CSB
U.S. Chemical Safety and
Hazard Investigation Board

Fatal Propylene Release and Explosion at Watson Grinding

Houston, Texas | *Incident Date: January 24, 2020* | **No. 2020-03-I-TX**

Investigation Report

Published: June 29, 2023

Safety Issues:

- **Process Safety Management**
- **Emergency Preparedness**

U.S. Chemical Safety and Hazard Investigation Board

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The January 24, 2020, explosion at Watson Grinding fatally injured three people:

Gerardo Castorena, Frank Flores, and Gilberto Mendoza Cruz.

Contents

Abbreviations

ACC	American Chemistry Council
ANSI	American National Standards Institute
ARPM	Association for Rubber Products Manufacturers
CCPS	Center for Chemical Process Safety
CGA	Compressed Gas Association
CSB	U.S. Chemical Safety and Hazard Investigation Board
EPA	U.S. Environmental Protection Agency
HFD	Houston Fire Department
HMRT	Hazardous Materials Response Team
HVOF	High Velocity Oxygen Fuel
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PLC	Programmable Logic Controller
PSM	Process Safety Management
RIA	Robotic Industries Association
RMP	Risk Management Program

Executive Summary

Shortly before 4:30 a.m. on January 24, 2020, an accidental release of propylene accumulated and exploded inside a building at the Watson Grinding and Manufacturing Co. (Watson Grinding) facility in Houston, Texas. The explosion fatally injured two employees and injured two additional employees. A nearby resident was also fatally injured. The explosion damaged hundreds of nearby structures, including homes and several businesses. On February 6, 2020, Watson Grinding filed for bankruptcy, and the company is no longer in business.

The U.S. Chemical Safety and Hazard Investigation Board (CSB) investigated the incident and found that prior to the incident, a hose disconnected from its fitting inside a coating booth (known as Booth 4) and released propylene, a flammable hydrocarbon vapor, which accumulated inside the coating building at Watson Grinding. When Watson Grinding employees arrived at the facility the following morning, an explosive concentration of propylene had formed inside the building. When one of the employees entered the building and turned on the lights, the flammable propylene vapor ignited, resulting in an explosion.

Cause

The CSB determined the cause of the accidental release of propylene was a degraded and poorly crimped rubber welding hose that disconnected from its fitting inside a coating booth, combined with two other circumstances (1) not closing the manual shutoff valve at the propylene storage tank at the conclusion of production operations the previous workday; and (2) the inoperative automated gas detection alarm, exhaust fan startup, and gas shutoff system. The CSB concluded that the propylene vapor likely ignited when an employee entered the coating building and turned on the lights.

Contributing to the cause of the incident was the lack of a comprehensive process safety management program, including the absence of critical process safety information, a hazard assessment of the propylene process, a mechanical integrity program, a management of change review, and written operating procedures. Contributing to the severity of the incident was the lack of an effective emergency response plan that should have instructed workers to evacuate from the area, prevented others from entering the area, and notified emergency responders when the flammable propylene gas leak was suspected or detected.

Safety Issues

The CSB's investigation identified the safety issues below.

1. **Process Safety Management.** Had Watson Grinding developed and implemented an effective process safety management program to identify and control hazards, the incident could have been prevented.[a] Several elements of a process safety management program, if implemented, could have helped prevent this incident, including process safety information, process hazard analysis, management of change, mechanical integrity, and operating procedures. (Section 4.1)

2. **Emergency Preparedness.** Watson Grinding's emergency response plan did not address responding to a propylene gas leak. Watson Grinding also did not train its employees to recognize or respond to a propylene gas release. As a result, on the day of the incident, employees did not evacuate from the area after suspecting a propylene leak, did not prevent others from entering the area, and did not contact emergency responders for help. (Section 4.2)

Recommendations

To Compressed Gas Association (CGA)

2020-03-I-TX-R1

Urge member companies that handle hazardous chemicals to share information with their customers about (1) the safety issues described in this report and (2) why their customers should develop and implement effective process safety management systems as part of their own internal safety programs, including informing member companies' customers about CGA P-86, *Guideline for Process Safety Management*, the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*, or an equivalent approach.

To Matheson Tri-Gas Inc.

2020-03-I-TX-R2

Provide your customers with information about (1) the safety issues described in this report and (2) why your customers should develop and implement effective process safety management systems as part of their own internal safety programs, including informing customers about CGA P-86, *Guideline for Process Safety Management*, the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*, or an equivalent approach.

[a] Watson Grinding's propylene process described in this investigation was not covered by the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) standard, or the U.S. Environmental Protection Agency's (EPA) Risk Management Program (RMP) rule. The OSHA PSM standard did not apply because the amount of propylene stored at the Watson Grinding facility was below the threshold quantity of 10,000 pounds. Although propylene is listed as a regulated substance under EPA's RMP rule, the RMP rule did not apply because the amount of propylene that Watson Grinding stored on-site did not meet the threshold quantity of 10,000 pounds. In addition, neither the OSHA PSM standard nor the EPA RMP rule covers hazardous substances, such as propylene, when the material is used as a fuel.

1 Background

1.1 Watson Grinding

James Watson founded Watson Grinding and Manufacturing Company (Watson Grinding) in 1960 as a small specialty grinding shop in Houston, Texas.[a] Over the next few decades, the company expanded to include a full-scