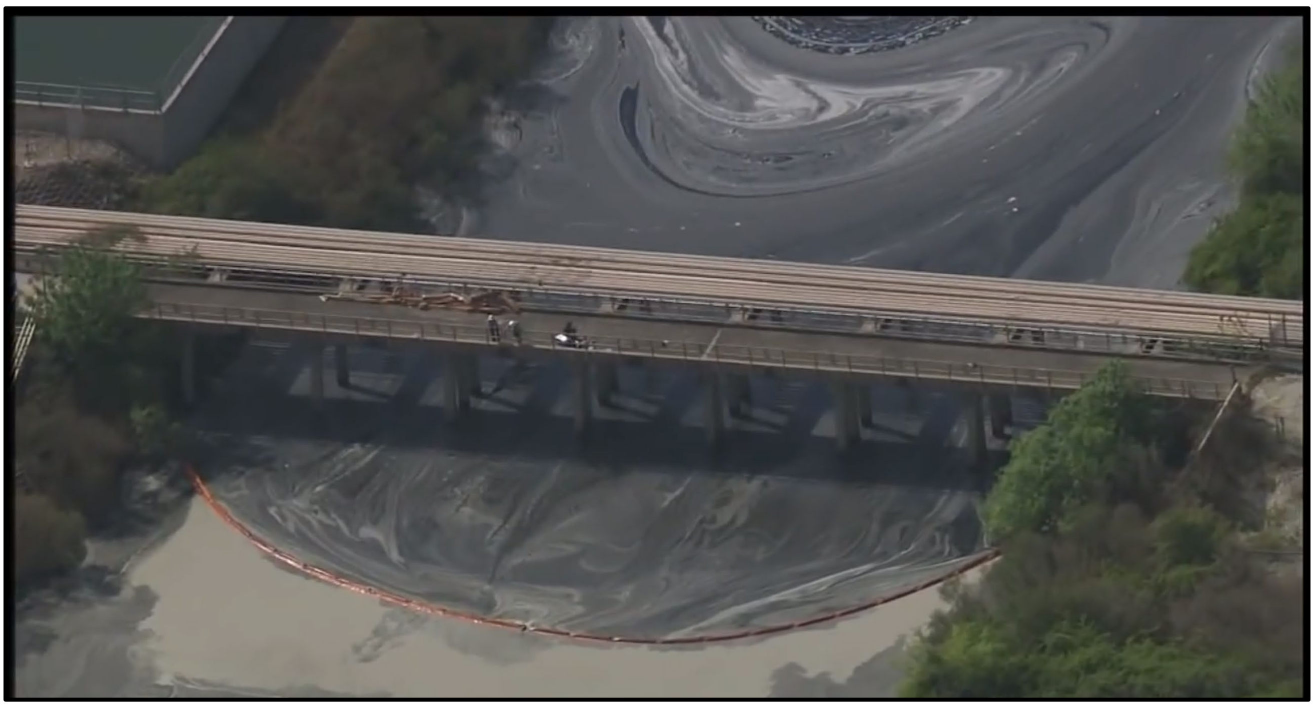

Figure 19. Booming operations conducted in the area of the Houston Ship Channel (Credit: ABC13).

[a] Shoreline Cleanup and Assessment Techniques (SCAT) surveys to determine the progress of cleanup along segments of affected shoreline were conducted in a joint effort by ITC, USCG, TCEQ, and Texas Parks and Wildlife Department. The SCAT survey team provided recommendations to the Unified Command regarding the need for additional active cleanup, passive cleanup, and/or monitoring.

[b] Boom – floating, physical barriers to oil, made of plastic, metal, or other materials, that slow the spread of oil and keep it contained. Skilled teams deploy boom using mooring systems, such as anchors and land lines [72].

[c] Early in the response a total of 34 vessels, including 15 skimmers, were on scene and actively conducting 24-hour clean-up operations in Tucker Bayou and adjacent areas.

[d] Skimmers – boats and other devices that can remove oil from the sea surface before it reaches sensitive areas along a coastline. In **Figure 19**, oil is being skimmed from the sea surface by a "vessel of opportunity." Sometimes, two boats will tow a collection boom, allowing oil to concentrate within the boom, where it is then picked up by a skimmer [72].

Cleanup operations continued over the course of the next several weeks. A total of 214 response vessels, 142 skimmers, and 50 vacuum trucks, and the placement of nearly 168,000 feet of spill containment boom were utilized during the response. As of May 20, 2019, cleanup operations of all shoreline segments, except for Tucker Bayou (comprising 0.87 miles of shoreline), were complete. Unified Command partners agreed on June 19, 2019, that Tucker Bayou would be transitioned and addressed under a long-term remediation phase and not as part of the emergency response phase [16].

2.5 Incident Consequences and Community Impact

The ITC Deer Park incident had a direct impact on the surrounding community, including multiple shelter-in-place orders and closures due to benzene-related air quality concerns (**Figure 20**) [17]. Beginning on the morning of Sunday, March 17, 2019, the City of Deer Park issued a precautionary shelter-in-place order for a portion of the community and neighboring industrial facilities.[a] That shelter-in-place order was later expanded to include the entire City of Deer Park, at which time a portion of State Highway 225 was also closed to all traffic. Working under a Unified Command with the EPA, TCEQ, Harris County, USCG, and other agencies, ITC was directed to conduct air monitoring.[b] TCEQ, the EPA, and Harris County staff also deployed air monitoring resources beginning on March 17, 2019. The shelter-in-place order was lifted early the next morning after ITC publicly released an environmental report issued by CTEH that showed all air quality detections recorded were below levels that would represent a public health concern. The City of Deer Park also reopened State Highway 225.

[a] All times listed are approximate and in Central Time.

[b] ITC deployed its contractor, the Center for Toxicology and Environmental Health (CTEH), to conduct handheld, real-time air monitoring in accordance with two distinct sampling plans: one for the local community and another for the industrial area.

Figure 20. Photo showing plume of black smoke from First & Second 80's tank farm fire. (Credit: The Texas Tribune [18])

From Monday, March 18, through Friday, March 22, 2019, six school districts (Deer Park, La Porte, Pasadena, Channelview, Galena Park, and Sheldon) cancelled classes and activities on some of the days out of an abundance of caution.[a]

On Thursday, March 21, 2019, elevated levels of benzene were detected in the northern portion of Deer Park between 4:02 and 8:23 a.m. following the extinguishment of the tank farm fire. Levels remained below those that would pose any immediate health risk; however, the City of Deer Park issued a second precautionary shelter-in-place order that morning, during which time residents were advised to remain indoors, close all doors and windows, and turn off air conditioning or heating systems to prevent chemical vapors from entering the homes. As a result, the same six local school districts closed all campuses and cancelled all activities for the day [18] Air contaminant levels were resolved roughly five hours after they were initially detected, and the shelter-in-place order was lifted later that morning at approximately 11:40 a.m.

On Friday, March 22, 2019, the containment wall surrounding the First & Second 80's tank farm partially collapsed, allowing a mixture of hydrocarbon and petrochemical products and firefighting foam to release from containment and enter the surrounding waterways. As a result of the release, a seven-mile stretch of the Houston Ship Channel adjacent to the ITC Deer Park terminal was temporarily closed [13]. Additionally, Harris County

[a] On Monday, March 18, 2019, both Deer Park Independent School District (ISD) and neighboring La Porte ISD cancelled classes and activities for the day, out of an abundance of caution [66]. On Wednesday, March 20, 2019, six local school districts, including Channelview ISD, Deer Park ISD, Galena Park ISD, La Porte ISD, Pasadena ISD, and Sheldon ISD, made the decision to close for the day and cancel all activities, out of an abundance of caution [18]. On Friday, March 22, 2019, Deer Park ISD, La Porte ISD, and Pasadena ISD once again cancelled all classes and activities for the day. [18]

announced the closure of its waterfront parks, as did the City of LaPorte [14]. The release also resulted in elevated levels of VOCs detected in the vicinity of the terminal, which caused the San Jacinto Monument, Battleship Texas State Parks, and the Lynchburg Ferry to temporarily close.

Local waterways and waterfront parks near the terminal remained closed the following week as cleanup operations continued in the surrounding waterways. However, no additional shelter-in-place orders were issued, and all local school districts impacted by the ITC incident reopened campuses on Monday, March 25, 2019, without any further disruption. ITC, Harris County, TCEQ, and the EPA each continued their respective air monitoring activities in the area; no additional elevated levels of benzene or VOCs were detected.

On June 19, 2019, Unified Command partners transitioned this incident from the emergency response phase to the long-term remediation phase. Long-term remediation included ITC's disposal of approximately 387,000 barrels of liquid waste at several disposal facilities. As of October 2019, ITC had also processed approximately 51,700 barrels of fire-related wastewater on-site through its wastewater plant [16].

The Natural Resource Damage Assessment and Restoration Program reported that an estimated 470,000–523,000 barrels of a mixture of fire water, firefighting aqueous film-forming foams, and petrochemical products from the storage tanks were released into Tucker Bayou and adjacent waters, sediments, and habitats. The long-term environmental damage is still under assessment. In February 2022, the Texas Parks and Wildlife Department, TCEQ, Texas General Land Office, U.S. Department of the Interior, and the National Oceanic and Atmospheric Administration (NOAA) published a natural resource damage assessment plan, which is intended to serve as the guiding document for all damage assessment activities related to the March 17, 2019, incident [19].

This incident did not result in any injuries or fatalities. ITC estimated that property damage resulting from the loss of the First & Second 80's tank farm associated with the March 17, 2019, incident exceeded $150 million.

3 Technical Analysis

This incident occurred when the butane-enriched naphtha product released from the Tank 80-8 circulation pump and found an ignition source, causing a fire to erupt and engulf the tank's piping manifold. Over the next three days, the massive fire spread to 12 additional aboveground storage tanks in the tank farm before emergency responders fully extinguished the flames. Two days later, the secondary containment wall surrounding the tank farm partially collapsed, allowing the mixture of released hydrocarbon products, firefighting foam, and contaminated water in the containment area to release into the surrounding waterways.

As discussed below, the CSB's investigation established that problems with the mechanical integrity of the Tank 80-8 circulation pump enabled the release of the butane-enriched naphtha product and contributed to the fire's cause.

The pump installed in the Tank 80-8 piping manifold at the time of the incident was a *Goulds Model 3196 XLT-X* chemical process pump.[a] The pump consisted of a liquid end and power end, connected by a frame adapter

[a] According to company records, the circulation pump involved in the incident was first installed in the Tank 80-8 piping manifold around March 2007.

(**Figure 21**). The liquid end was comprised of the casing, impeller, seal chamber, and mechanical seal gland.[a] The mechanical seal was designed to contain the butane-enriched naphtha product inside the seal chamber as it flowed through the pump. The seal gland mounted flush to the seal chamber cover and was secured by four gland nuts threaded onto the seal chamber studs that extended through designated slots on the seal gland. The power end was comprised of the bearing frame, pump shaft, two sets of ball bearings, and oil seals. The purpose of the two sets of ball bearings was to support the pump shaft. The inboard bearing was responsible for carrying radial loads,[b] and the outboard bearing was responsible for carrying both radial and thrust (axial) loads. The pump shaft extended from the impeller through the seal chamber and bearing frame to the motor coupling.

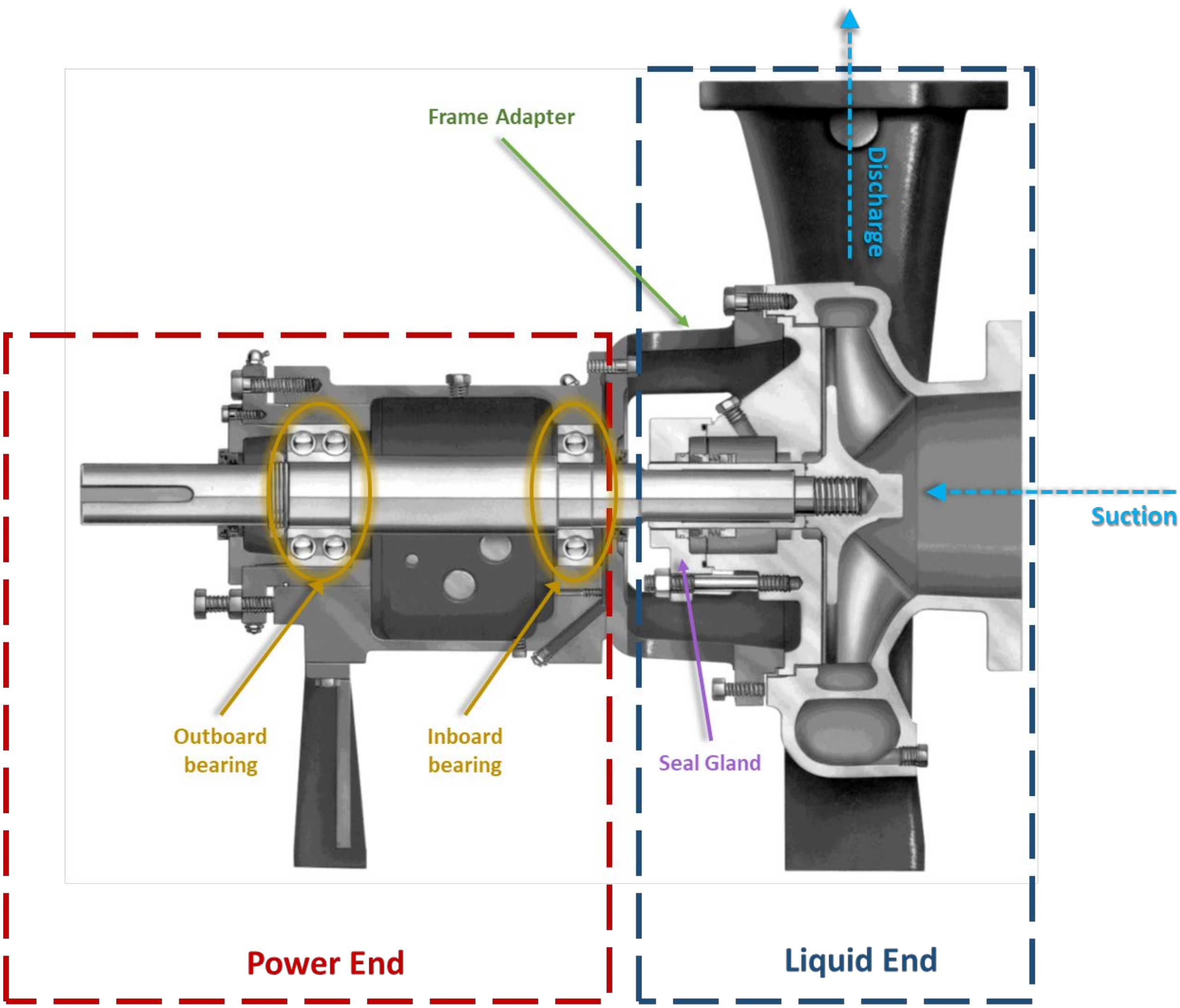

Figure 21. Sectional view of *Goulds Model 3196 XLT-X* chemical process pump. This view identifies the pump's liquid end, power end, and rigid frame adapter. (Credit: *Goulds*, annotations by CSB)

[a] The seal found in place post-incident was a Chesterton S20™ Tandem Dual Cassette Seal, which was also designed for use with the Goulds Model 3196 XLT-X pump

[b] Radial loads are forces that are perpendicular to the axis of the shaft, parallel to the bearing's radius.

Following the incident, the Tank 80-8 circulation pump skid was transported to a third-party facility for inspection and teardown (**Figure 22**). The pump was fully disassembled to allow for visual examination of its individual components and documentation of their condition. Severe degradation and wear damage were observed on the pump shaft, seal, and outboard bearing. Substantial abrasive wear was visible on the pump shaft adjacent to the seal on the inboard side of the bearing housing (**Figure 23**). Extensive contact wear was also visible on the seal gland (**Figure 24**).

Figure 22. Tank 80-8 pump removed from ITC Deer Park terminal. Pictured is the pump kit on a pallet, as removed from the incident site. (Credit: CSB)

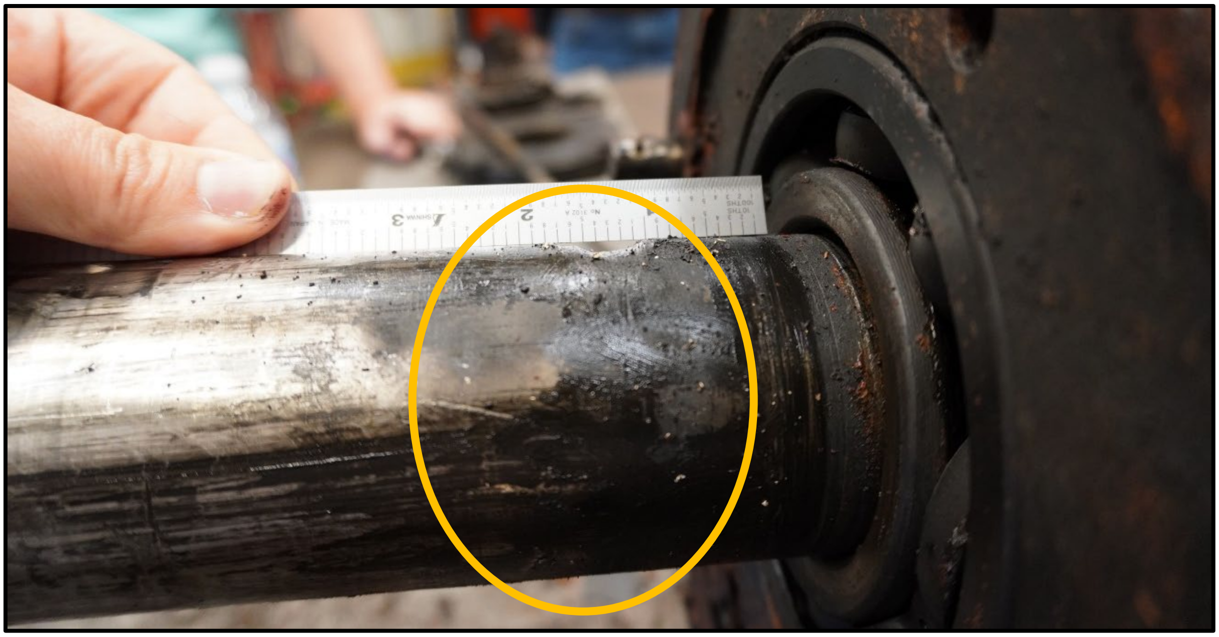

Figure 23. The severe abrasive wear damage observed on the Tank 80-8 pump shaft adjacent to inboard side of bearing housing, on August 30, 2019. (Credit: CSB)

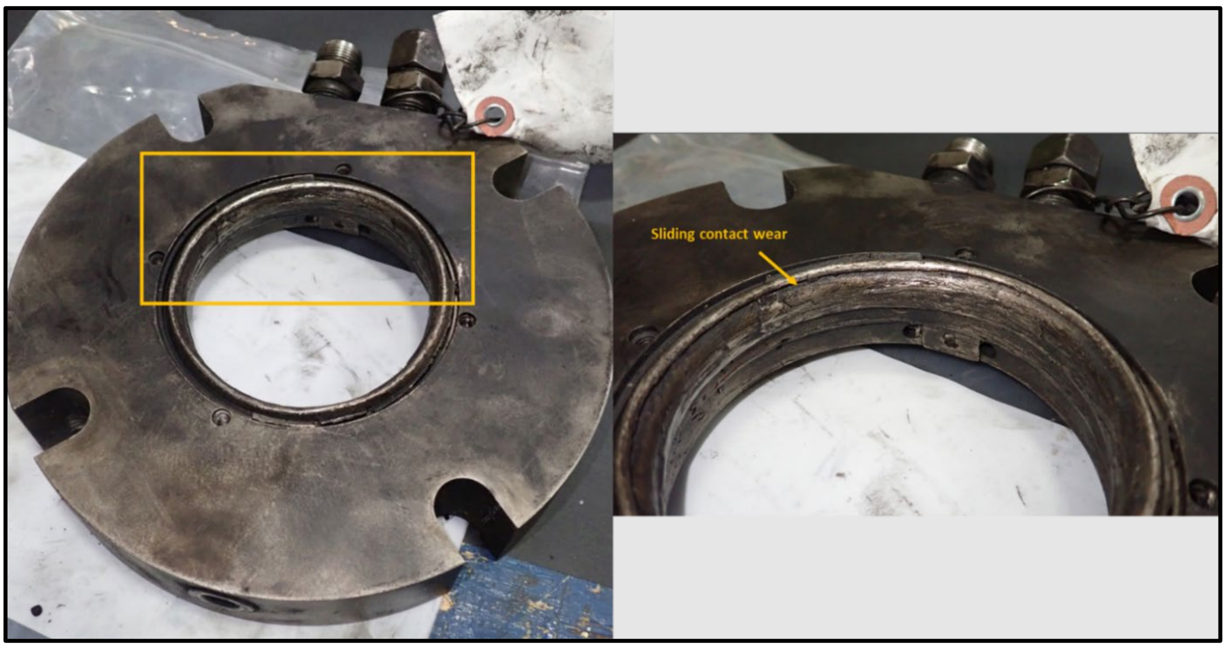

Figure 24. Smeared metal on inside surface of seal gland that indicates sliding contact with the pump shaft. (Credit: Stress Engineering)

Four gland nuts secured the seal gland to the seal chamber cover to prevent the butane-enriched naphtha product from leaking from the pump, as shown in **Figure 25**. Post-incident inspection of the Tank 80-8 circulation pump revealed that none of the four gland nuts remained in place and that the seal gland was completely separated from the seal chamber cover (**Figure 26**). Additionally, the barrier fluid steel tubing used to provide lubrication to the mechanical seal via the seal gland was found severed from the nearby external seal pot and wrapped around the pump shaft.

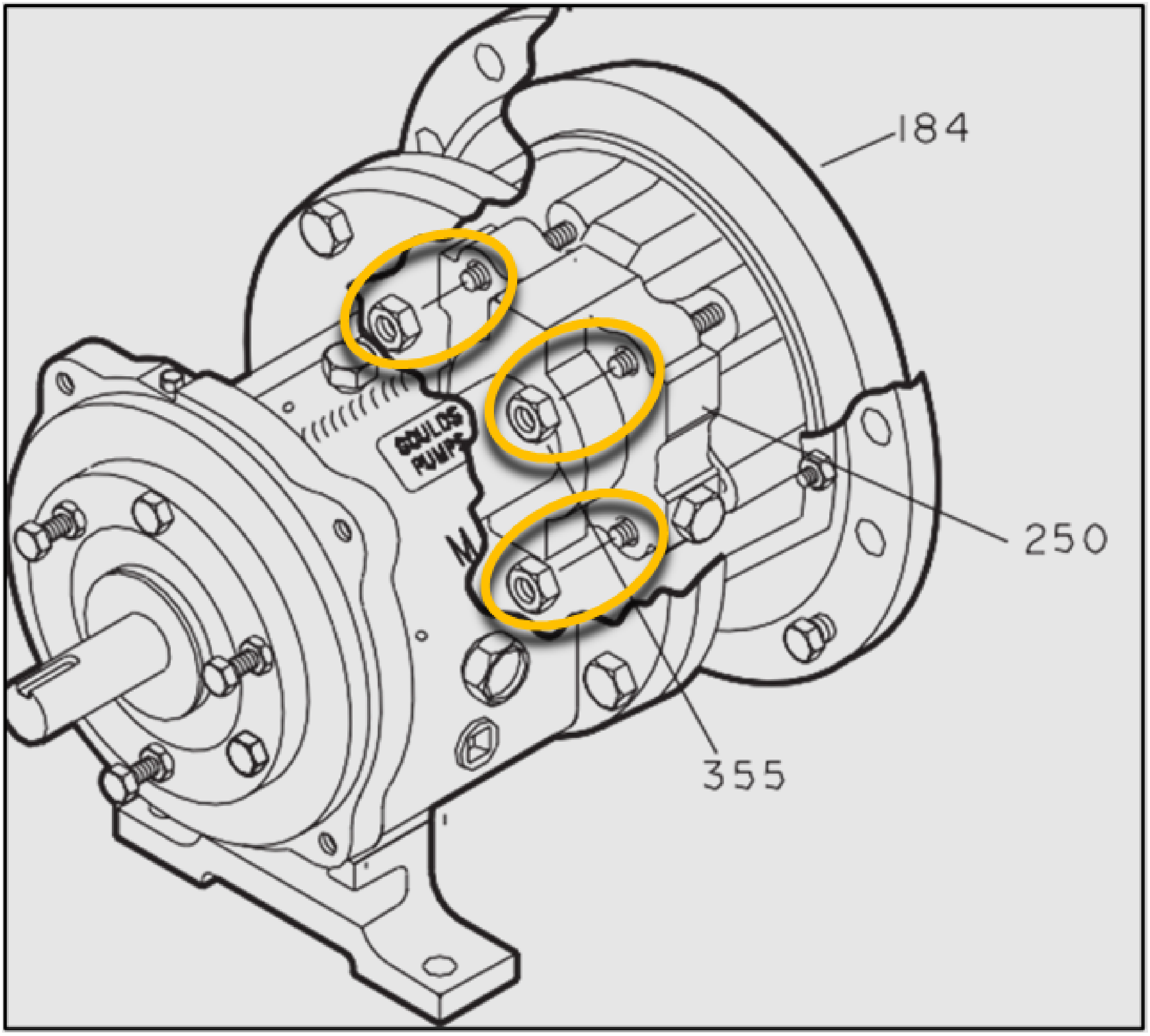

Figure 25. Cutaway drawing of *Goulds* chemical process pump showing the locations of three of the four gland nuts that held the seal gland in place against the seal chamber cover. *Note: fourth gland nut is not visible in drawing*. [Credit: *Goulds*, annotations by CSB]

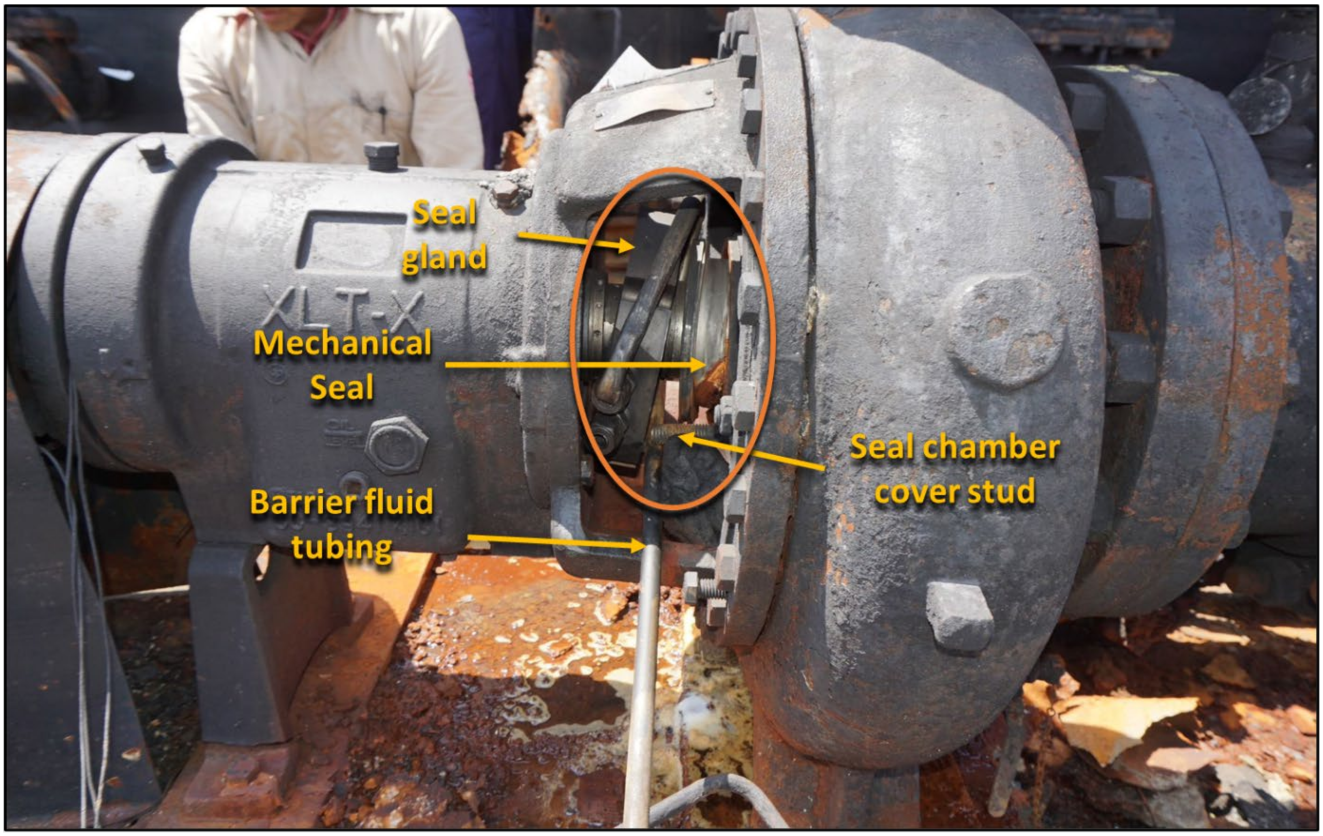

Figure 26. Tank 80-8 circulation pump. This photo shows the point of separation observed between the mechanical seal gland and seal chamber cover where the butane-enriched naphtha product released. (Credit: CSB).

Post-incident examination of the internal threads of the three seal chamber studs that supported the seal gland showed non-uniform deformation around the circumference of the threads that projected through the slots on the seal gland (**Figure 27**). Metallography completed on one of the studs identified flattening of the thread crowns (**Figure 28**).[a] The non-uniform deformation of the threads that projected through the slots on the seal gland and flattening of the thread crowns are indicative of radial compression contact, as opposed to a shear force contact on the threads. Therefore, the damage was likely caused by the seal chamber studs making vibrational contact with the seal gland slots as the gland nuts loosened and eventually released from the studs. Based on the post-incident condition of the pump, the CSB concludes that the butane-enriched naphtha product release initiated when the Tank 80-8 circulation pump's gland nuts loosened from the seal chamber cover, allowing the seal gland to separate from the seal chamber cover and consequently creating a path for butane-enriched naphtha product to release.

[a] The internal threads of the blind holes in which the studs were located, as well as the threads on the studs where they engaged the blind holes, were in good condition.

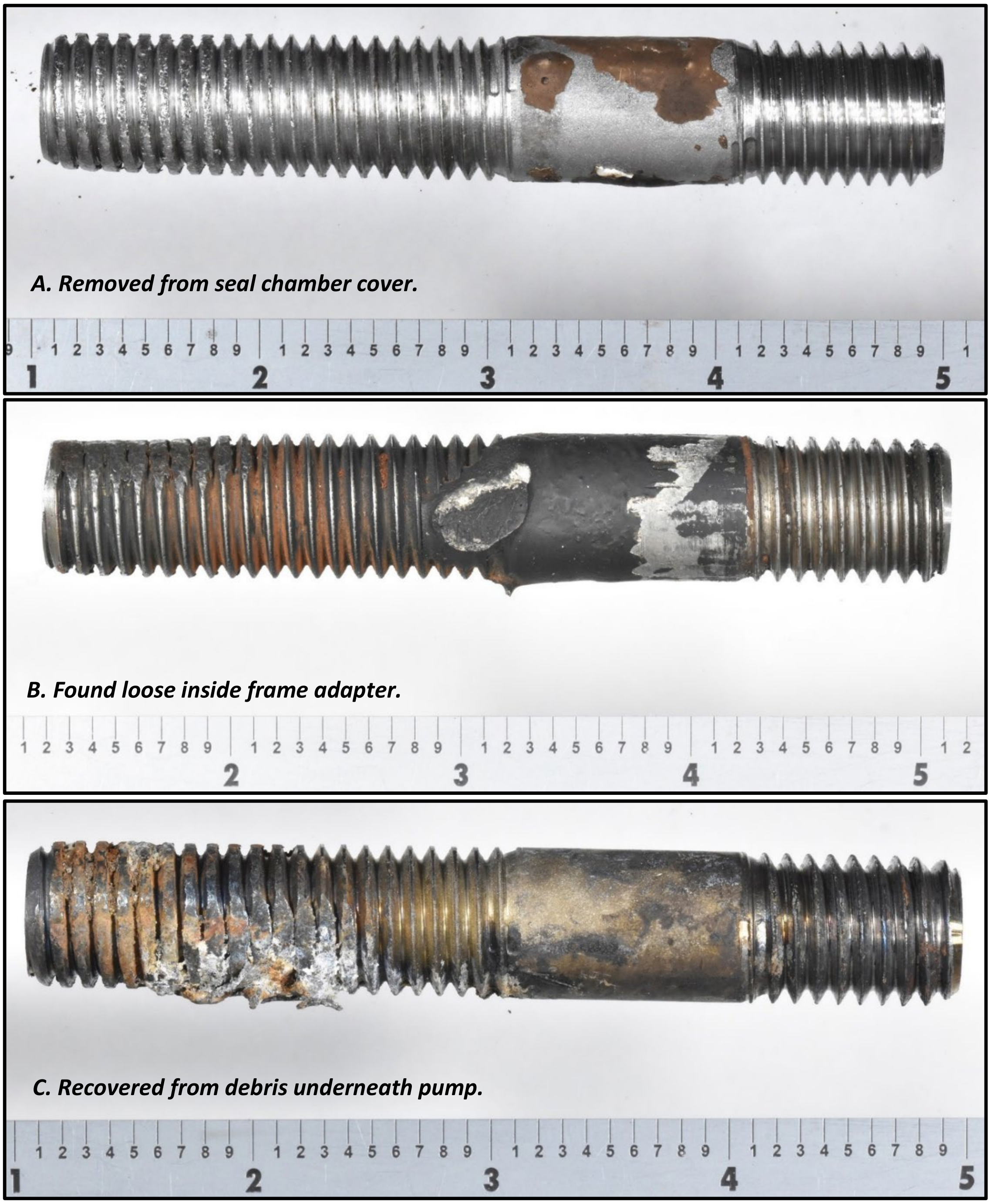

Figure 27. Three seal chamber cover studs recovered from Tank 80-8 circulation pump, post-cleaning. The longer threaded ends passed through the slots in the seal gland, while the shorter threaded ends were engaged in the seal chamber cover. (Credit: Stress Engineering)

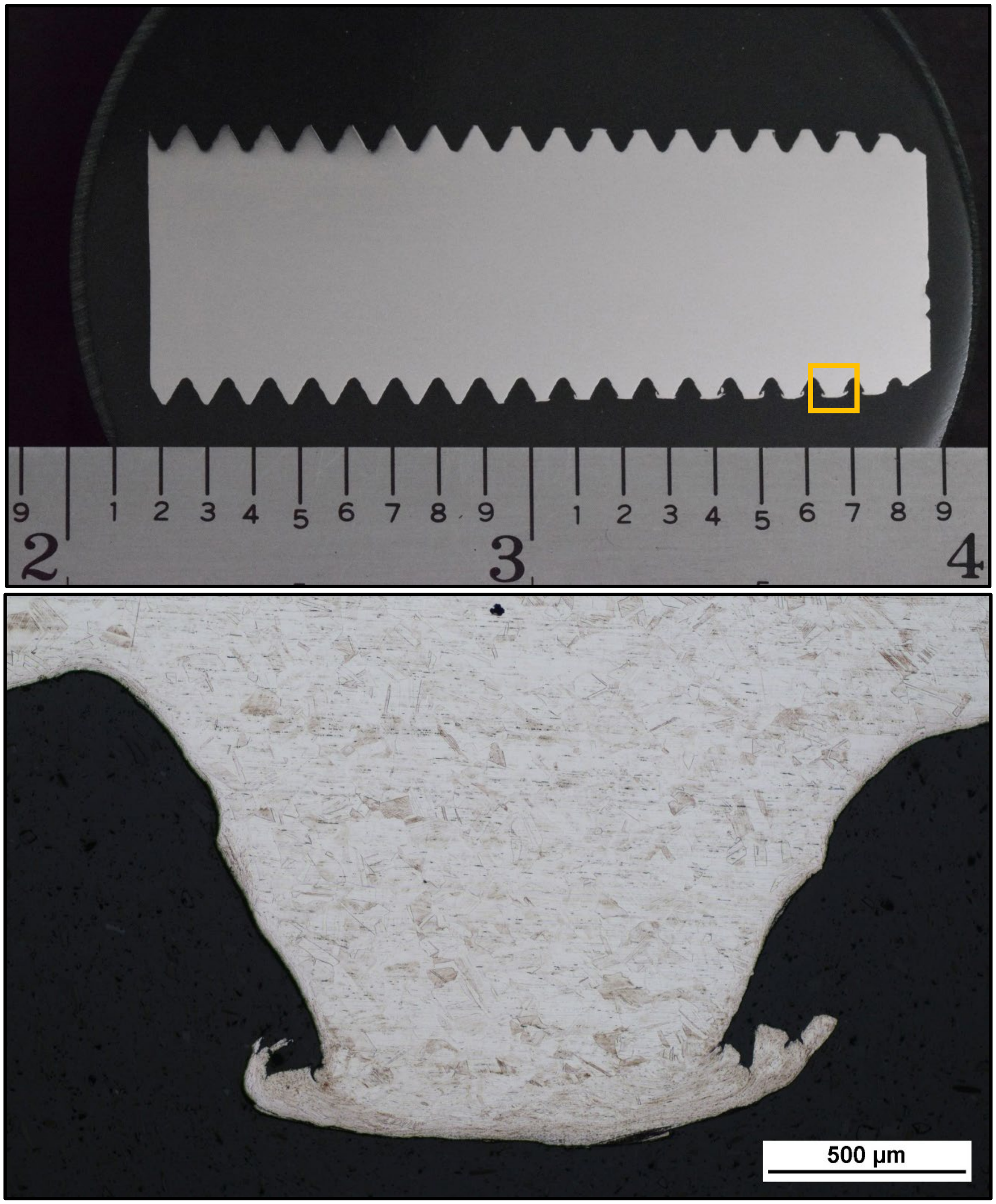

Figure 28. Section of threads from seal chamber stud that projected through slots in seal gland, where flattening of the thread crowns was observed (Credit: Stress Engineering)

Prior to disassembly of the Tank 80-8 circulation pump, radial displacement of the pump shaft was observed on the outboard side on the bearing frame, which is typically indicative of extensive bearing failure. Subsequent disassembly of the bearing housing confirmed failure of the outboard thrust bearing.

The Tank 80-8 circulation pump was in operation on the morning of March 17, 2019. Once the outboard bearing failed, the pump shaft would have been left largely unsupported, which in turn would have allowed extensive upward deflection on the outboard end of the pump shaft (due to the weight of the impeller on the inboard end of the pump shaft) and shaft centerline misalignment. As the Tank 80-8 circulation pump continued to operate under these conditions, the high-speed rotation of the largely unsupported pump shaft likely induced significant vibration in the pump, which increased as the misalignment amplified. Beginning at approximately 9:30 a.m. that morning, the recorded tank volume began to decrease and the average flow rate for the tank began to increase with no intended change in operation having occurred. This was likely the result of the gland nuts loosening from the seal chamber studs, which allowed the seal gland to separate from the seal chamber cover, consequently creating an opening for butane-enriched naphtha product to release from the pump.[a] Based on the extensively degraded condition of the outboard thrust bearing and the seal chamber studs observed post-incident, the CSB concludes that Tank 80-8's circulation pump likely continued to operate past the point of outboard bearing failure while circulating the butane-enriched naphtha product. The bearing failure likely led to significant pump vibration, which loosened the gland nuts that secured the mechanical seal in place, causing the seal to separate and allow the release of the flammable mixture.

The Tank 80-8 circulation pump continued to operate as the butane-enriched naphtha product released from the failed pump to the atmosphere for roughly 30 minutes before the fire erupted at about 10:00 a.m. During this time period, approximately 200 barrels (8,400 gallons) of the butane-enriched naphtha product accumulated in the area around the pump in the Tank 80-8 piping manifold. Due to the high vapor density of the hazardous substance, the butane-enriched naphtha product's flammable vapors likely hovered near ground level and collected in low-lying areas around the Tank 80-8 pump skid. There was no vibration monitoring system installed on the Tank 80-8 circulation pump nor was there an LEL gas detection system in the area to alert personnel of the ongoing release.

As the pump shaft continued to rotate, the high-speed grinding of the two metal surfaces caused a groove to form on the pump shaft near the inboard side of the bearing housing. The depth of the groove on the pump shaft created by the metal-to-metal contact indicates the pump continued to operate for several minutes after the seal gland fully separated from the seal chamber cover (**Figure 23**). The CSB concludes that accumulated flammable vapors in the area around the Tank 80-8 pump skid were likely ignited as a result of heat generated from the metal-to-metal contact between the unrestrained seal gland and pump shaft.

4 SAFETY ISSUES

The following sections discuss the safety issues contributing to the incident, which include:

- **Pump Mechanical Integrity.** ITC did not have a formal mechanical integrity procedure in place that defined requirements for maintaining the mechanical integrity of Tank 80-8 and its associated equipment, including the Tank 80-8 circulation pump. A formal mechanical integrity program for pumps in highly hazardous chemical service could have prevented this incident by providing ITC with additional opportunities to identify pump issues prior to the incident. The mechanical seal on the pump failed on March 17, 2019, allowing butane-enriched naphtha product to release from the pump while it continued to operate.

[a] The combined pressure of flowing butane-enriched naphtha product and motion of the pump shaft would have caused the unrestrained seal gland to propel forward, strike the inboard side of the bearing frame, and rotate once around the pump shaft, as evidenced by the barrier fluid tubing that was found severed and wrapped itself around the pump shaft. Once this occurred, the forward edge of the unrestrained seal gland had come to rest against the rotating pump shaft (**Figure 26**).

- **Flammable Gas Detection Systems.** Tank 80-8 was not equipped with a flammable gas detection system to warn personnel of a hazardous atmosphere resulting from loss of containment from the tank or its associated equipment. In 2014, a hazard review team recommended the addition of flammable gas detection systems near Tank 80-8; however, ITC did not implement this recommendation and did not document why it was not implemented. In the absence of a flammable gas detection system, there were no alarms to alert personnel about the initial release of butane-enriched naphtha product around the Tank 80-8 piping manifold. Consequently, the butane-enriched naphtha product continued to release from the failed pump for approximately 30 minutes, completely undetected, before its flammable vapors eventually ignited.

- **Remotely Operated Emergency Isolation Valves.** Tank 80-8 and the other aboveground storage tanks located in the First & Second 80's tank farm were not equipped with ROEIVs designed to mitigate process releases remotely from a safe location. The primary drivers for identifying the need for this type of equipment would have been through implementation of hazard assessments, such as those required by of the OSHA PSM standard and the EPA RMP rule, as well as insurance company audits and/or corporate risk evaluations results. On the day of the incident, the large volume of butane-enriched naphtha product contained in Tank 80-8 could not be remotely or automatically isolated, and it continued to release, via the failed pump, fueling the fire that continued to intensify around the tank. As the Tank 80-8 fire intensified, flames from the fire spread to adjacent tank piping manifolds in the tank farm and eventually compromised the equipment, causing breaches in piping that allowed the hydrocarbon and petrochemical products contained in the storage tanks to release into the common containment area.

- **Tank Farm Design.** Although the First & Second 80's tank farm was designed largely in accordance with applicable NFPA 30 requirements, elements of the tank farm design, including tank spacing, subdivisions, engineering controls for pumps located inside the containment area, and drainage systems, made it difficult for emergency responders to slow or prevent the spread of the initial fire, and allowed the fire to spread to other tanks within the tank farm. While NFPA 30 defines minimum requirements for tank farm design, additional industry guidance documents provides more robust tank farm design recommendations. While ITC was not required to implement additional industry guidance recommendations, many of which were developed after construction of the First & Second 80's tank farm, implementation of such recommendations could have prevented the escalation of this incident.

- **PSM and RMP Applicability.** ITC did not apply a formal process safety management program to Tank 80-8 because neither the OSHA PSM standard nor the EPA RMP rule applied to Tank 80-8 and its associated equipment. Tank 80-8 was not covered by the OSHA PSM standard due to the atmospheric storage tank exemption in the standard, and the EPA RMP rule did not apply due to the flammability rating exemption in the rule for the butane-enriched naphtha mixture. Although ITC applied some process safety management elements across the terminal, the company did not apply other key elements, such as Mechanical Integrity and Process Hazard Analysis, to atmospheric storage tanks in highly hazardous chemical service. Applying these elements would have provided the company with additional opportunities to identify and control hazards through multiple layers of protection, including the examples of preventative and mitigative safeguards discussed in this report. Thus, had ITC developed and implemented a comprehensive process safety management program that effectively identified and controlled hazards for Tank 80-8 and its related equipment, the incident could have been prevented.

4.1 Pump Mechanical Integrity

The American Petroleum Institute (API) defines mechanical integrity as the management of critical process equipment to ensure it is designed and installed correctly and that it is operated and maintained properly [20, p. 4]. Mechanical integrity is an asset management program that encompasses the actions or activities needed to ensure that process equipment is designed, fabricated, installed, operated, and maintained throughout its service life so that it can safely and reliably provide the desired performance. Properly managing and maintaining process equipment reduces the likelihood of unexpected equipment failure resulting from inadequate or infrequently performed maintenance.

4.1.1 Mechanical Integrity Program

ITC has a *Mechanical Integrity* procedure (ITC-08-A-3.06) in place for certain equipment at its Deer Park terminal. The procedure defines requirements for maintaining the mechanical integrity of equipment used to handle and store chemicals regulated by the OSHA PSM standard and/or EPA RMP rule. It is also intended to establish management systems to ensure compliance with these standards. The defined scope of the ITC procedure states:

> "*The requirements of this procedure apply to equipment handling or storing chemicals at the ITC Deer Park and Pasadena facilities identified in Regulated Chemicals Table ITC-08-A-a7 and any others identified by Senior Management. The equipment includes but is not limited to:*
>
> - *Pressure vessels and storage tanks;*
> - *Piping systems (including piping components such as valves);*
> - *Relief and vent systems and devices;*
> - *Emergency shutdown systems;*
> - *Controls (including monitoring devices and sensors, alarms, and interlocks) and,*
> - *Pumps.*"

Under the "equipment requirements" section of the procedure, specific requirements are listed for pressure vessels and storage tanks, piping systems, relief and vent systems and devices, emergency shutdown systems, and controls. The requirements include inspection frequency or intervals for each type of equipment, and in some cases the specific procedures that maintenance personnel are expected to use to complete the relevant inspection or testing. The equipment requirements section of the procedure does not, however, include any specific requirements for pumps, even though they are listed as included equipment in the scope.

Furthermore, the requirements contained in ITC's *Mechanical Integrity* procedure are only applicable to equipment handling or storing chemicals identified in the *ITC Regulated Chemicals Table.* According to the referenced table, neither naphtha nor butane is listed as a regulated chemical at the ITC Deer Park terminal. ITC also took the position that Tank 80-8 and its associated equipment to be covered under the OSHA PSM standard based on the flammable liquid atmospheric storage tank exemption (further discussed in Section 4.5.1).[a] As such, Tank 80-8 and its associated equipment were not subject to the ITC Deer Park terminal's *Mechanical Integrity* procedure.[b] The OSHA PSM standard and EPA RMP rule exemptions are further discussed in Section 4.5.

The OSHA PSM standard's Mechanical Integrity element includes specific requirements for 1) establishing and implementing written procedures to maintain process equipment, 2) training employees involved in maintaining process equipment, 3) performing inspections and tests on process equipment at specified frequencies, 4) correcting deficiencies in process equipment, and 5) quality assurance, which includes performing checks to ensure that equipment is installed properly and that maintenance materials and spare parts are suitable for the relevant process application. In the case where a company does not consider the OSHA PSM standard to be applicable to certain equipment, it could rely on voluntary guidelines, such as the Center for Chemical Process Safety's (CCPS's)[c] *Guidelines for Risk Based Process Safety (RBPS)* to design and implement an effective process safety management program to manage risks at its facilities. The RBPS Guidelines are not mandatory, but they are intended to help organizations design and implement more effective process safety management systems [21].

Approximately three months prior to the incident, on December 4, 2018, ITC removed the Tank 80-8 circulation pump from service due to a report of the pump "making a loud noise," with the pump's bearing housing observed to be shaking and vibrating. Maintenance personnel rebuilt the pump at the maintenance shop, using some spare parts, and reinstalled it onto the existing pump skid.[d] This rebuild work included the installation of new inboard and outboard bearings and a new mechanical seal, which were the same parts that failed during the March 17, 2019, incident.[e,f] Following the pump replacement in December 2018, no additional noise issues involving the Tank 80-8 circulation pump were reported to the maintenance department, and the pump appeared to operators to be operating normally the night before the incident.

Although the CSB could not ascertain the cause(s) of the Tank 80-8 circulation pump failure on March 17, 2019, the CSB identified the following mechanical integrity elements that could have reduced the likelihood of the

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[a] 29 CFR § 1910.119(a)(1)(ii)(B)

[b] As discussed in detail in Section 4.5.1.2, following the March 2019 incident, OSHA cited the ITC Deer Park terminal for violation of the PSM standard. OSHA and ITC eventually entered into a settlement agreement, whereby ITC paid the penalties for the alleged violations and agreed to conduct an enhanced abatement at the ITC Deer Park terminal. However, in the settlement ITC did not concede its belief that Tank 80-8 was exempt from coverage under the OSHA PSM standard, and the PSM compliance related language was removed from the citations.

[c] The American Institute of Chemical Engineers (AIChE) created the CCPS in 1985 after the chemical disasters in Mexico City, Mexico, and Bhopal, India, to develop and disseminate technical information for use in the prevention of major chemical accidents [82].

[d] Maintenance personnel positioned the pump on the existing pump skid and slid it into place against the existing pump casing gasket. Once in position, maintenance personnel bolted the frame adapter to the pump casing, bolted the pump feet to the pump skid, set the clearance, filled the external seal pot, and pressure tested the pump using plant nitrogen. They then used the straight edge method to verify motor/pump alignment before re-coupling the replacement pump with the motor.

[e] Maintenance personnel commonly referred to the seal chamber as the "stuffing box." According to personnel, it is an old industry or slang term that came about since they used to stuff packing into the chamber, as opposed to seals, which are used today.

[f] Maintenance personnel disassembled the power end of the pump and used a wire brush to remove surface rust from the ductile iron surfaces, checked fit and tolerances on the bearing housing, and cleaned the pump shaft. Once they verified that all parts of the power end were in good condition, they pressed new inboard and outboard bearings on the pump shaft, inserted the pump shaft assembly in the bearing housing, and installed new labyrinth seals on both ends of the assembled bearing housing. Maintenance personnel cleaned the parts, checked tolerances, set a new mechanical seal in the seal chamber, and used the gland nuts to fasten the seal gland to the seal chamber cover.

Tank 80-8 circulation pump's outboard bearing failure that caused the mechanical seal to separate on the day of the incident:

- ITC did not have a written pump rebuild or replacement procedure in place that referenced the pump manufacturer's recommended instructions to ensure a proper installation of the Tank 80-8 circulation pump when it was rebuilt in December 2018.[a]
- ITC did not provide maintenance personnel with formal, documented training related to pump maintenance and repair work and did not have a formal program in place to assess their competency.[b]
- ITC did not have a formal Preventative Maintenance (PM) program[c] in place for the Tank 80-8 circulation pump that included routine maintenance and inspection activities recommended by the pump manufacturer.[d]
- ITC did not have a quality assurance program in place at the ITC Deer Park terminal to allow it to confirm the origin of replacement parts used in the rebuild of the failed Tank 80-8 circulation pump.

ITC uses similar style pumps throughout its Deer Park terminal to facilitate the movement of process materials. Based on the company's reliance on this type of rotating equipment to move large volumes of hazardous substances throughout the terminal, ITC should take necessary measures to ensure the mechanical integrity of its pumps so that they operate safely, perform as designed, and do not unexpectedly fail and release hazardous substances to the environment, regardless of whether the OSHA PSM standard or EPA RMP rule are applicable to the equipment. Specifically, ITC's *Mechanical Integrity* procedure, which is currently only applicable to PSM- and RMP-covered equipment, should include specific requirements for maintaining the mechanical integrity of pumps at the terminal, like the requirements listed in the procedure for pressure vessels and storage

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[a] Maintenance personnel told CSB investigators that the company did not have a written pump replacement procedure, but they were aware of and *could* reference the *Goulds Installation, Operation, and Maintenance (IOM) Instructions,* as needed, when rebuilding and replacing a pump. However, there was no requirement for maintenance personnel to use these instructions, as pump rebuilds and replacements were considered routine. Accordingly, maintenance personnel did not follow the pump alignment procedure outlined in the *Goulds IOM Instructions*. For example, instead of using the dial indicators referenced in the *Goulds IOM Instructions,* maintenance personnel typically used either a laser alignment tool or the straight edge method to complete pump alignments at the ITC Deer Park terminal. Maintenance personnel explained that they used the straight edge method in this instance because they had already installed the necessary shims to ensure proper alignment when the existing pump was first installed nearly 12 years earlier, in March 2007.

[b] ITC hires individuals with experience in relevant areas of expertise, and maintenance personnel receives training through shadowing other personnel and participating in vendor training programs. Not all of the maintenance personnel employed with ITC at the time of the incident listed having past experience with pumps or rotating equipment on their training records or application materials. Further, maintenance personnel did not receive any formally documented training directly related to pumps or other rotating equipment. Instead, they received much of their training through shadowing other personnel in the field and participating in vendor training programs, as applicable. Regardless, they were all deemed to demonstrate an adequate level of competency to perform the duties associated with their role and were expected to maintain and repair pumps and rotating equipment throughout the ITC Deer Park terminal.

[c] ITC routinely monitored the physical condition of pumps at the ITC Deer Park terminal as part of biweekly maintenance walkthroughs and completed reactive maintenance on the pumps based on observations made during the walkthroughs. The company did not, however, have a preventative maintenance program in place for its pumps that included the *Goulds* recommended maintenance schedule. According to maintenance personnel, the only work order generated through the maintenance planning system for Tank 80-8 pump maintenance was one to change out both the bearing frame and seal pot oil on an annual basis.

[d] The *Goulds IOM Instructions* for the Tank 80-8 circulation pump states that a routine maintenance program can extend pump life and asserts that "well maintained equipment will last longer and require fewer repairs." Additionally, the document provides a recommended "Routine Maintenance Schedule" for its customers that includes routine maintenance items to monitor, including bearing lubrication, seal monitoring, vibration analysis, discharge pressure, and temperature monitoring. The recommended maintenance schedule in the *Goulds IOM Instructions* also includes recommended routine, three-month, and annual inspection items for its customer's maintenance personnel to perform.

tanks, piping systems, relief and vent systems and devices, emergency shutdown systems, and controls. The CSB concludes that the ITC Deer Park terminal's management systems lacked essential mechanical integrity program items, such as maintenance procedures, training for pump replacements and rebuilds, and routine preventative maintenance activities as recommended by the pump manufacturer, for equipment in highly hazardous chemical service that was not covered by OSHA PSM or EPA RMP requirements. A formal mechanical integrity program for all pumps in highly hazardous chemical[a] service could have prevented this incident by allowing ITC to have additional opportunities to identify Tank 80-8's circulation pump issues prior to the incident. A mechanical integrity program is part of a comprehensive process safety management system (further discussed in Section 4.5). Accordingly, the CSB recommends that ITC develop and implement a process safety management system for the ITC Deer Park terminal applicable to all atmospheric storage tanks and associated equipment in highly hazardous chemical service. The program should follow industry guidance provided in publications such as the American Petroleum Industry's API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*. (**2019-01-I-TX-R1**)

4.1.2 Condition Monitoring

Condition monitoring can be a proactive method to identify pump issues before a pump is severely damaged, which in turn can help prevent hazardous chemical releases. One of the most common methods of condition monitoring for rotating equipment is vibration monitoring and analysis, which can help detect issues such as imbalance, misalignment, bearing issues, and looseness [22]. Vibration can be detected in a variety of ways, ranging from basic handheld collectors to more sophisticated networked systems. In many chemical and petrochemical facilities, a baseline vibration program with monthly vibration monitoring may help flag problems long before a pump nears deterioration, allowing maintenance departments to minimize pump repair costs. Some companies equip their pumps with online condition monitoring systems that detect operating parameters in real time and alert the operators to abnormal conditions through alarms. In describing how condition monitoring relates to predictive maintenance, one author writes, "while machinery failure may be unpredictable, emerging failure is detectable" [23].

The Tank 80-8 circulation pump was not equipped with a condition monitoring system capable of detecting excess vibration in the equipment. Additionally, ITC did not have a vibration monitoring practice or program in place for the pump at the time of the incident aside from biweekly maintenance walkthroughs where operators identified vibration issues from equipment noise or leaks.

Based on the condition of the Tank 80-8 circulation pump bearings observed during post-incident inspection and testing, condition monitoring equipment, like the options discussed above, may have detected vibration readings outside of the established limits. In turn, these readings should have triggered an alarm to alert personnel that there was an issue that needed to be investigated. Thus, the CSB concludes that ITC did not retrofit the Tank 80-8 circulation pump with vibration monitoring equipment, which resulted in pump vibration going undetected and allowed the outboard bearing to continue to degrade to failure. Had ITC installed vibration monitoring equipment on the Tank 80-8 circulation pump, excessive vibration likely would have triggered an alarm, and

[a] The PSM standard defines "highly hazardous chemical" as "a substance possessing toxic, reactive, flammable, or explosive properties…" 29 C.F.R. § 1910.119(b).

ITC operators could have shut down the pump before the bearing failed, preventing the butane-enriched naphtha product release.

The American National Standards Institute (ANSI) American National Standard for Rotary Pumps – Guidelines for Condition Monitoring (ANSI/HI 9.6.9–2018) [25][a] is intended to give pump users a tool for condition monitoring of rotary positive displacement pumps. The document discusses several indicators that may be monitored or reviewed on rotary pumps to predict and identify pump failure modes [25, p. 1].

When the Tank 80-8 circulation pump was originally purchased from *Goulds*, the pump manufacturer did not offer the option of built-in condition monitoring capability for the equipment. However, aftermarket condition monitoring equipment was available from various sources, so ITC could have purchased the equipment and outfitted the pump with continuous condition monitoring capabilities.[b]

Since the time of the incident, ITC has begun installing sensors on pumps at its Deer Park terminal. According to ITC, the equipment will allow operators working in the field to access and monitor pump vibration, temperature, and run-time data. To date, a total of 110 pumps at the terminal have been equipped with sensors. Incorporating condition monitoring technology on all pumps throughout the ITC Deer Park terminal should allow personnel to proactively identify and address potential issues with the pumps, as opposed to identification after failure, as was the case with the Tank 80-8 circulation pump. As such, the CSB recommends that ITC develop and implement a condition monitoring program for all pumps in highly hazardous chemical service at the ITC Deer Park terminal. Ensure that condition monitoring equipment is programmed with control limits, including but not limited to vibration, consistent with ANSI/HI 9.6.9.-2018, that trigger alarms when control limits are exceeded, and that operating procedures and training reflect the appropriate actions to take when an alarm is triggered. (**2019-01-I-TX-R2**)

4.2 Flammable Gas Detection Systems

Gas detection systems are implemented in many process industries to protect personnel, property, and neighboring communities from the potential consequences of an accidental release. For example, flammable gas detection systems trigger alarms whenever a specified concentration of a flammable gas or vapor is exceeded to provide early warning to personnel so that actions may be taken to prevent the formation and ignition of flammable gas mixtures.[c] In some cases, these alarms may also prompt activation of interlocks or other protective devices to prevent further product release. API Standard 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* (API STD 2610), a voluntary industry standard,

[a] ANSI/HI 9.6.9-2018 was sponsored and published by the Hydraulic Institute.

[b] As technology has evolved since 2006, *Goulds* now offers an updated power end called the *Goulds 3196 i-FRAME® power end*, which includes an *i-ALERT®* device integrated in the unit. The *i-ALERT®* device constantly monitors the condition of the pump's bearings to ensure that they are running within established temperature and vibration limits. Whenever a deviation from these limits is detected, the device visually alarms with red flashing lights to alert operators of the recognized abnormal conditions. *Goulds* also now offers the *i-ALERT® 2* equipment health monitor, which makes condition monitoring possible on virtually any piece of equipment. The *i-ALERT® 2* is a Bluetooth-enabled device that can be affixed to pumps or other equipment to provide monitoring and diagnostic capabilities to the equipment.

[c] There are various technologies to detect combustible gases/vapors that are widely used [67, p. 293]. Typical application for flammable gas detection systems include pump seals and flanges for hydrocarbon detection and in bulk storage areas [68, p. 32]. Flammable gas detectors should be positioned at low points or near ground level since flammable vapors are typically heavier than air and tend to remain close to the ground.

mentions use of flammable gas detection systems in its discussion of emergency shutdown systems and procedures in terminal and tank facilities: "When fire protection or vapor-detection systems are activated, they should automatically activate the emergency shutdown system" [25, p. 37].

Tank 80-8 was not equipped with a flammable gas detection system to warn personnel of a hazardous atmosphere resulting from loss of containment from the tank or its associated piping manifold equipment. The two most recent property insurance surveys[a] conducted at the ITC Deer Park terminal indicate that gas detection capability existed elsewhere at the terminal at the time of the incident. The survey conducted on April 10, 2017, indicates that LPG storage and light hydrocarbon handling areas in the terminal were equipped with combustible gas detectors. The survey conducted on October 25, 2018, indicates that LPG storage areas and butadiene vessels at the terminal were also equipped with gas detection systems.

ITC indicated that the company had *"an ongoing program and associated recurring annual budget for installation of LEL monitors in areas at the Deer Park facility based on process hazard analyses (PHAs) that identify the potential risk associated with a product leak in that area."* Since the OSHA PSM standard and EPA RMP rule did not apply to Tank 80-8, ITC was not required to formally perform a PHA on this system at least once every five years. According to available documentation, Tank 80-8 did not have an initial PHA and was not on a recurring PHA cycle. In addition, prior to the incident, the company had not scheduled installation of a flammable gas detection system in the vicinity of the Tank 80-8 piping manifold.

Although the OSHA PSM standard and EPA RMP rule did not apply to Tank 80-8, ITC used its MOC process to document the Tank 80-8 Truck Butane Injection System project.[b] Prior to implementation of the Tank 80-8 truck butane injection system, ITC completed a hazard review for the project as part of this MOC. The project team used the Hazard and Operability (HAZOP)[c] technique to identify the hazards and consequences associated with operation of the proposed truck butane injection system. The team recognized that one of the hazards

KEY LESSON

Terminals and storage tank facilities that handle large volumes of flammable or highly hazardous substances should implement flammable gas detection systems to protect personnel, property, and neighboring communities from the potential consequences of an accidental release. These types of systems should be installed in areas around pumps, seals, flanges, and other common leak locations. These systems should be adequately designed, maintained, inspected, and tested to ensure reliability. Inspection and testing frequencies must be established to ensure the system provides adequate warning of the presence of flammable substances.

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[a] These surveys provided a qualitative risk assessment of the assets and operation of the ITC Deer Park terminal for the purpose of property damage and business interruption insurance loss prevention. They also provided recommendations for areas for improvement from an insurance perspective.

[b] Although parts of the ITC Deer Park terminal were not covered under the OSHA PSM standard, the company applied some elements of PSM, including MOC, to the entire terminal.

[c] HAZOP is a systematic qualitative technique to identify process hazards and potential operating problems using a series of guide words to study process deviations [84].

KEY LESSON

While most hazard and risk assessments consider the risk of single failures at a time, it is important for companies to realize that major incidents happen when multiple failures occur. To prevent these catastrophic events from occurring, companies should ensure the appropriate number of layers of protection are in place to mitigate the likelihood and reduce the severity of events when they do occur. Therefore, when determining when, how, or whether to complete the recommendations from hazard assessments, companies should ensure the appropriate number of preventative and mitigative safeguards are in place such that a single failure of a preventative or mitigative safeguard will not result in a catastrophic event. Leadership should ensure adequate safeguards are in place, as soon as practicable, for hazards identified by the team, especially when engineering controls are recommended and not yet installed.

involved with product storage and circulation was potential loss of containment, the consequences of which were product release, fire, explosion, exposures, injuries, and fatalities. They identified several potential safeguards, including flammable gas detection, that, if implemented, lowered the risk ranking from high to medium. As a result, the project team recommended that ITC "consider projects for LEL meters/deluge at pumps" however, ITC ultimately decided not to install an LEL detector or deluge system at the Tank 80-8 circulation pump and did not document a justification for not implementing this safety recommendation. The CSB concludes that had Tank 80-8 been subject to the OSHA PSM standard and/or the EPA RMP rule, ITC would have been required to track the recommendation to install a flammable gas detection system such as an LEL detector or deluge system at the Tank 80-8 circulation pump to completion and document the resolution in a timely manner.[a]

On the day of the incident, there was no flammable gas detection system in the area, and the release of butane-enriched naphtha product from the failed Tank 80-8 circulation pump did not trigger any alarms in the area to alert personnel in the CCR of the initial release of flammable material around the Tank 80-8 piping manifold. Consequently, butane-enriched naphtha product continued to release from the failed pump for approximately 30 minutes, completely undetected, before its flammable vapors eventually ignited. The CSB concludes that had a flammable gas detection system existed in the vicinity of the Tank 80-8 circulation pump, it could have provided adequate time for personnel to detect and attempt to secure the butane-enriched naphtha product release before its flammable vapors eventually ignited.

The CSB recommends that ITC install flammable gas detection systems with associated alarm functions in product storage and transfer areas at the ITC Deer Park terminal where flammable substance releases could occur. Develop

[a] 29 C.F.R. § 1910.119(e)(5): "The employer shall establish a system to promptly address the team's findings and recommendations; assure that the recommendations are resolved in a timely manner and that the resolution is documented; document what actions are to be taken; complete actions as soon as possible; develop a written schedule of when these actions are to be completed; communicate the actions to operating, maintenance and other employees whose work assignments are in the process and who may be affected by the recommendations or actions."

and implement a response plan and operator training for actions to take when an alarm sounds. (**2019-01-I-TX-R3**)

Since the incident, ITC has expanded its ongoing program of risk-based installation of LEL monitors/flammable gas detectors throughout the ITC Deer Park terminal. According to the company, ITC has installed 196 additional LEL monitors/flammable gas detectors at the terminal, through March 2023, as part of this program. ITC intends to continue the staged installation of additional LEL monitors/flammable gas detectors in the atmospheric storage tank farms across the terminal.

Facilities like ITC should have flammable gas detection systems in place that are designed and installed properly; maintained properly; and have procedures, training, testing, and drills associated with their proper operation. API STD 2610 mentions the use of vapor-detection systems in emergency shutdown systems; however, it and several of its normative references[a] do not explicitly discuss flammable gas detection systems in describing leak detection systems for terminals and tank facilities [25].[b] The CSB concludes that terminals and tank facilities that store flammable substances should develop, implement, and maintain flammable gas detection systems to alert workers to hazardous conditions and allow them to respond in a timely manner.

The CSB recommends that API update API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities*, or other appropriate products to include flammable gas detection systems within the leak detection section or where appropriate. The discussion of flammable gas and/or leak detection should address both engineering and administrative controls, including actions associated with responding to a catastrophic or emergency leak (**2019-01-I-TX-R6**).

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[a] Normative references are those documents that contain material that must be understood and used to implement a standard [74].

[b] Leak detection programs allow for the detection and prompt resolution of a release with the goal of mitigating its consequences. Applying a similar approach to terminals and tank facilities that store highly hazardous chemicals could allow each facility to establish its own leak detection strategy, methods, and performance measures. API Recommended Practice 1175, *Leak Detection – Program Management* (API RP 1175) provides guidance on developing a leak detection program for pipelines that could be referred to as a basis for developing a leak detection program at terminals and tank facilities [79]. API's recommended leak detection program includes the following components:

- Management commitment and leadership
- Risk assessment
- Selection of leak detection methods
- Performance targets, metrics, and key performance indicators
- Testing
- Procedures for recognition and response
- Alarm management
- Roles, responsibilities, and training
- Reliability and maintenance requirements for leak detection equipment
- Overall performance evaluation of the leak detection program
- Training
- Management of change
- Improvement process

4.3 REMOTELY OPERATED EMERGENCY ISOLATION VALVES

Tank 80-8 was not equipped with a remotely operated emergency isolation valve (ROEIV) to isolate the contents of the aboveground storage tank from the piping manifold in the event of a release.[a] At the time of the incident (and currently) ROEIVs were not required under applicable atmospheric storage tank standards [26, p. 7]. Regarding its corporate standards or policies on the application and use of ROEIVs, ITC informed the CSB that *"ITC installs motor operated valves on tank discharges as the tanks are taken out of service for periodic API 653."* In the case of Tank 80-8, the next API 653[b] inspection was scheduled to take place in November 2022.

Several recognized industry process safety sources recommend the use of ROEIVs on equipment containing large volumes of flammable and toxic material:

- CCPS[c] states that "[r]emote isolation of equipment containing hazardous material is necessary to mitigate a release of hazardous material when there has been loss of containment. Isolation can be accomplished with the appropriate location of remotely operated… [emergency block valves (EBVs)]. Remotely operated EBVs should be located such that major process equipment or unit operations can be isolated in the event of a loss of containment" [27].
- The *Health and Safety Executive* (HSE)[d] states that "appropriate means of isolation, which may include [Remotely Operated Shutoff Valves], should be provided between individual inventory units to limit the quantity of substance that can be released from any single failure" [28, p. 26].
- In 2020, Marsh Specialty published a risk engineering position paper on ROEIVs, stating, "Many small incidents have escalated into major losses because personnel were unable to reach, and close, manual block valves safely or quickly enough, leading to unconstrained supply of fuel to the fire" [29, p. 2].
- API STD 2610 for terminal and tank facilities recommends, "Emergency shutdown systems and procedures should be provided at all product transfer facilities. [...] The emergency shutdown system should shutdown all flow and provide a visual or audible indication to personnel in the area [...]" [25, p. 37].

A past insurance audit for the ITC Deer Park terminal conducted in October 2018 indicates that LPG tanks located in another area of the terminal were equipped with electric motor operated valves (MOVs) that were programmed to close the inlet valve and automatically shut down the associated pumps under certain scenarios. Over the years, consistent with its inspection schedule, ITC had equipped twelve of the fifteen (15) 80,000-

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[a] An emergency or remotely operated isolation valve is often referred to as an ROEIV, an emergency isolation valve (EIV), or an emergency block valve (EBV). These types of valves are equipped with actuators and configured to be quickly and reliably operated from a safe location, such as a control room [27, p. 7].

[b] API 653 is the standard for tanks over 50 feet tall or having a diameter greater than 30 feet. The standard covers the maintenance, inspection, alteration, and repair of steel, field-erected aboveground storage tanks (ASTs) built to API STD 650 or API 12C standards. API 653 external inspections are required every five years, and API 653 internal inspections, which require the tank to be out of service, are required every 10 years. All inspections must be performed by a licensed inspector.

[c] CCPS is a not-for-profit corporate membership organization within AIChE, with over 200 members, that identifies and addresses process safety needs in the chemical, pharmaceutical, and petroleum industries. While CCPS does not establish any requirements, its publications are intended to help organizations design and implement more effective process safety management systems.

[d] The Health and Safety Executive (HSE) is Britain's national regulator for workplace health and safety.

barrel storage tanks located in the First & Second 80's tank farm with MOVs (**Figure 29**); however, ITC did not equip these valves with fusible links,[a] programming logic, or other protective measures to help ensure that these valves would automatically close in the event of a power outage, fire, or other event ("Fail-Closed").

Tank No.	Pump (Y/N)	MOV (Y/N)	Product	Approx. Quantity (barrels)
80-1	Y	Y	YUBASE 6	49,800
80-2	Y	Y	Gasoline blendstock	42,300
80-3	Y	Y	Gasoline blendstock	33,400
80-4	Y	Y	YUBASE 4 PLUS	35,700
80-5	Y	N	Xylene	38,400
80-6	Y	Y	Gasoline blendstock	49,400
80-7	Y	N	PYGAS	43,600
80-8	Y	N	Naphtha product	70,800
80-9	Y	Y	-	-
80-10	Y	Y	PyGAS	14,400
80-11	N	Y	Base oil	52,900
80-12	N	Y	-	-
80-13	N	Y	Toluene	14,700
80-14	Y	Y	PyGAS	15,800
80-15	Y	Y	PyGAS	9,400

Figure 29. List of aboveground atmospheric storage tanks, associated equipment, and products contained in First & Second 80's tank farm. (Credit: CSB)

On the day of the incident, a single pump seal failure escalated to a catastrophic incident. When the flammable butane-enriched naphtha ignited, the resulting fire caused a power outage to the controls communication system almost immediately after ignition, which rendered all the First & Second 80's tank farm MOVs inoperable and incapable of providing remote isolation. As a result, when the Tank 80-8 circulation pump failed, the large volume of butane-enriched naphtha product contained in the 80,000-barrel atmospheric storage tank could not be remotely or automatically isolated. Additionally, since the flames immediately engulfed the entire area, neither ITC personnel nor emergency responders were able to physically access the supply and return valves on the tank to manually close them and isolate the tank. As a result, the butane-enriched naphtha product continued to release from Tank 80-8, via the failed pump, and fueled the fire that continued to intensify around Tank 80-8 and its piping manifold. The CSB concludes that had Tank 80-8 been equipped with a remotely operated emergency isolation valve (ROEIV), the butane-enriched naphtha product release could have been secured

[a] Fusible link valves are shut-off valves that close automatically in the presence of fire. The fusible link is a heat-sensitive device that releases a spring pack when exposed to high temperature, allowing the valve to close [73].

without the need for personnel to enter the tank farm, allowing emergency responders to extinguish the initial fire earlier in the response.

As the Tank 80-8 fire intensified, flames from the fire spread across the common containment area to adjacent tank piping manifolds in the First & Second 80's tank farm. The flames eventually compromised the equipment, causing breaches in piping that allowed the hydrocarbon and petrochemical products contained in the storage tanks to release into the common containment area. Since none of the storage tanks were equipped with ROEIVs and the MOVs that were present were rendered inoperable, there was no opportunity to isolate any of the impacted tanks. As a result, the hydrocarbon and petrochemical products stored in the impacted tanks continued to release, further fueling and expanding the fire throughout the tank farm. Consequently, the fire that originated in the Tank 80-8 piping manifold burned for nearly three days and involved twelve (12) of the fifteen (15) 80,000-barrel capacity atmospheric storage tanks commonly contained in the First & Second 80's tank farm. The CSB concludes that had remotely operated emergency isolation valves (ROEIVs) configured to "Fail-Closed" been installed on Tank 80-8 and the other 14 tanks in the First & Second 80's tank farm, the tanks could have been secured without the need for personnel to enter the tank farm after power was lost to all motor operated valves (MOVs), and the quantity of the materials released could have been reduced. Thus, the CSB recommends that ITC install remotely operated emergency isolation valves configured to "Fail-Closed" for all atmospheric storage tanks that contain highly hazardous chemicals or liquids with a flammability rating of NFPA-3 or higher at the ITC Deer Park terminal (**2019-01-I-TX-R4**).

While ROEIVs were not as common when the First & Second 80's tank farm was originally constructed, they could have been incorporated by way of equipment upgrades or modifications. The primary drivers for identifying the need for this type of equipment would have been through implementation of hazard assessments, such as those required by the PSM process standard and the RMP rule, insurance company audits, and/or corporate risk evaluations results. As previously discussed, ITC took the position that the atmospheric storage tanks in the First & Second 80's tank farm were not subject to OSHA's PSM standard or EPA's RMP rule (discussed further in Section 4.5).[a] Moreover, the insurance audits of the ITC Deer Park terminal did not identify any concerns with

KEY LESSON

Companies that handle large volumes of flammable or highly hazardous substances should assess their capability to remotely isolate these substances in the event of a loss of containment. Aboveground atmospheric storage tanks that contain large volumes of these substances should be equipped with remotely operated emergency isolative valves (ROEIVs) so that releases can be mitigated quickly and remotely from a safe location. The ROEIVs should be equipped with fusible links or configured to automatically close in the event of a power outage or other event ("Fail-Closed").

[a] As discussed in detail in Section 4.5.1.2, following the March 2019 incident, OSHA cited the ITC Deer Park terminal for violation of the PSM standard. OSHA and ITC eventually entered into a settlement agreement, whereby ITC paid the penalties for the alleged violations and agreed to conduct an enhanced abatement at the ITC Deer Park terminal. However, in the settlement ITC did not concede its belief that Tank 80-8 was exempt from coverage under the OSHA PSM standard, and the PSM compliance related language was removed from the citations.

the absence of ROEIVs in the tank farm. NFPA 30, *Flammable and Combustible Liquids Code* (NFPA 30)[a] [30] and API Recommended Practice 2021, *Management of Atmospheric Storage Tank Fires* (API RP 2021)[b] [31] do not dictate the use of specific technologies, such as ROEIVs, but do include performance and/or functional requirements that can be achieved through their use.

Since the time of the incident, ITC informed the CSB that they initiated a phased program to install independent, fire-safe, emergency shutdown valves at all product storage tanks across the facility. According to the information provided, the emergency shutdown valves will be pneumatically operated, with both remote and local controls, and include fusible links for automatic shutdown during a fire event. ITC indicated that the enhancement also includes upgraded fire-rated gaskets with higher temperature tolerances. To date, ITC has completed installation of 98 emergency shutdown valves at the ITC Deer Park terminal. The company indicated that ongoing implementation of this program will be conducted in conjunction with ITC's existing program for conducting tank enhancements when tanks are taken out of service for inspection or other reasons, with tanks containing products with higher NFPA flammability ratings being addressed on a more accelerated basis.

The ITC Deer Park terminal incident demonstrates the extent and severity of what can happen when large-volume storage tanks, situated in a common containment area, cannot be remotely isolated in the event of an unintended release and fire. The CSB investigated two other incidents in 2019 in which lack of ROEIVs contributed to the severity of the consequences:

- On June 21, 2019, a pipe elbow in the Philadelphia Energy Solutions (PES) hydrofluoric acid (HF) alkylation unit ruptured. A large vapor cloud—composed of about 95% propane, 2.5% HF, and 2.5% other hydrocarbons—engulfed part of the unit. The vapor cloud ignited two minutes after the release began, causing a large fire. The CSB investigated this incident and found that the release location could not be isolated from the rest of the process [32].

- On November 27, 2019, a series of explosions occurred at the TPC Group (TPC) Port Neches Operations (PNO) facility, located in Port Neches, Texas, after highly flammable butadiene was released from the process unit. The explosions caused a process tower to propel through the air and land within the facility, other process towers to fall within the unit, extensive facility damage, and fires that burned for more than a month within the facility. The butadiene unit was destroyed, forcing the facility to cease butadiene production operations indefinitely. The CSB investigated this incident and found that the TPC PNO butadiene process was not equipped with ROEIVs designed to mitigate process releases remotely from a safe location. As a result, the release location could not be isolated from the rest of the process [34].

The CSB intends to conduct further analyses of incidents involving lack of remote isolation capability to determine the appropriate course(s) of action to recommend to industry groups and regulatory agencies.

[a] NFPA 30, *Flammable and Combustible Liquids Code* provides safeguards to reduce the hazards associated with the storage, handling, and use of flammable and combustible liquids, including tank farm design, construction, and spacing requirements.

[b] API RP 2021, *Management of Atmospheric Storage Tank Fires* provides experience-based information to enhance the understanding of fires in atmospheric storage tanks containing flammable and combustible materials. It provides information to assist management and fire suppression personnel to manage the needs associated with safely fighting fire in aboveground storage tanks.

4.4 TANK FARM DESIGN

Tank 80-8 was situated in the center of the First & Second 80's tank farm, which consisted of fifteen (15) 110-foot diameter, 80,000-barrel capacity aboveground atmospheric storage tanks located within a common containment area that measured approximately 732 feet in length by 449 feet in width and was surrounded by a roughly 4-foot tall concrete containment wall.

NFPA 30 provides safeguards to reduce the hazards associated with the storage, handling, and use of flammable and combustible liquids, including tank farm design, construction, and spacing requirements.[a] At the time of construction of the First & Second 80's tank farm, the 1973 version of NFPA 30 would have been in effect [10].[b]

The CSB contracted a third-party fire protection specialist, Jensen-Hughes, to evaluate and provide perspective on the tank farm fire (Appendix D). The attached Jensen-Hughes report provides additional details of ITC Deer Park's tank farm design. In addition, the CSB contracted a structural engineering firm, Atlas Engineering, to evaluate the containment wall failure (Appendix E).

4.4.1 TANK SPACING

In reviewing ITC's First & Second 80's tank farm spacing, the Jensen-Hughes report concluded that the tank farm spacing was designed in accordance with most of the NFPA 30 requirements for floating roof aboveground atmospheric tanks in place at the time the tank farm was constructed, including:

- Required minimum distance from property line and nearest side of public way or building (Section 2110) [9, p. 17] (Appendix D, pg. 13); and
- Required minimum shell-to-shell spacing between any two adjacent tanks (i.e., not less than one-sixth their diameters) (Section 2122) [9, p. 21] (Appendix D, pg. 13).

In addition to the above minimum tank spacing requirements, Section 2125 of the 1973 version of NFPA 30 states:

> When tanks are in a diked area containing Class I or Class II liquids,[c] or in the drainage path of Class I or Class II liquids, and are compacted in three or more rows or in an irregular pattern, greater spacing or other means may be required by the authority having jurisdiction to make inside tanks accessible for fire fighting purposes [9, p. 22].

[a] https://www.nfpa.org/News-and-Research/Data-research-and-tools/Hazardous-Materials/The-fire-risk-of-Intermediate-Bulk-Containers/About-NFPA-30.

[b] The 1973 edition of NFPA 30 covers tank storage requirements under Chapter II.

[c] Flammable liquids are classified by NFPA as Class I liquids. Class I liquids are further subdivided into three classes: IA, IB, and IC. These liquids have flash points below 100℉ or less. Combustible liquids are classified by NFPA as Class II and Class III liquids. Class II liquids have flash point at or above 100℉ and below 140℉, while Class III combustible liquids have a flash point at or above 140℉ and below 200℉. The butane-enriched naphtha product in Tank 80-8 was a Class I liquid.

The 2018 edition of NFPA's *Flammable and Combustible Liquids Code Handbook* (2018 NFPA 30 Handbook) notes that tank spacing for larger tanks is an arbitrary fraction of tank diameter, sufficient to permit an orderly and safe arrangement for pipelines and to prevent the spread of fire from one tank to another. The handbook also notes, "Spacing alone is not a safeguard against fire spread from spilled liquid," and directs the user to Section 22.11 for the control of spills (Note to 22.4.2.1*) [34].

When the tank farm was constructed, ITC spaced the 15 tanks in three rows of five roughly 36 feet from one another, in accordance with the minimum required shell-to-shell spacing distance specified in NFPA 30. The company later installed four fixed fire monitors in the interior of the tank farm in 2018. According to ITC, these interior fire monitors (in conjunction with the fire monitors mounted on the periphery of the tank farm) were intended to allow the company to direct at least one fire monitor to any tank manifold within the tank farm.

In order to understand the mechanism by which the fire spread, Jensen-Hughes modeled the combined pool fire and tank fire and examined its thermal outputs. The detailed fire modeling results indicated that flames issuing from the roofline tank vents did not provide enough heat to cause the fire to spread to adjacent tanks; however, the synergistic effects of the tank fire and ground-level liquid pool fire were sufficient to lead to ignition of adjoining tanks. According to the expert's report:

> [T]he results of the study indicate that the coupled impact of a tank fire and a liquid pool fire may need to be considered in evaluating the minimum safe separation distance of future installations and to evaluate existing installations, particularly older installations that predate the availability of safety features or equipment that aid in mitigating such conditions. Although a relatively limited pool fire was examined in this analysis, the combined impact of the pool and vent fires significantly raised the radiant exposure to adjoining tanks. Were the pool fire expanded in the model, as it did during the ITC Deer Park fire, igniting the contents of adjacent tanks from radiant heat exposure would be more likely (Appendix D, pg. 22).

While NFPA 30 defines minimum requirements for tank farm design, additional industry discussions were taking place regarding tank farm fire safety around the time of construction of the First & Second 80's tank farm. For example, in July 1974, the Oil Insurance Association (OIA)[a] published *Loss Control Bulletin No. 400-1*, which discusses losses involving atmospheric storage tanks resulting from tank fires [35]. According to this document, the severity of tank fires is most affected by "spacing, common containment (diking), piping within containment areas, and inadequate foam and fire water supplies," all of which can be "controlled and reduced by good fire prevention practices." Accordingly, the document contains a series of comments and recommendations for tank spacing, including:

> Generous spacing between individual tanks and between tank fields and process areas is a must. Radiant heat has damaged adjacent exposed tanks over a tank diameter away even when there has been no ignition of the second tank. Heavy water streams may provide somewhat of an alternative by protecting exposed

[a] The OIA merged with Factory Insurance Association in 1975 and is now called Industrial Risk Insurers. It is a consortium of major stock property and casualty insurers formed to write large, highly protected risks and to provide fire laboratory facilities and engineering services.

tanks, but their availability and continuity cannot be relied upon with certainty [35, p. 45].

KEY LESSON

NFPA 30 provides safeguards to reduce the hazards associated with the storage, handling, and use of flammable and combustible liquids, including tank farm design and spacing requirements. While NFPA 30 defines minimum requirements for tank farm design and spacing, other voluntary industry guidance documents including FM Global Loss Prevention Data Sheet (FM LPDS) 7-88, *Outdoor Ignitable Liquid Storage Tanks*; and API RP 2021, *Management of Atmospheric Tank Fires*; and API STD 2610, *Design, Construction, Operation, Maintenance and Inspection of Terminals and Tank Facilities* provide more robust tank farm design criteria.

The *Loss Control Bulletin No. 400-1*, recommends storage tanks with capacities greater than 50,000 barrels to be spaced one and a half times the tank diameter apart. In the case of the First & Second 80's tank farm, this would have meant that the 15 storage tanks would have been spaced 165 feet apart, according to the recommendation. Because these and other general industry guidance documents do not contain strict, enforceable requirements such as those in NFPA 30; companies typically evaluate these considerations for their own facilities as applicable. For example, a property insurance survey conducted at the ITC Deer Park terminal on April 10, 2017, noted that tank spacing in the First & Second 80's tank farm was "tight," but did not identify any discrete concerns or recommendations related to tank spacing.

During the March 2019 incident, emergency responders were unable to access or activate the fixed fire monitor that was designed to reach Tank 80-8, as it was engulfed in flames from the fire in the Tank 80-8 piping manifold. Additionally, the positions of other fixed fire monitors inside the tank farm did not allow for them to be aimed directly at the fire engulfing the Tank 80-8 piping manifold, as they were not designed to reach that area. As a result, the fire spread to an adjacent tank. The fixed fire monitors located inside the tank farm may have been added to the First & Second 80's tank farm to address the compacted tank spacing concerns identified in NFPA 30; however, they were ineffective during the response to this event. The CSB concludes that although the First & Second 80's tank farm was designed in accordance with applicable NFPA 30 tank farm spacing requirements in place at the time the tank farm was constructed, the NFPA 30 recommendation for additional spacing for compacted tank farm layouts was not included in the design. This design, which allowed for reliance on administrative controls and emergency response, allowed the Tank 80-8 fire to spread and involve additional tanks in the tank farm.

The CSB recommends that ITC conduct an evaluation of the design of all new and existing tank farms at the ITC Deer Park terminal. The evaluation should identify additional engineering controls needed to address minimal tank spacing (**2019-01-I-TX-R5**).

4.4.2 Subdivisions

In reviewing ITC's First & Second 80's tank farm containment area, the Jensen-Hughes report concluded that the containment area was designed in accordance with the following NFPA 30 requirement for floating roof aboveground atmospheric tanks in place at the time the tank farm was constructed:

- Volumetric capacity of the diked area should be sized to accommodate the greatest amount of liquid that can be released from the largest tank within the diked area, with consideration of any other tanks within the containment accounted for (Section 2173(a)) [9, p. 29] (Appendix D, pg. 14).

In addition to this containment requirement, Section 2173(g) of the 1973 version of NFPA 30 required[a] that each diked area containing two or more tanks be subdivided by drainage channels or at least by intermediate curbs in order to prevent spills from endangering adjacent tanks within the diked area. Section 2173(g)(2) of NFPA 30 states:

> When storing normally stable flammable or combustible liquids in tanks not covered in sub-paragraph (1), one sub-division for each tank in excess of 100,000 gallons (2,500 bbls) and one sub-division for each group of tanks (no tank exceeding 100,000 gallons capacity) having an aggregate capacity not exceeding 150,000 gallons (3,570 bbls) [9, p. 30].

Section 2173(g)(4) of NFPA 30 further specifies that:

> The drainage channels or intermediate curbs shall be located between tanks so as to take full advantage of the available space with due regard for the individual tank capacities. Intermediate curbs, where used, shall be not less than 18 inches in height [9, p. 30].

With regards to the First & Second 80's tank farm subdivisions, the Jensen-Hughes report states:

> The drainage as provided segregates the tank farm into groups of three tanks each, while Section 2173(g)(2) would have required the drainage to be provided such that each tank was separated from adjoining tanks. Section 2173 allows for the use of intermediate containment walls to either replace drainage or augment drainage, however no intermediate containment walls are provided. The sloping and draining across the entire tank area, evidenced by a general slope from the north to south direction and additional drains at the south side of the farm, may have been provided to offset the lack of inlets between tanks. In theory, the slope would move any spilled liquids away from the immediate tank of concern and transfer the liquids to the drainage system at the south side. As an alternative approach, the provided condition doesn't satisfy the intent of the requirements in Section 2713(g)(2) (Appendix D, pg. 14).

[a] In this section of the code, NFPA 30 states that these requirements apply to drainage and diked areas for aboveground tanks "except that in particular installations these provisions may be waived or altered at the discretion of the authority having jurisdiction when the tanks under consideration do not constitute a hazard to adjoining property" [10, p. 28]. The CSB could not determine whether the Harris County Fire Marshal waived this requirement for the First & Second 80's tank farm at the time it was constructed.

The 1974 OIA *Loss Control Bulletin No. 400-1* had made the following observations about tank farm subdivisions:

> Common diking (more than one tank within one dike[a] area) has been the greatest single factor in determining the size of a loss wherever it has been involved. It has usually proved almost impossible to prevent the spread of fire to other tanks when they are not separated by dikes. Further, when more than one tank is burning, extinguishment of any of them is vastly more difficult and total destruction usually results. Where full separating dikes are impossible, careful consideration should be given to diversion dikes and grading to drain away from other tanks [36].

ITC had "small concrete containment area[s]" immediately adjacent to the majority of the tanks at its facility, including Tank 80-8 (**Figure 30**). ITC's Spill Prevention Control and Countermeasure Plan (SPCC) stated that these concrete containment areas were designed to provide local containment and drainage capabilities for pumps and valves associated with the tanks: "Leaks, drips, etc. that originate at the pumps/valves are contained and immediately drained to the wastewater treatment system via the chemical drain system." This was the only containment area that separated Tank 80-8 spills from adjacent tanks. On the day of the incident, the butane-enriched naphtha product released from Tank 80-8 overflowed this small containment area and entered the common containment area of the tank farm.

[a] NFPA defines a dike as a structure used to establish an impounding area or containment [71].

Figure 30. Small concrete containment area around the Tank 80-8 circulation pump. (Credit: CSB)

The CSB concludes that ITC's First & Second 80's tank farm was not subdivided as was required by NFPA 30. Although the subdivisions of the diking required by NFPA 30 likely would have been insufficient to hold the full contents of Tank 80-8, additional subdivisions could have slowed the spread of the butane-enriched naphtha product and allowed responders the opportunity to access and activate the fixed fire monitors located within the containment area to fight the fire surrounding the Tank 80-8 piping manifold before it spread to adjacent tanks.

The First & Second 80's tank farm was not the only tank farm at the ITC Deer Park terminal that contained this type of arrangement. Among others at the terminal, the Third 80's tank farm, located adjacent to the First & Second 80's tank farm (see **Figure 3**), contained 12 large-capacity atmospheric storage tanks and their associated piping manifolds/equipment, spaced similarly, within a common containment area. As a result, the CSB recommends that ITC conduct an evaluation of the design of all new and existing tank farms at the ITC Deer Park terminal. The evaluation should identify additional engineering controls needed to address subdivisions between tanks (**2019-01-I-TX-R5**).

4.4.3 Process Equipment within Secondary Containment

The Tank 80-8 circulation pump, and 11 other pumps were located inside the secondary containment area in the First & Second 80's tank farm. NFPA 30 has permitted and still permits placement of process equipment within tank farms. Starting in 2012, NFPA began to require closer examination of placement of process equipment within tank farms; however, NFPA 30 does not retroactively apply. The 2012 edition states:

> **22.12.3* Location of Equipment.** If located in a remote impoundment area, a diked area, or a spillway draining to a remote impoundment area, process equipment, pumps, instrumentation, and electrical utilization equipment shall be located or protected so that a fire involving such equipment does not constitute an exposure hazard to the tank or tanks in the same area for a period of time consistent with emergency response capabilities. **(2012 – 22.12.3*)**
>
> **A.22.12.3** Methods of preventing an exposure hazard include intermediate diking, drainage, or fire protection features such as water spray systems, monitors, or fire-resistive coatings. High integrity pumps or equipment also constitute a method of limiting exposure hazards. **(2012 – A.22.12.3)** [36]

Other industry guidance acknowledged the increased risk of locating pumps inside tank farms prior to the 2012 NFPA 30 update. For example, OIA's 1974 *Loss Control Bulletin No. 400-1* states: "Pumps should be installed outside of dikes, not only because they are sources of ignition but also because they may be vital for the transfer of product to a safe tank." A more recent industry guidance document, API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal & Tank Facilities*, first published in 1994, states: "pumps inside secondary containment are considered ignition sources due to the possibility of mechanical seal failures and should be located outside the secondary containment area." It adds that "if pumps are located within containment areas, sound risk management principles should be used to mitigate the risks of locating the pump inside the secondary containment area" [26].

ITC did implement some engineering controls to mitigate the risks of operating the Tank 80-8 circulation pump inside the secondary containment area. As mentioned previously, the circulation pump was located inside a small concrete containment area designed to capture and direct "leaks, drips, etc." from the pump into the chemical drain system. In addition, in 2018, ITC added four new fire monitors to the interior area of the tank farm to allow the company to direct at least one fire monitor to any tank manifold within the tank farm.

ITC had an opportunity to revisit its engineering controls around the Tank 80-8 circulation pump in 2014, when the company performed a voluntary PHA to evaluate risks associated with adding butane injection capability to the tank. The team recognized that one of the hazards involved with product storage and circulation was potential loss of containment, the consequences of which were product release, fire, explosion, exposures, injuries, and fatalities. The project team recommended that ITC "consider projects for LEL meters/deluge at pumps"; however, ITC ultimately decided not to install an LEL detector or deluge system at the Tank 80-8 circulation pump. On the day of the March 2019 incident, the one monitor that was designed to reach the Tank 80-8 manifold required manual activation and was already engulfed in the fire when emergency responders arrived. The CSB concludes that had ITC implemented additional engineering safeguards, such as flammable gas detection systems and remotely operated emergency isolation valves (ROEIVs), to mitigate the risks of operating the Tank 80-8 circulation pump inside the secondary containment area, the spread of the initial fire could have been slowed or prevented.

The CSB recommends that ITC conduct an evaluation of the design of all new and existing tank farms at the ITC Deer Park terminal. The evaluation should identify additional engineering controls needed to address placement of process equipment in containment areas (**2019-01-I-TX-R5**).

4.4.4 DRAINAGE

There were two drainage systems in place within the First & Second 80's tank farm: a chemical drain system and stormwater drain system. Materials collected in the chemical drain system were routed via underground piping to the terminal's wastewater treatment system. The stormwater drainage system was responsible for collecting stormwater from the First & Second 80's tank farm and directing it through pipes and control structures to an adjacent drainage ditch through a discharge location near the northwest corner of the tank farm (**Figure 31**). A Harris County drainage ditch was located just outside of the containment wall and inside of Tidal Road on the north side of the First & Second 80's tank farm.

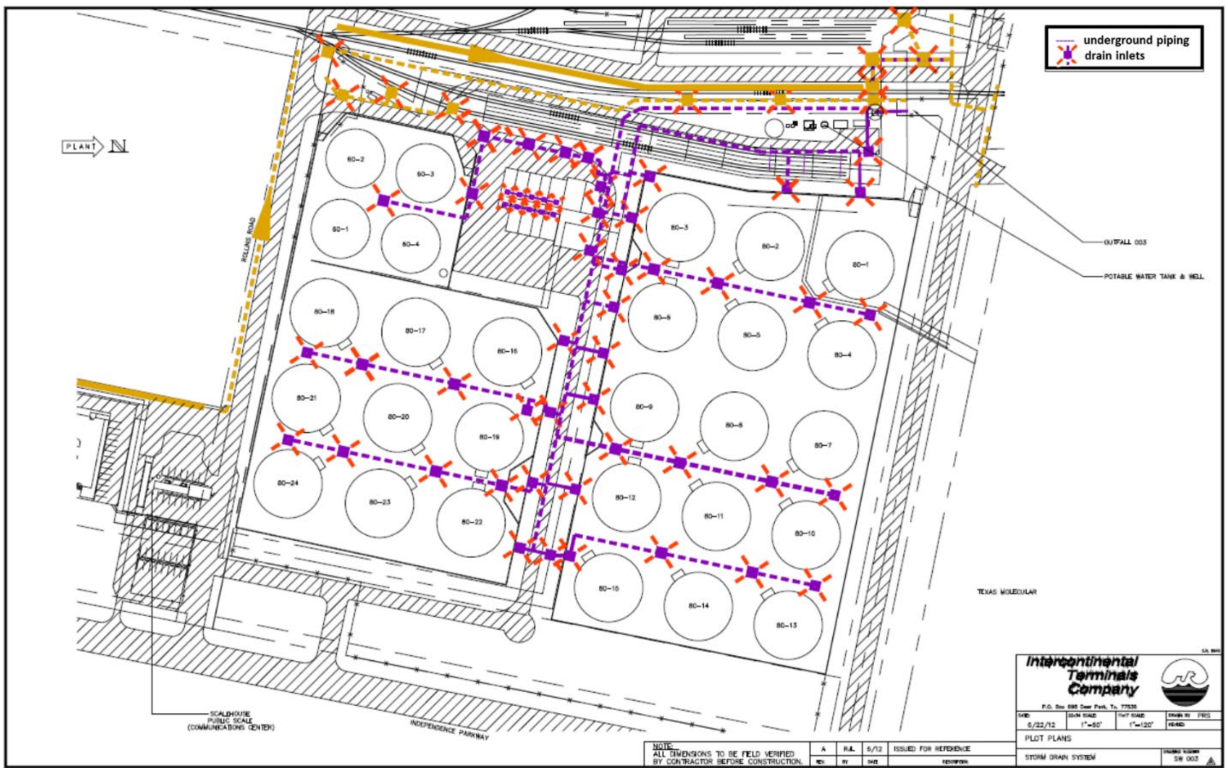

Figure 31. Plot plan of First & Second 80's tank farm stormwater drain system. (Credit: ITC)

Although the First & Second 80's tank farm was designed largely in accordance with NFPA 30 (1973 edition), a convergence of several issues related to liquid accumulation resulted in complications during the emergency response, including:

- The stormwater drain system in the tank farm was unable to quickly remove the quantity of released materials and firewater from the containment area;

- The stormwater drains were generally positioned along the same pathway as the transverse piping that ran north to south in between the tanks;
- The tank farm was graded to facilitate drainage to stormwater catch basins on the south side of the tank farm; and
- The containment wall failed, allowing the mixture of hydrocarbon products, firefighting foam, and contaminated water to eventually enter the Houston Ship Channel.

The stormwater drain system allowed the water, released materials, and firefighting foam to accumulate in the containment area while emergency responders were fighting the fire. The tank farm grading also provided a means for the fire to spread across the tank farm. The water and released materials flowed toward the transverse piping and piping manifolds and then south, which would have caused a "running fire" (i.e., one that tracked with the spill) that exposed other tanks and their respective piping manifolds prior to entering the drainage system. Since both naphtha and xylene are lighter than water,[a] the initially released flammable products floated on top of the water in the containment area, ignited, and caused several small fires to burn on the water surface where gaps in the foam existed. The movement of the fire toward the south prevented emergency responders from accessing the firewater system valves and foam connections located along the containment wall on the south side of the tank farm. It also prevented emergency responders from being able to position personnel at the monitor nozzles or employ other fire apparatus or equipment in this area.

Burning liquid on the ground or floating on the water during the initial and subsequent releases likely contributed to thermal exposure to the tanks as the burning liquid moved toward and then passed the tanks on its way toward drains. This movement continued as the stormwater drainage system became overwhelmed by the volume of materials, which partially explains the fire spread. This also helps explain why fire damage on the south side of the tank farm was more severe than on the north side.

The CSB contracted a structural engineering firm, Atlas Engineering, to evaluate the containment wall failure that occurred several days after the initial fire began (Appendix E). Although Atlas arrived at the ITC Deer Park terminal two years after the incident, in 2021, after remediation measures had already been performed, they were able to observe that "the wall was of adequate height to meet NFPA requirements for capacity and total height and contained waterstop detailing in an effort to maintain a water-tight wall" (Appendix E, pg. 24). In addition, the First & Second 80's tank farm was designed to retain at least 100% of the largest tank within the tank farm in line with NFPA 30 requirements. Regarding its tank farm containment walls, ITC's Spill Prevention, Control, and Countermeasure (SPCC) plan noted:

> Based on good engineering practice and site-specific factors, these containment/diversionary systems, including walls and floors, are capable of containing and are constructed to be sufficiently impervious to contain a discharge from one of the bulk oil storage *containers* until cleanup can occur; thereby minimizing the potential for a harmful discharge of oil into or upon navigable water of the United States.

[a] Xylene has a specific gravity of 0.87, compared with that of water, which is 1.0.

With no design documents available, Atlas could not evaluate the containment wall's original design basis or potential changes to the containment wall since its original design; however, more than one bulk storage tank was compromised during the March 17, 2019, incident, and the containment area was filled with hydrocarbon products, firefighting foam, and contaminated water for days. Based on drone footage from the incident, Atlas observed:

> The containment wall primarily displaced laterally [...] due to excessive lateral soil and hydrostatic pressures [...]. [...] With potential for as much as 4-feet of fire suppression water retained in the containment wall for days, this possibly led to saturation of the soils and increased lateral earth pressures against the containment wall (Appendix E, pg. 26).

The CSB concludes that the accumulation of hydrocarbon products, firefighting foam, and contaminated water within the First & Second 80's tank farm containment area contributed to the fire spreading to additional tanks in the common containment area. The accumulation likely also contributed to the containment wall failure, which allowed a mixture of hydrocarbon products, firefighting foam, and contaminated water to be released into the local waterways.

Section 9.2.3 of API STD 2610 addresses drainage of rainwater in tank farms. According to the document, unless other provisions are made for drainage, the floor of the diked area shall be graded to at least 1% for every 50 feet away from the tank(s) or to the dike base, whichever is less [25]. Additionally, the document states:

> The sloped area shall be directed toward one or more drain openings or retention areas. Major paths of drainage should be routed, or internal intermediate diking shall be provided, so that piping, equipment, tanks, or vessels will not be seriously exposed should flammable or combustible liquid in the drainage ditch ignite [25, p. 25].

API STD 2610 was not published until 1994, and thus did not exist at the time that the First & Second 80's tank farm was constructed; however, the recommendations contained in API STD 2610 can be considered while evaluating future recommendations related to the design of ITC's tank farms' drainage systems. The CSB recommends that ITC conduct an evaluation of the design of all new and existing tank farms at the ITC Deer Park terminal. The evaluation should assess the adequacy of the containment wall and drainage system designs, accounting for the impact of firefighting activities, including the application of firewater and foam on these systems (**2019-01-I-TX-R5**).

4.5 PSM and RMP Applicability

4.5.1 OSHA Process Safety Management (PSM) Standard

OSHA promulgated the *Process Safety Management of Highly Hazardous Chemicals* standard (29 C.F.R. § 1910.119), or PSM standard, on February 24, 1992,[a] following several significant incidents involving the

[a] The PSM standard became effective on May 26, 1992.

accidental release of highly hazardous chemicals[a] that resulted in worker injuries and fatalities [37]. The PSM standard, comprised of 14 key elements, requires facilities to develop and implement a process safety management program for covered processes[b] involving highly hazardous chemicals that integrates technologies, procedures, and management practices to help ensure safe and healthful workplaces. The main objective of the PSM standard is to prevent or minimize the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals, as these releases may result in toxic, fire, or explosion hazards [38].[c]

According to 29 C.F.R. §1910.119(a)(1), the requirements of the PSM standard are applicable to any process that involves highly hazardous chemicals, at or above the specified threshold quantities. In terms of applicability, OSHA defines a process as "any activity involving a highly hazardous chemical including any use, storage, manufacturing, handling, or on-site movement of such chemicals, or combination of these activities" [39]. OSHA provides a *List of Highly Hazardous Chemicals, Toxics and Reactives* in Appendix A[d] of the standard that includes the chemical names and threshold quantities of hazardous chemicals that are subject to the standard. In addition to processes involving the chemicals included on this list, the PSM standard is also applicable to any process that involves any Category 1 flammable gas or a flammable liquid with a flash point below 100ºF, in quantities of 10,000 pounds or more, on-site in one location, with two exceptions [39]. The first exception is for hydrocarbon fuels used solely for workplace consumption as a fuel, and the second exception is for flammable liquids stored in atmospheric tanks and kept below their normal boiling point without chilling or refrigeration [39]. The second exception is commonly referred to in industry as the "flammable liquid atmospheric storage tank exemption."

4.5.1.1 PSM Standard Applicability at ITC Deer Park Terminal

ITC applied OSHA PSM standard requirements to covered processes and storage tanks containing highly hazardous chemicals at the ITC Deer Park terminal, which did not include Tank 80-8 and the other atmospheric storage tanks in the First & Second 80's tank farm. The Deer Park terminal housed 242 fixed storage tanks, ranging in size from 8,000- to 160,000-barrel capacities, at the time of the incident. The tanks were used to store various petrochemical liquids and gases, fuel and bunker oils, and distillates. Specifically, ITC determined that storage tanks containing butadiene, isoprene, LPG, and vinyl acetate monomer were covered processes under the PSM standard. ITC took the position that the remainder of storage tank operations at the terminal, including Tank 80-8 and the other tanks located in the First & Second 80's tank farm, were not PSM-covered processes. According to ITC, the storage of butane-enriched naphtha product in Tank 80-8 was exempt from PSM coverage based on the atmospheric storage tank exemption.

ITC informed CSB investigators that the company assesses applicability of the OSHA PSM standard for all new processes and products at the terminal and makes a determination of applicability prior to the introduction of the new process or product at the terminal. When the company receives a customer request for a new process or product, it is initially directed to the Safety, Health, Environmental & Security (SHES) Department for

[a] The OSHA PSM standard defines "highly hazardous chemical" as "a substance possessing toxic, reactive, flammable, or explosive properties…" 29 C.F.R. § 1910.119(b).

[b] The PSM standard defines a "process" as "any activity involving a highly hazardous chemical including any use, storage, manufacturing, handling, or the on-site movement of such chemicals, or combination of these activities…" 29 C.F.R. § 1910.119(b).

[c] 29 C.F.R. § 1910.119. *Purpose.*

[d] 29 C.F.R. § 1910.119. Appendix A.

evaluation of regulatory and permitting applicability, which includes the PSM standard. The customer request is then distributed to other relevant departments, including the Operational Excellence group, for further evaluation. Upon completion of review, ITC either approves or denies the new request.

According to the process outlined above, when the customer request for adding butane injection capability to Tank 80-8 was received in 2014, the request was directed to the SHES and Operational Excellence groups for evaluation of PSM standard applicability. The VP SHES told investigators that he was involved in the initial review of the customer request, as was the Manager of Operational Excellence, and they determined that the request was not subject to coverage under the PSM standard since flammable liquid storage in an atmospheric tank was exempt from coverage. He told investigators that adding butane to the naphtha stored in Tank 80-8 did not change the product stored in the tank; it was still naphtha, which was not subject to PSM standard requirements.

4.5.1.2 OSHA Citations for PSM Standard Violations

Following the March 17, 2019, incident at the ITC Deer Park terminal, OSHA launched an inspection of the facility. As a result of the inspection, OSHA issued four citations to ITC with a proposed penalty of $53,040 [40]. The citation included four serious violations of the OSHA PSM standard. These violations are listed below:

- "The employer failed to document that it complied with Recognized and Generally Accepted Good Engineering Practices (RAGAGEP) such as, but not limited to NFPA 11 "Low, medium, and high-expansion foam systems" and NFPA 16 "Standard for the installation of foam water sprinkler and foam-water spray systems". The employer failed to ensure the foam generating equipment such as the foam-concentrate tank and pump were constructed to resist or located so that they were protected against exposure to fire.
- In the 2nd 80s tank farm, the employer failed to implement written procedures, including those outlined in the ITC Mechanical Integrity Program, to maintain the ongoing fitness for service of Tank 80-8 injection/recirculation piping and components. This condition exposed employees to fire hazards.
- The employer failed to perform inspection and test in accordance with Recognized and Generally Accepted Good Engineering Practices (RAGAGEP), such as but not limited to API 570 "Piping Inspection Code" and API 574 "Inspection Practices for Piping System Components". The employer failed to perform inspection and tests on Tank 80-8 cargo pump discharge circulation piping and injection point process piping.
- The employer failed to correct deficiencies on process equipment, when process piping that was below its minimum required thickness was used to inject and mix Butane with Naphtha in order to raise the octane levels in Tank 80-8."

ITC contested these citations, and a settlement agreement was reached on September 15, 2020, that included amendments to each of the four violations [42]. ITC did not admit to any violations of the "Occupational Safety and Health Act or regulations or standards promulgated there under" as part of the settlement agreement. The parties also agreed that any amendments to these citations do not affect the Secretary's interpretation of the originally cited standards, compliance with the standards, or application of the standards. The revised citations are listed below:

- "The employer failed to ensure the foam generating equipment such as the foam-concentrate tank and pump were constructed to resist or located so that they were protected against exposure to fire.
- The employer failed to implement written procedures to maintain the ongoing fitness for service of Tank 80-8 injection/recirculation piping and components.
- The employer failed to perform inspections and tests on Tank 80-8 cargo pump discharge circulation piping and injection point process piping.
- The employer failed to detect deficiencies on process equipment."

ITC also agreed to conduct an enhanced abatement at its Deer Park facility and to comply with all applicable abatement verification provisions 29 C.F.R. §1903.19 as part of the settlement agreement [42]. The terms of the enhanced abatement, as described in Exhibit A of the settlement agreement, included a series of exercises to be completed by the company for 180 existing storage tanks ("covered tanks") and their associated piping and equipment ("covered tank systems") at the Deer Park facility.[a]

The exercises involved compiling safety information for each of the covered tanks and covered tank systems; performing hazard reviews for the covered tanks to address the hazards associated with loading, unloading, transfer, and storage activities; updating operating procedures for covered tank systems; and verifying training for employees engaged in operating or maintaining the covered tank systems. The abatement also included a Mechanical Integrity element to develop inspection and testing practices for covered tanks and covered tank systems, including piping systems, pumps, tank relief systems, emergency shutdown systems, safety-related pressure and temperature transmitters, high-level switches, LEL gas detectors, and radar level gauges.

Deliverable dates for the abatement items ranged from one year to 30 months from the effective date of the agreement, October 1, 2020. Per the abatement, ITC agreed to meet with OSHA every six months until completion of the abatement to discuss progress on the activities described above and to notify OSHA of any tanks removed from service.

4.5.1.3 Historical Problems with the Atmospheric Storage Tank Exemption

ITC took the position that the storage of the butane-enriched naphtha product in Tank 80-8 was excluded from coverage under the OSHA PSM standard based on an exemption for "flammable liquids stored in atmospheric tanks or transferred which are kept below their normal boiling point without benefit of chilling or refrigeration" that exists in the standard.[b] As previously stated, following the incident, OSHA cited the ITC Deer Park terminal for violation of its PSM standard. Following issuance of this citation, OSHA and ITC entered into a settlement agreement, whereby ITC agreed to conduct an enhanced abatement at the ITC Deer Park terminal. However,

[a] All of the storage tanks contained in the First & Second 80's tank farm, including Tank 80-8, were removed from the facility following the incident. As such, these tanks are not included on the list.

[b] 29 C.F.R. § 1910.119(a)(1)(ii)(b)

under the settlement agreement, ITC did not concede that Tank 80-8 was covered under the OSHA PSM standard, and OSHA removed all PSM compliance-related language from the citations.

The “atmospheric storage tank exemption” is original to the OSHA PSM standard. Despite it being a point of contention and topic of debate since its inception, the exemption remains unchanged. Following promulgation of the standard, OSHA published an instructional document on September 28, 1992, entitled *29 C.F.R. §1910.119, Process Safety Management of Highly Hazardous Chemicals – Compliance Guidelines and Enforcement Procedures,* for the purpose of establishing uniform policies, procedures, standard clarifications, and compliance guidance for enforcement of the PSM standard. Appendix B of the document, *Clarifications and Interpretations of the PSM Standard*, contains guidance that “shall be followed in interpreting the PSM standard for compliance purposes.” For the purpose of interpreting the standard, OSHA stated in the document that the atmospheric storage tank exemption is applicable to “flammable liquids in tanks, containers and pipes used only for storage and transfer (to storage), and not connected to a process or a process vessel” [42, p. 93] Since that time, OSHA has published several Letters of Interpretation (LOIs) that address the exemption, as well as court rulings.

The CSB investigated two incidents, in 2001 and in 2009, in which it determined that the atmospheric storage tank PSM exemption contributed to the incidents:

- On July 17, 2001, an explosion occurred at the Motiva Enterprises LLC Delaware City Refinery (DCR) in Delaware City, Delaware [43]. One contract employee died and eight workers were injured when a spent sulfuric acid storage tank failed and released its contents, which ignited. Approximately 1.1 million gallons of spent sulfuric acid were released; 99,000 gallons reached the Delaware River. As a result of its investigation, the CSB found that Motiva did not consider the acid tank farm to be covered by requirements of the OSHA PSM standard as a result of the atmospheric storage tank exemption. The CSB stated in its report that the incident would likely not have occurred if good process safety management practices had been adequately implemented, such as mechanical integrity, MOC, and pre-startup safety review.

  The CSB issued recommendation 2001-05-I-DE-R1 to OSHA to ensure that atmospheric storage tanks interconnected with a process with at least 10,000 pounds of a flammable substance are PSM covered. At the time of writing this report, this recommendation is in “Open – Unacceptable Response” status [44].

- On October 23, 2009, a large explosion occurred at the Caribbean Petroleum Corporation (CAPECO) facility in Bayamón, Puerto Rico, during offloading of gasoline from a tanker ship, the *Cape Bruny*, to the CAPECO tank farm onshore [45]. A five-million-gallon aboveground storage tank overflowed into a secondary containment dike. The gasoline spray aerosolized, forming a large vapor cloud, which ignited after reaching an ignition source in the wastewater treatment area of the facility. The blast and fire from multiple secondary explosions resulted in significant damage to 17 of the 48 petroleum storage tanks and other equipment onsite and in neighborhoods and businesses off-site. The fires burned for almost 60 hours. As a result of its investigation, the CSB found that the U.S. regulatory system does not consider bulk aboveground storage tank terminals storing flammable liquid to be highly hazardous, even those near communities. Further, the CSB found that due to a lack of regulatory coverage under the OSHA PSM standard and the EPA RMP rule, tank terminal facilities are not required to conduct risk assessments to address flammable hazards on-site or to follow RAGAGEP.

> The CSB made recommendation 2010-02-PR-R4 to OSHA to revise the Flammable and Combustible Liquids standard (29 CFR § 1910.106), including establishing hazard analysis, management of change, and mechanical integrity management system elements for bulk aboveground storage tanks, similar to the PSM standard. At the time of writing this report, this recommendation is in "Open – Awaiting Response or Evaluation/Approval of Response" status.

On December 9, 2013, OSHA published a *Request for Information on Process Safety Management and Prevention of Major Chemical Accidents (78 FR 73746)* in response to Section 6(a) of Executive Order 13650: Improving Chemical Facility Safety and Security [38]. Within this document was a list of "Rulemaking and Enforcement Policy Change Options Under Consideration." According to this document:

> OSHA has determined that revisions to its PSM standard may be needed to address issues in coverage. As specified in Executive Order 13650, the Agency is also considering related revisions to its Explosives and Blasting Agents standard to address potential issues in coverage; updates to its Flammable Liquids standard and Spray Finishing standard to better align with current versions of applicable consensus standards; and changes in its enforcement policies for these standards.
>
> OSHA identified a number of rulemaking and policy options through the Agency's PSM NEPs, its investigation of major accidents, and its review of recommendations from the safety community. OSHA identified the following topics as potential candidates for rulemaking or enforcement policy changes:
>
> 11. Clarifying the PSM Exemption for Atmospheric Storage Tanks
>
> Pursuant to paragraph (a)(1)(ii) of Sec. 1910.119, the PSM standard applies to processes involving a flammable liquid or gas on site in one location in a quantity of 10,000 pounds or more. However, paragraph (a)(1)(ii)(B) contains an exemption for "[f]lammable liquids stored in atmospheric tanks or transferred which are kept below their normal boiling point without benefit of chilling or refrigeration."
>
> In Secretary of Labor v. Meer Corporation (1997) (OSHRC Docket No.95-0341), an administrative law judge ruled that PSM coverage does not extend to flammables stored in atmospheric tanks, even if the tanks are connected to a process. As a result, employers can exclude the amount of flammable liquid contained in an atmospheric storage tank, or in transfer to or from storage, from the quantity contained in the process when determining whether a process meets the 10,000-pound threshold quantity. The Meer decision was contrary to OSHA's earlier interpretation of paragraph (a)(1)(ii)(B), which was that the standard covered all stored flammables when connected to, or in close proximity to, a process.

> OSHA believes that revising paragraph (a)(1)(ii)(B) to include flammable liquids in atmospheric storage tanks within or connected to a PSM covered process would improve the safety of workers by remedying the issue in PSM enforcement that has existed since the Meer decision. In the questions in this RFI, the Agency requests comment on revising paragraph (a)(1)(ii)(B) to clarify that the PSM standard covers all stored flammables when connected to, or in close proximity to, a process [38].

The CSB responded to OSHA's Request for Information on March 31, 2014, with comments on several topic areas, including the exemption for atmospheric storage tanks outlined in the PSM standard [46]. In its letter, the CSB outlined why blending and mixing operations should be included in the scope of a process and urged OSHA to eliminate the atmospheric storage tank exemption and/or to revise the Flammable Liquids standard (29 C.F.R. §1910.106) to require additional safeguards for atmospheric storage tanks, including:

- Requirements for mechanical integrity during design, construction, and maintenance.
- A requirement for the conduct of written management of change analyses.
- Requirements for the installation and maintenance of an automatic liquid overfill protection system [46, p. 2].

On November 9, 2022, the CSB submitted comments on OSHA's September 20, 2022, Federal Register Notice (87 Fed. Reg. 57520) to address the agency's PSM standard modernization rulemaking project (PSM STD Modernization) [47]. The CSB urged OSHA to eliminate the atmospheric storage tank exemption, stating:

> OSHA's preamble to the PSM standard stated that the reason for the exemption is that ASTs were already regulated under 29 CFR 1910.106 Flammable liquids (106 STD). The 106 STD is intended to address fire and explosion hazards of flammable liquids, unlike the PSM standard which is to prevent or minimize the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals. The 106 STD contains some requirements for how ASTs will be designed but lacks mechanical integrity requirements during design, construction, and maintenance as well as management of change analysis when changes occur.
>
> Additionally, because of the AST exemption and litigation, the PSM's coverage of certain flammables above a threshold quantity does not extend to those applicable stored flammables if they are contained in ASTs, even if they are connected to a process. To address this issue the CSB issued Recommendation No. 2001-05-I-DE-R1 to OSHA from its Motiva Enterprises Sulfuric Acid Tank Explosion investigation to expand coverage under the PSM standard to include ASTs. In addition to the CSB's Motiva investigation, the AST exemption issue was a factor in the Caribbean Petroleum Refining Tank Explosion and Fire (CAPECO) investigation and the Intercontinental Terminal Company (ITC) Tank Fire investigation (pending) [47].

The CSB concludes that the atmospheric storage tank exemption in the OSHA PSM standard continues to allow for catastrophic incidents to occur because necessary safeguards are not being implemented for equipment that should otherwise be covered under the PSM standard. Examples from past CSB investigations include the July 17, 2001, Motiva Enterprises sulfuric acid tank explosion and the October 23, 2009, Caribbean Petroleum Corporation tank fire and explosion, in addition to the March 17, 2019, ITC tank fire incident discussed in this report.

Coverage under the OSHA PSM standard requires that process equipment handling highly hazardous chemicals is subject to a comprehensive PSM program that integrates technologies, procedures, and management practices to help ensure safe and healthful workplaces. Implementation of this type of program results in the addition of safeguards to ensure the equipment used to handle these chemicals continues to operate safely and as designed. These safeguards are intended to prevent or minimize the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals from the process equipment. OSHA defines a process as "any activity involving a highly hazardous chemical including any use, storage, manufacturing, handling, or on-site movement of such chemicals, or combination of these activities" [39].

As such, had it not been for the atmospheric storage tank exemption, Tank 80-8 and its circulation pump would have been subject to the requirements contained in the OSHA PSM standard, including the Mechanical Integrity, PHA, and MOC requirements discussed in this report. The CSB concludes that had the OSHA PSM standard applied to Tank 80-8 and its related equipment, ITC would have been required to implement a formal PSM system to provide the company with additional opportunities to identify and control hazards for Tank 80-8 and its associated equipment.

Based upon the CSB's November 9, 2022, comments to OSHA regarding the modernization of PSM specific to the difference in purposes between the 106 STD and the PSM standard, and the need to prevent or minimize the consequences of catastrophic releases posed by category 1 flammable gases and flammable liquids in aboveground storage tanks currently exempted by 29 CFR § 1910.119(a)(1)(ii)(B):

- the CSB supersedes CSB Recommendation No. 2001-05-I-DE-R1 from the Motiva Enterprises Sulfuric Acid Tank Explosion investigation and CSB Recommendation No. 2010-02-PR-R4 from the Caribbean Petroleum Refining Tank Explosion and Fire

and

- the CSB herewith recommends that OSHA eliminate the atmospheric storage tank exemption from the PSM standard (**2019-01-I-TX-R7**).

4.5.1.4 Center for Chemical Process Safety Risk Based Process Safety

Even though the PSM standard did not apply to Tank 80-8 and its associated equipment, ITC could have voluntarily chosen to apply the broadly accepted framework for process safety management contained in the CCPS's *Guidelines for Risk Based Process Safety* [48]. While the guidelines are not a requirement, the book provides 20 elements of a process safety management program to help organizations design and implement more effective process safety management systems. These elements include Hazard Identification and Risk Analysis, which correlates to the OSHA PSM element of PHA; MOC; and Asset Integrity and Reliability, which correlates to the OSHA PSM element of Mechanical Integrity.

Although ITC applied some PSM elements across its entire Deer Park terminal, such as MOC and incident investigation, the company did not apply other key elements of a comprehensive process safety management system to atmospheric storage tanks in highly hazardous chemical service, such as Tank 80-8. Examples of these elements include:

- **Asset Integrity and Reliability:** Had ITC had formal maintenance procedures and training for pump replacements, and a routine preventative maintenance program for the pumps as recommended by the pump manufacturer, ITC could have identified issues with the Tank 80-8 circulation pump before it failed within three months of installation; and
- **Hazard Identification and Risk Analysis:** Had ITC conducted a comprehensive and effective process hazard analysis on the First & Second 80's tank farm, the company could have evaluated and implemented additional engineering controls such as flammable gas detection systems, remote isolation equipment, and/or tank farm subdivisions as needed to promptly detect and secure flammable tank product leaks, slow the spread of flammable material to adjacent tanks inside the tank farm containment area, and allow emergency responders to access equipment such as fire monitors designed to respond to tank fires.

A comprehensive process safety management system would have provided the company with additional opportunities to identify and control hazards through multiple layers of protection, including the examples of preventative and mitigative safeguards discussed in this report. As such, the CSB concludes that had ITC implemented a comprehensive process safety management system that effectively identified and controlled the hazards for Tank 80-8 and its related equipment, the company could have prevented this incident. The CSB recommends that ITC develop and implement a process safety management system for the ITC Deer Park terminal applicable to all atmospheric storage tanks and associated equipment in highly hazardous chemical service. The program should follow industry guidance provided in publications such as the American Petroleum Industry's API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*. (**2019-01-I-TX-R1**).

KEY LESSON

Companies have a duty of care to ensure safety at facilities that handle flammable or highly hazardous substances and protect surrounding communities and the environment regardless of whether the hazardous substance(s) onsite fall under OSHA's PSM standard or EPA's RMP rule. To prevent catastrophic incidents, a company should apply a comprehensive process safety management system such as CCPS's Guidelines for Risk Based Process Safety or CCPS' Guidelines for Implementing Process Safety Management Systems.

4.5.2 EPA Risk Management Program (RMP) Rule

The Clean Air Act (CAA) Amendments require the EPA to promulgate regulations to prevent accidental releases of regulated substances and reduce the severity of those releases that do occur.[a] Congress provides under the CAA Amendments that the EPA must "promulgate reasonable regulations and appropriate guidance to provide, to the greatest extent practicable, for the prevention and detection of accidental releases of regulated substances and for response to such releases by the owners or operators of the sources of such releases."[b] Under the authority of the CAA section 112I, the EPA adopted the RMP regulations at 40 C.F.R. Part 68 (the RMP rule), which required compliance by 1999.

The RMP rule requires facilities that contain more than a threshold quantity of any of the listed toxic or flammable substances[c] in a process to prepare and submit to the EPA an RMP containing emergency contact information, descriptions of processes and hazardous chemicals on-site, an accident history, and worst-case release scenarios.[d] Unlike the PSM standard, the RMP rule does not include an exemption for atmospheric storage of flammable liquids [49].[e]

The RMP rule defines three different Program levels (Program 1, 2, or 3) based on a process unit's potential for impact to the public and the requirements to prevent incidents.[f] Program 3 processes are subject to additional, more stringent prevention program requirements, including: MOC reviews, mechanical integrity, training, and PHAs. These prevention program elements are based primarily on the OSHA PSM standard, and much of the language contained in each element is identical to the OSHA PSM standard.

On January 6, 1998, the EPA modified the RMP rule by adding a provision for the threshold determination of flammable substances in a mixture intended to "better focus accident prevention activities on stationary sources with high hazard operations and reduce duplication with other similar requirements."[g] This provision contained in 40 C.F.R. § 68.115(b)(2)(i) states the following:

> [I]f the concentration of the substance is one percent or greater by weight of the mixture, then, for purposes of determining whether a threshold quantity is present at the stationary source, the entire weight of the mixture shall be treated as the regulated substance unless the owner or operator can demonstrate that the mixture itself does not have a National Fire Protection Association [NFPA] flammability hazard rating of 4.[h]

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[a] See 61 FR 3667, p. 1.

[b] CAA Amendments Section 112(r)(7)(B)(i); 104 STAT 2399 Page 165. Public Law 101-549 – November 15, 1990.

[c] According to 40 CFR § 68.10(a), "[a]n owner of operator of a stationary source that has more than a threshold quantity of a regulated substance in a process, as determined under § 68.115, shall comply with the requirements of this part no later than the latest of the following dates…"

[d] See 40 CFR § 68.12. General Requirements.

[e] Section 112(r)(B)(i) states that the RMP rule "shall cover storage, as well as operations."

[f] See 40 CFR § 68.10. Applicability.

[g] 63 FR 640 – List of Regulated Substances and Thresholds for Accidental Release Prevention; Amendments.

[h] The criteria for the NFPA-4 flammability rating are contained in the 1996 edition of NFPA 704 [75], and the 1996 edition of NFPA 30 [31]. EPA's RMP rule incorporates both standards by reference. In NFPA 704, NFPA-4 rating criteria are defined as a liquid having a flash point below 73°F and boiling point below 100°F.

Prior to the incident, ITC submitted its most recent RMP to the EPA on March 12, 2018 [50]. According to the RMP, ITC was applying RMP rule requirements to certain covered processes and tanks containing regulated substances at the ITC Deer Park terminal. Specifically, ITC's RMP included covered processes containing 1,3-butadiene, 1-butene, 1,3-pentadiene, isoprene, and vinyl acetate monomer. ITC's RMP did not include the remainder of the hazardous substances stored at the terminal, including the naphtha and butane mixture contained in Tank 80-8.

According to ITC records reviewed by the CSB, Tank 80-8 contained approximately 1.4 million pounds of butane at the time of the incident, well above the threshold quantity of 10,000 pounds. ITC did not, however, include the butane and naphtha mixture contained within Tank 80-8 as a process chemical in its RMP. ITC pointed to 40 C.F.R. § 68.115(b)(2)(i) and asserted that the butane-enriched naphtha product contained in Tank 80-8 was not subject to the RMP rule because it was an NFPA-3[a] rated material rather than an NFPA-4 rated material.

The product contained in Tank 80-8 at the time of the incident contained over 8% butane by weight. ITC acknowledged that the amount of butane in the butane-enriched naphtha product exceeded 1%[b] by weight but asserted that the "mixture of chemical substances" contained in Tank 80-8 was excluded from determining whether the RMP threshold amount of butane was met under the provisions of 40 C.F.R. § 68.115(b)(2)(i). While the placard affixed to Tank 80-8 at the time of the incident displayed an NFPA flammability rating "4" for the butane-enriched naphtha product contained in the tank (see **Figure 4**), ITC provided documents showing that the material was an NFPA flammability rating "3." Although the EPA RMP rule does not regulate NFPA-3 rated liquids, these materials are hazardous based on their inherent properties. NFPA 704 states that these substances produce hazardous atmospheres with air under almost all ambient temperatures and are readily ignited under almost all conditions [51, p. 7].

The CSB has investigated several high-consequence chemical incidents that involved materials rated lower than an NFPA "4." The CSB discussed above the Motiva incident that occurred on July 17, 2001, which occurred when flammable vapors inside a storage tank containing spent sulfuric acid[c] were ignited, causing an explosion and fatally injuring one worker. Despite the severity of the incident, the Motiva SDS showed a flammability rating that can range between "0" and "3" for the spent sulfuric acid, and the tank was not covered by the EPA RMP rule [43]. Similarly, the CSB investigated the CAPECO incident discussed above, which occurred on October 23, 2009, in Bayamón, Puerto Rico. During that investigation, the CSB found that NFPA-3 rated gasoline was the source of the tremendous explosion and fire and posed a significant hazard to the environment and surrounding communities. The CSB subsequently issued Recommendation No. 2010-02-I-PR-R1 to the EPA to modify various regulations to address mixtures containing NFPA-3 rated materials. Currently that recommendation is in an "open" status, meaning it has not yet been implemented.

One of the most notable recent incidents resulting in several technical and regulatory recommendations in the United Kingdom (UK) is an explosion and fire that occurred at the Buncefield oil storage depot in Hemel Hemptstead, Hertfordshire, UK, on December 11, 2005. During this incident, a vapor cloud explosion and

a The criteria for the NFPA-3 flammability rating are defined as a liquid having a flash point below 73°F and boiling point at or above 100°F, and those liquids having a flash point at or above 73°F and below 100°F.

b The butane added to the tank between December 2018 and March 2019 was more than 8% of the total product by weight.

c Spent sulfuric acid normally contains small amounts of flammable materials. Light hydrocarbons in the acid can vaporize and create a flammable atmosphere above the liquid surface if sufficient oxygen is present.

multiple tank fires occurred after a tank was overfilled with gasoline. The explosion generated significant blast pressure, resulting in additional loss of containment that led to fire and other damage involving 22 tanks. There were no fatalities, but 43 people were injured, and the damage to nearby commercial and residential property totaled $1.5 billion [52]. Similar to the CAPECO and the ITC incidents, Buncefield involved a substance (in the case of Buncefield, it was petrol, or gasoline) that is typically considered an NFPA-3 rated material [53] [54].

While the CSB is not validating ITC's NFPA "3" determination, ultimately the application of this regulatory provision resulted in ITC not developing and implementing an effective PSM program, including a comprehensive PHA and MOC review, under the RMP rule for its Tank 80-8 operations. The CSB concludes that had the EPA RMP rule applied to Tank 80-8 and its circulation pump, this incident likely would not have occurred. For example, had ITC implemented an effective process safety management program, such as what the RMP rule requires, even if the pump had leaked, additional safeguards such as flammable gas detection and remote isolation equipment should have been available to quickly identify and stop the release.

The CSB also concludes that NFPA-3 flammability rated materials have resulted in significant explosions and fires similar to those contemplated to occur from NFPA-4 rated materials. As such, the EPA RMP rule language in 40 C.F.R. § 68.115(b)(2)(i) does not appear to be in alignment with the congressional mandates set out in the Clean Air Act Amendments to prevent accidental releases and mitigate the consequences of such releases.[a]

The CSB supersedes CSB Recommendation No. 2010-02-PR-R1 from the CAPECO investigation and herewith recommends that the EPA modify 40 C.F.R. § 68.115(b)(2)(i) to expand coverage of its RMP rule to include all flammable liquids, including mixtures, with a flammability rating of NFPA-3 or higher (**2019-01-I-TX-R8**).

5 CONCLUSIONS

5.1 FINDINGS

1. The butane-enriched naphtha product release initiated when the Tank 80-8 circulation pump's gland nuts loosened from the seal chamber cover, allowing the seal gland to separate from the seal chamber cover and consequently creating a path for butane-enriched naphtha product to release.

2. Tank 80-8's circulation pump likely continued to operate past the point of outboard bearing failure while circulating the butane-enriched naphtha product. The bearing failure likely led to significant pump vibration, which loosened the gland nuts that secured the mechanical seal in place, causing the seal to separate and allow the release of the flammable mixture.

[a] The CSB also notes that in response to this incident, the TCEQ issued a proposed rulemaking entitled *Chapter 338 – Aboveground Storage Vessel Safety Program*. This proposed rule, which is supposed to be adopted as a final rule in the fall of 2023, would provide additional requirements for certain aboveground storage vessels. It proposes to incorporate by reference certain sections of the EPA RMP rule, including the NFPA flammable rating provision at 40 C.F.R. § 68.115(b)(2)(i). As such, had TCEQ's proposed rule been in effect at the time of the incident, it would not have applied to ITC's Tank 80-8. The proposed rule would apply to Tank 80-8, however, if EPA would modify 40 C.F.R. § 68.115(b)(2)(i) to expand coverage to include all flammable liquids, including mixtures, with an NFPA-3 flammability rating or higher.

3. Accumulated flammable vapors in the area around the Tank 80-8 pump skid were likely ignited as a result of heat generated from the metal-to-metal contact between the unrestrained seal gland and pump shaft.

4. The ITC Deer Park terminal's management systems lacked essential mechanical integrity program items, such as maintenance procedures, training for pump replacements and rebuilds, and routine preventative maintenance activities as recommended by the pump manufacturer, for equipment in highly hazardous chemical service that was not covered by OSHA PSM or EPA RMP requirements. A formal mechanical integrity program for all pumps in highly hazardous chemical service could have prevented this incident by allowing ITC to have additional opportunities to identify Tank 80-8's circulation pump issues prior to the incident.

5. ITC did not retrofit the Tank 80-8 circulation pump with vibration monitoring equipment, which resulted in pump vibration going undetected and allowed the outboard bearing to continue to degrade to failure. Had ITC installed vibration monitoring equipment on the Tank 80-8 circulation pump, excessive vibration likely would have triggered an alarm, and ITC operators could have shut down the pump before the bearing failed, preventing the butane-enriched naphtha product release.

6. Had Tank 80-8 been subject to the OSHA PSM standard and/or the EPA RMP rule, ITC would have been required to track the recommendation to install a flammable gas detection system such as an LEL detector or deluge system at the Tank 80-8 circulation pump to completion and document the resolution in a timely manner.

7. Had a flammable gas detection system existed in the vicinity of the Tank 80-8 circulation pump, it could have provided adequate time for personnel to detect and attempt to secure the butane-enriched naphtha product release before its flammable vapors eventually ignited.

8. Terminals and tank facilities that store flammable substances should develop, implement, and maintain flammable gas detection systems to alert workers to hazardous conditions and allow them to respond in a timely manner.

9. Had Tank 80-8 been equipped with a remotely operated emergency isolation valve (ROEIV), the butane-enriched naphtha product release could have been secured without the need for personnel to enter the tank farm, allowing emergency responders to extinguish the initial fire early in the response.

10. Had remotely operated emergency isolation valves (ROEIVs) configured to "Fail-Closed" been installed on Tank 80-8 and the other fourteen tanks in First & Second 80's tank farm, the tanks could have been secured without the need for personnel to enter the tank farm after power was lost to all motor operated valves (MOVs), and the quantity of the materials released could have been reduced.

11. Although the First & Second 80's tank farm was designed in accordance with applicable NFPA 30 tank farm spacing requirements in place at the time the tank farm was constructed, the NFPA 30 recommendation for additional spacing for compacted tank farm layouts was not included in the design. This design, which allowed for reliance on administrative controls and emergency response, allowed the Tank 80-8 fire to spread and involve additional tanks in the tank farm.

12. ITC's First & Second 80's tank farm was not subdivided as was required by NFPA 30. Although the subdivisions of the diking required by NFPA 30 likely would have been insufficient to hold the full contents of

Tank 80-8, additional subdivisions could have slowed the spread of the butane-enriched naphtha product and allowed responders the opportunity to access and activate the fixed fire monitors located within the containment area to fight the fire surrounding the Tank 80-8 piping manifold before it spread to adjacent tanks.

13. Had ITC implemented additional engineering safeguards, such as flammable gas detection systems and remotely operated emergency isolation valves (ROEIVs), to mitigate the risks of operating the Tank 80-8 circulation pump inside the secondary containment area, the spread of the initial fire could have been slowed or prevented.

14. The accumulation of hydrocarbon products, firefighting foam, and contaminated water within the First & Second 80's tank farm containment area contributed to the fire spreading to additional tanks in the common containment area. The accumulation likely also contributed to the containment wall failure, which allowed a mixture of hydrocarbon products, firefighting foam, and contaminated water to be released into the local waterways.

15. The atmospheric storage tank exemption in the OSHA PSM standard continues to allow for catastrophic incidents to occur because necessary safeguards are not being implemented for equipment that should otherwise be covered under the PSM standard. Examples from past CSB investigations include the July 17, 2001, Motiva Enterprises sulfuric acid tank explosion and the October 23, 2009, Caribbean Petroleum Corporation tank fire and explosion, in addition to the March 17, 2019, ITC tank fire incident discussed in this report.

16. Had the OSHA PSM standard applied to Tank 80-8 and its related equipment, ITC would have been required to implement a formal PSM system to provide the company with additional opportunities to identify and control hazards for Tank 80-8 and its related equipment.

17. Had ITC implemented a comprehensive process safety management system that effectively identified and controlled the hazards for Tank 80-8 and its associated equipment, the company could have prevented this incident.

18. Had the EPA RMP rule applied to Tank 80-8 and its circulation pump, this incident likely would not have occurred. For example, had ITC implemented an effective process safety management program, such as what the RMP rule requires, even if the pump had leaked, additional safeguards such as flammable gas detection and remote isolation equipment should have been available to quickly identify and stop the release.

19. NFPA-3 flammability rated materials have resulted in significant explosions and fires similar to those contemplated to occur from NFPA-4 rated materials. As such, the EPA RMP rule language in 40 C.F.R. § 68.115(b)(2)(i) does not appear to be in alignment with the congressional mandates set out in the Clean Air Act Amendments to prevent accidental releases and mitigate the consequences of such releases.

5.2 Cause

The CSB determined that the cause of the incident was the release of flammable butane-enriched naphtha vapor from the failed Tank 80-8 circulation pump, which accumulated in the area and ignited, resulting in a fire. Contributing to the severity of the incident were the absence of a flammable gas detection system to alert the operators to the flammable mixture before it ignited approximately 30 minutes after the release began, and the absence of remotely operated emergency isolation valves (ROEIVs) to safely secure the flammable liquids in Tank 80-8 and the surrounding tanks in the First & Second 80's tank farm.

Elements of the tank farm design, including tank spacing, subdivisions, engineering controls for pumps located inside the containment area, and drainage systems also contributed to the severity of the incident by allowing the fire to spread to other tanks within the tank farm. The resulting accumulation of hydrocarbon and petrochemical products, firefighting foam, and contaminated water in the secondary containment area ultimately contributed to a breach of the containment wall and a release of materials to the local waterways.

Finally, the CSB determined that because of the atmospheric storage tank exemption contained in the OSHA PSM standard and the flammability exemption contained in the EPA RMP rule, ITC was not required to develop and implement a formal PSM program for Tank 80-8 and its associated equipment that could have provided a process to identify and control the specific hazards that resulted in this incident, which also contributed to this incident.

6 Recommendations

To prevent future chemical incidents, and in the interest of driving chemical safety excellence to protect communities, workers, and the environment, the CSB makes the following safety recommendations:

6.1 Previously Issued Recommendation Superseded by this Report

6.1.1 To OSHA from the Motiva Enterprise Sulfuric Acid Tank Explosion investigation

2001-05-I-DE-R1

Ensure coverage under the Process Safety Management Standard (29 CFR 1910.119) of atmospheric storage tanks that could be involved in a potential catastrophic release as a result of being interconnected to a covered process with 10,000 pounds of a flammable substance.

Superseded by ***2019-01-I-TX-R8*** *to OSHA in Section 6.2.3 below***.**

6.1.2 To OSHA from the Caribbean Petroleum Refining Tank Explosion and Fire investigation

2010-02-PR-R4

Revise the Flammable and Combustible Liquids standard (29 CFR § 1910.106) to require installing, using, and maintaining a high-integrity automatic overfill prevention system with a means of level detection, logic/control equipment, and independent means of flow control for bulk aboveground storage tanks containing gasoline, jet fuel, other fuel mixtures or blendstocks, and other flammable liquids having an NFPA 704 flammability rating of 3 or higher, to protect against loss of containment. At a minimum, this system shall meet the following requirements:

1. Separated physically and electronically and independent from the tank gauging system.
2. Engineered, operated, and maintained to achieve an appropriate level of safety integrity in accordance with the requirements of Part 1 of International Electro-technical Commission (IEC) 61511-SER ed1.0B-2004, Functional Safety – Safety Instrumented Systems for the Process Industry Sector. Such a system would employ a safety integrity level (SIL) documented in accordance with the principles in Part 3 of IEC 61511-SER ed1.0B-2004, accounting for the following factors:
   i. The existence of nearby populations and sensitive environments;
   ii. The nature and intensity of facility operations;
   iii. The extent/rigor of operator monitoring.
3. Proof tested in accordance with the validated arrangements and procedures with sufficient frequency to ensure the specified safety integrity level is maintained.

b) Establish hazard analysis, management of change and mechanical integrity management system elements for bulk aboveground storage tanks in the revised 1910.106 standard that are similar to those in the Process Safety Management of Highly Hazardous Chemicals standard (29 CFR § 1910.119) and ensure these facilities are subject to Recognized and Generally Accepted Good Engineering Practices (RAGAGEP).

Superseded by ***2019-01-I-TX-R8*** *to OSHA in Section 6.2.3 below*.

6.1.3 To EPA from the Caribbean Petroleum Refining Tank Explosion and Fire investigation

2010-02-I-PR-1

Revise where necessary the Spill Prevention, Control and Countermeasure (SPCC); Facility Response Plan (FRP); and/or Accidental Release Prevention Program (40 CFR Part 68) rules to prevent impacts to the environment and/or public from spills, releases, fires, and explosions that can occur at bulk aboveground storage facilities storing gasoline, jet fuels, blendstocks, and other flammable liquids having an NFPA 704 flammability rating of 3 or higher.

At a minimum, these revisions shall incorporate the following provisions:

a) Ensure bulk aboveground storage facilities conduct and document a risk assessment that takes into account the following factors:

1. The existence of nearby populations and sensitive environments;

2. The nature and intensity of facility operations;

3. Realistic reliability of the tank gauging system; and

4. The extent/rigor of operator monitoring.

b) Equip bulk aboveground storage containers/tanks with automatic overfill prevention systems that are physically separate and independent from the tank level control systems.

c) Ensure these automatic overfill prevention systems follow good engineering practices.

d) Engineer, operate, and maintain automatic overfill prevention systems to achieve appropriate safety integrity levels in accordance with good engineering practices, such as Part 1 of International Electro-technical Commission (IEC) 61511-SER ed1.0B-2004, Functional Safety – Safety Instrumented Systems for the Process Industry Sector.

e) Regularly inspect and test automatic overfill prevention systems to ensure their proper operation in accordance with good engineering practice.

*Superseded by **2019-01-I-TX-R9** to EPA in Section 6.2.4 below.*

6.2 New Recommendations

6.2.1 Intercontinental Terminals Company, LLC (ITC)

2019-01-I-TX-R1

Develop and implement a process safety management system for the ITC Deer Park terminal applicable to all atmospheric storage tanks and associated equipment in highly hazardous chemical service. The program should follow industry guidance provided in publications such as the American Petroleum Industry's API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*.

2019-01-I-TX-R2

Develop and implement a condition monitoring program for all pumps in highly hazardous chemical service at the ITC Deer Park terminal. Ensure that condition monitoring equipment is programmed with control limits, including but not limited to vibration, consistent with ANSI/HI 9.6.9.-2018, that trigger alarms when control limits are exceeded, and that operating procedures and training reflect the appropriate actions to take when an alarm is triggered.

2019-01-I-TX-R3

Install flammable gas detection systems with associated alarm functions in product storage and transfer areas at the ITC Deer Park terminal where flammable substance releases could occur. Develop and implement a response plan and operator training for actions to take when an alarm sounds.

2019-01-I-TX-R4

Install remotely operated emergency isolation valves configured to "Fail-Closed" for all atmospheric storage tanks that contain highly hazardous chemicals or liquids with a flammability rating of NFPA-3 or higher at the ITC Deer Park terminal.

2019-01-I-TX-R5

Conduct an evaluation of the design of all new and existing tank farms at the ITC Deer Park terminal against the applicable sections of the Third Edition of API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities* and the 2021 Edition of NFPA 30, *Flammable and Combustible Liquids Code*. At a minimum the evaluation should include, but is not limited to the following sections of API STD 2610:

Section 4	Site Selection and Spacing Requirements
Section 7	Fire Prevention and Protection
Section 8.1	Aboveground Petroleum Storage Tanks
Section 9	Dikes and Berms
Section 10	Pipe, Valves, Pumps, and Piping Systems
Section 11	Loading, Unloading, and Product Transfer Facilities

and the following chapters of NFPA 30:

Chapter 21	Storage of Ignitible (Flammable or Combustible) Liquids in Tanks – Requirements for All Storage Tanks and
Chapter 22	Storage of Ignitible (Flammable or Combustible) Liquids in Tanks – Aboveground Storage Tanks

The evaluation should identify additional engineering controls needed to address minimal tank spacing, subdivisions between tanks, and placement of process equipment in containment areas. In addition, the evaluation should assess the adequacy of the containment wall and drainage system designs, accounting for the impact of firefighting activities, including the application of firewater and foam on these systems. Develop and implement recommendations based on findings from the evaluation.

6.2.2 American Petroleum Institute (API)

2019-01-I-TX-R6

Update API STD 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities,* or other appropriate products to include flammable gas detection systems within the leak detection section or where appropriate. The discussion of flammable gas and/or leak detection should address both engineering and administrative controls, including actions associated with responding to a catastrophic or emergency leak.

6.2.3 Occupational Safety and Health Administration (OSHA)

2019-01-I-TX-R7

Eliminate the atmospheric storage tank exemption from the PSM standard.

6.2.4 Environmental Protection Agency (EPA)

2019-01-I-TX-R8

Modify 40 C.F.R. § 68.115(b)(2)(i) to expand coverage of the RMP rule to include all flammable liquids, including mixtures, with a flammability rating of NFPA-3 or higher.

7 Key Lessons for the Industry

To prevent future chemical incidents, and in the interest of driving chemical safety excellence to protect communities, workers, and the environment, the CSB urges companies to review these key lessons:

1. While most hazard and risk assessments consider the risk of single failures at a time, it is important for companies to realize that major incidents happen when multiple failures occur. To prevent these catastrophic events from occurring, companies should ensure the appropriate number of layers of protection are in place to mitigate the likelihood and reduce the severity of events when they do occur. Therefore, when determining when, how, or whether to complete the recommendations from hazard assessments, companies should ensure the appropriate number of preventative and mitigative safeguards are in place such that a single failure of a preventative or mitigative safeguard will not result in a catastrophic event. Leadership should ensure adequate safeguards are in place, as soon as practicable, for hazards identified by the team, especially when engineering controls are recommended and not yet installed.

2. Terminals and storage tank facilities that handle large volumes of flammable or highly hazardous substances should implement flammable gas detection systems to protect personnel, property, and neighboring communities from the potential consequences of an accidental release. These types of systems should be installed in areas around pumps, seals, flanges, and other common leak locations. These systems should be adequately designed, maintained, inspected, and tested to ensure reliability. Inspection and testing frequencies must be established to ensure the system provides adequate warning of the presence of flammable substances.

3. Companies that handle large volumes of flammable or highly hazardous substances should assess their capability to remotely isolate these substances in the event of a loss of containment. Aboveground atmospheric storage tanks that contain large volumes of these substances should be equipped with

remotely operated emergency isolative valves (ROEIVs) so that releases can be mitigated quickly and remotely from a safe location. The ROEIVs should be equipped with fusible links or configured to automatically close in the event of a power outage or other event ("Fail-Closed").

4. NFPA 30 provides safeguards to reduce the hazards associated with the storage, handling, and use of flammable and combustible liquids, including tank farm design and spacing requirements. While NFPA 30 defines minimum requirements for tank farm design and spacing, other voluntary industry guidance documents including FM Global Loss Prevention Data Sheet (FM LPDS) 7-88, *Outdoor Ignitable Liquid Storage Tanks*; and API RP 2021, *Management of Atmospheric Tank Fires*; and API STD 2610, *Design, Construction, Operation, Maintenance and Inspection of Terminals and Tank Facilities* provide more robust tank farm design criteria.

5. Companies have a duty of care to ensure safety at facilities that handle flammable or highly hazardous substances and protect surrounding communities and the environment regardless of whether the hazardous substance(s) onsite fall under OSHA's PSM standard or EPA's RMP rule. To prevent catastrophic incidents, a company should apply a comprehensive process safety management system such as CCPS's *Guidelines for Risk Based Process Safety* or CCPS' *Guidelines for Implementing Process Safety Management Systems*.

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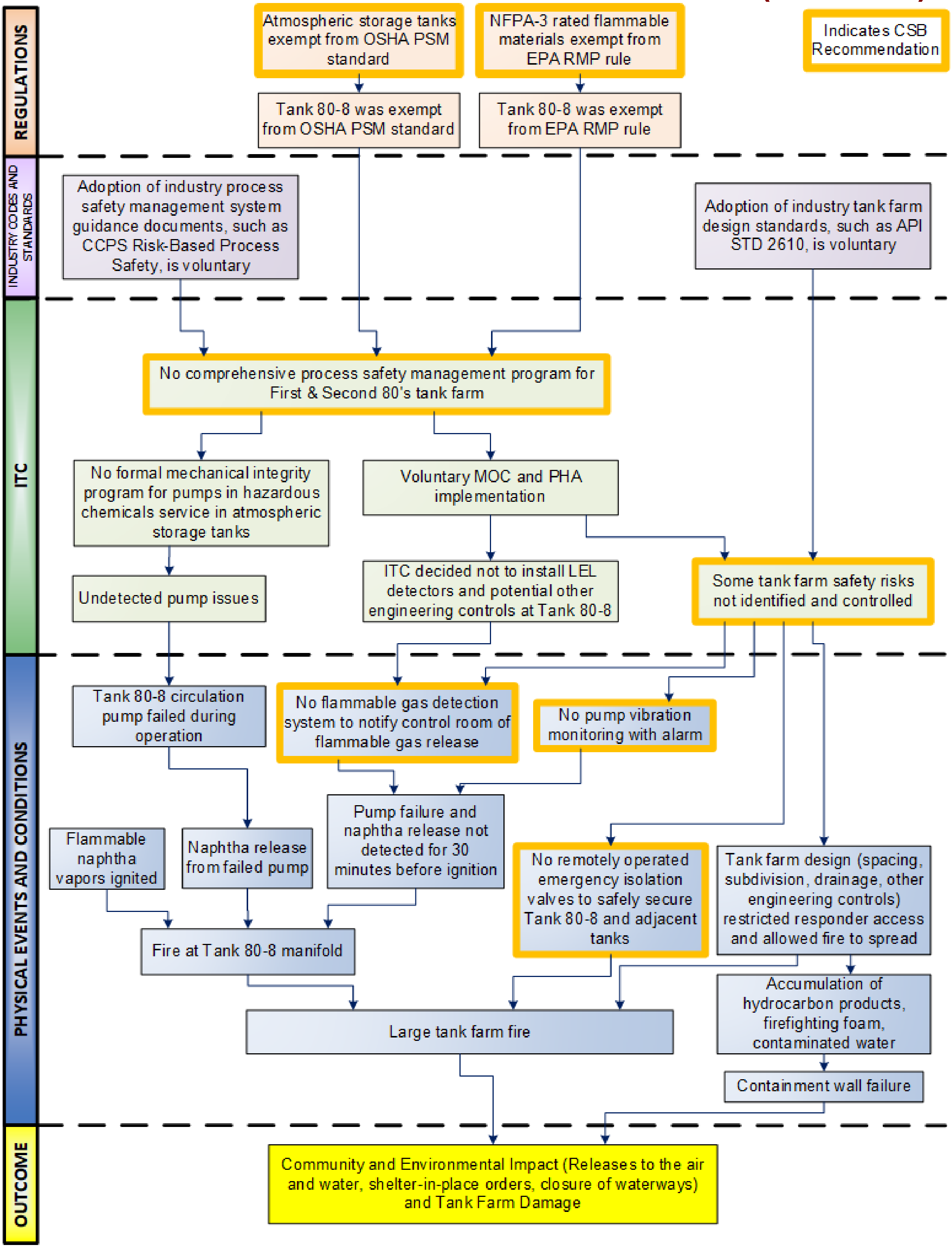
APPENDIX A—SIMPLIFIED CAUSAL ANALYSIS (ACCIMAP)



Appendix B—Description of Surrounding Area

The demographic information of the population residing within roughly a three- mile of the ITC Deer Park terminal is contained below in **Figure 32** and **Figure 33**.

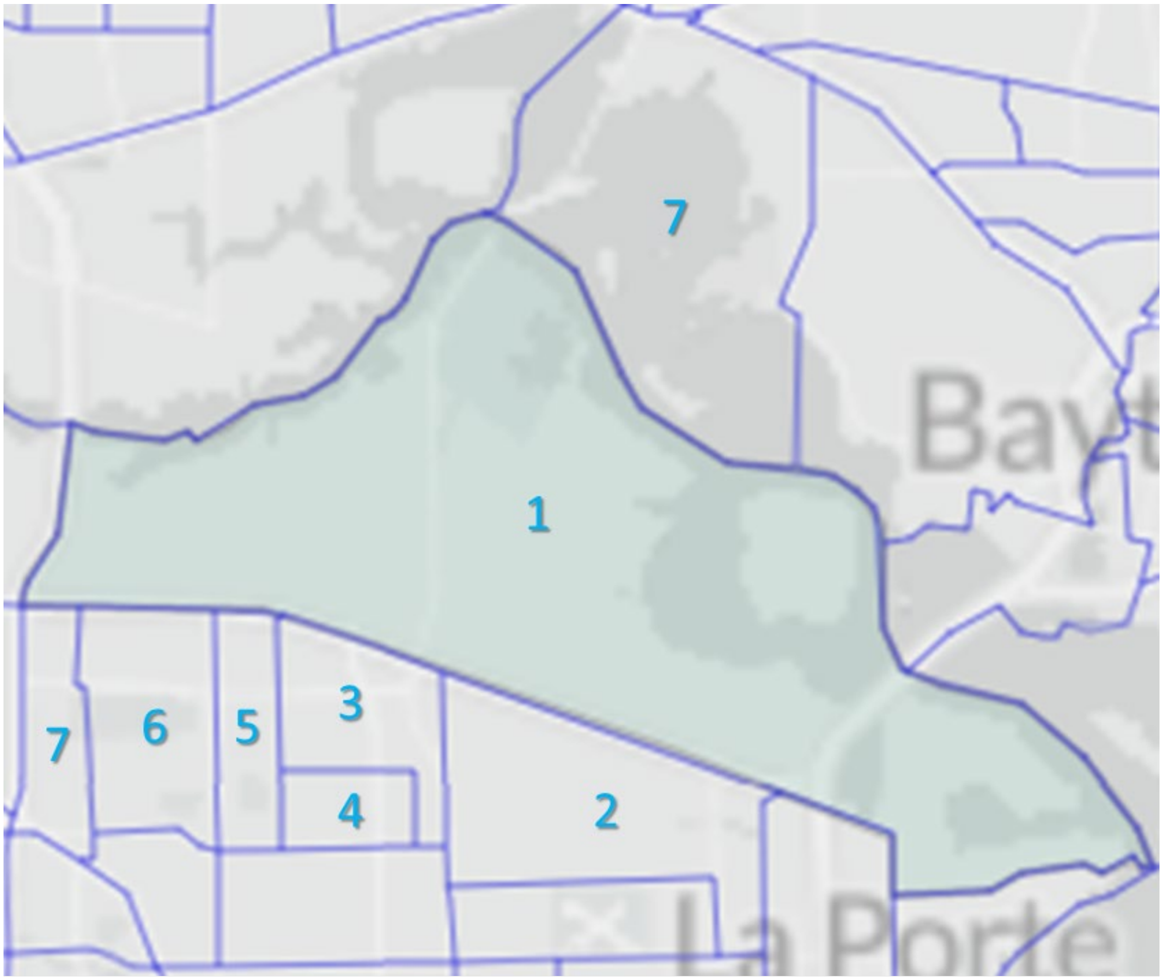


Figure 32. Census tracts contained in roughly three-mile radius of the ITC Deer Park terminal. (Credit: Census Reporter, annotations by CSB)

Tract Number	Population	Median Age	Race and Ethnicity		Per Capita Income	% Poverty	Number of Housing Units	Types of Structures	
1	0	0	0%	White	$ -	0.0%	0	0%	Single Unit
			0%	Black				0%	Multi-Unit
			0%	Native				0%	Mobile Home
			0%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			0%	Two+					
			0%	Hispanic					
2	5,189	36	57%	White	$ 81,586	14.6%	1,578	86%	Single Unit
			1%	Black				0%	Multi-Unit
			0%	Native				13%	Mobile Home
			0%	Asian				2%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			0%	Two+					
			41%	Hispanic					
3	3,052	37.2	86%	White	$ 44,158	2.6%	1,020	94%	Single Unit
			0%	Black				0%	Multi-Unit
			0%	Native				6%	Mobile Home
			0%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			2%	Two+					
			12%	Hispanic					
4	5,181	36.2	58%	White	$ 43,137	4.5%	1,911	100%	Single Unit
			3%	Black				0%	Multi-Unit
			0%	Native				0%	Mobile Home
			4%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			6%	Two+					
			28%	Hispanic					
5	5,007	33.2	60%	White	$ 31,112	11.4%	1,774	83%	Single Unit
			1%	Black				15%	Multi-Unit
			0%	Native				1%	Mobile Home
			2%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			35%	Hispanic					
6	5,889	42.1	54%	White	$ 33,520	5.4%	2,296	78%	Single Unit
			0%	Black				22%	Multi-Unit
			0%	Native				0%	Mobile Home
			0%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			45%	Hispanic					
7	3,616	42.3	47%	White	$ 38,386	5.1%	1,342	95%	Single Unit
			1%	Black				0%	Multi-Unit
			0%	Native				4%	Mobile Home
			1%	Asian				1%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			50%	Hispanic					

Figure 33. Tabulation of demographic data for the populations within the census tracts shown in **Figure 32**. (Credit: CSB)

APPENDIX C—INCIDENT TIMELINE

Date	Time *(approximate)*	Event
3/16/2019	6:54 p.m.	Tank 80-8 circulation pump started
	7:23 – 8:15 p.m.	First butane delivery completed
	9:30 – 10:29 p.m.	Second butane delivery completed
3/17/2019	7:25 – 8:45 a.m.	DCS data indicates pump discharge pressure increase
	9:30 – 10:00 a.m.	DCS data indicates tank level, pump discharge pressure decreases
	10:00 a.m.	Security camera captures footage of fire in tank farm
	10:01 a.m.	DCS communication lost for Tank 80-8 circulation pump
	10:03 a.m.	Security officer sounded fire alarm, ERT response begins
	10:05 a.m.	Announcement over all-call system
	10:10 a.m.	E-notify message sent over computer system
	12:09 p.m.	Power loss in tank farm; all DCS communication lost
	Before 1:00 p.m.	City of Deer Park issued a precautionary shelter-in-place order
	3:00 p.m.	Tank 80-5, containing xylene, ignited
3/18/2019	1:30 a.m.	Fire continues; eight storage tanks on fire
	Before 5:30 a.m.	Additional toluene tank (80-13) caught on fire but extinguished
	3:00 p.m.	Six tanks involved in fire
	4:00 p.m.	Reduction in water pressure due to malfunction of two third-party fireboard pumps and an increased demand of water supply Tanks 80-9 and 80-12 re-ignite, total of eight tanks on fire
	5:00 p.m.	ITC contacts US Fire Pump for assistance
	10:00 p.m.	Full water pressure restored
3/19/2019	12:13 a.m.[a]	ITC and US Fire Pump signed agreement; US Fire Pump mobilized from Louisiana
	After 2:30 a.m.	Second temporary reduction in water pressure Two additional tanks (80-14 and 80-15) caught fire Tanks 80-9 and 80-12 collapsed, their fires extinguished
	6:48 a.m.	US Fire Pump arrived on-scene with additional resources
	1:00 p.m.	US Fire Pump resources actively engaged alongside local responders
	After 1:00 p.m.	Tanks 80-4 and 80-7 caught fire
	3:45 p.m.	Tanks 80-11, 80-14, 80-15 extinguished Seven tanks still on fire (80-2, 80-3, 80-4, 80-5, 80-6, 80-7, 80-8)
	9:45 p.m.	Four tanks on fire (80-2, 80-3, 80-5, 80-6)
3/20/2019	3:00 a.m.	Fires extinguished
	5:20 p.m.	Tank 80-5 flare-up; responders were able to contain quickly

[a] US Fire Pump headquarters is located in Holden, Louisiana.

3/21/2019	Between 4:02 and 8:23 a.m.	Elevated levels of benzene detected in the northern portion of Deer Park; City of Deer Park issued a precautionary shelter-in-place order
	Morning	ITC began moving product out of the compromised tanks
	11:40 a.m.	Shelter-in-place order lifted
3/22/2019	12:15 p.m.	Secondary containment wall partially collapsed; ITC recommended shelter-in-place
	3:40 p.m.	Tanks 80-2, 80-3, 80-5 re-ignited; extinguished in roughly one hour
3/23/2019	4:00 a.m.	Containment wall secured
		Recovery of released hydrocarbon and petrochemical products, foam, and water from the tank farm and the adjacent drainage ditch began
		Spill containment and clean-up operations to remove the released products from Tucker Bayou and the Houston Ship Channel began
4/1/2019		ITC issued public statement indicating that the tank farm was stable; Nine tanks secured (removed remaining product)
5/20/2019[a]		Clean-up operations of all shoreline segments (except Tucker Bayou) complete
6/19/2019		Incident transitioned from emergency phase to long-term remediation phase
7/29/2019		Deconstruction and cleaning of all 15 tanks complete

[a] On June 19, 2019, Unified Command partners agreed that Tucker Bayou would be transitioned and addressed under a long-term remediation phase and not part of the emergency response phase.

Appendix D—Fire Protection Evaluation Report

Appendix E—Atlas Engineering Report

Access both appendices from the CSB website:

https://www.csb.gov/intercontinental-terminal-company-itc-tank-fire

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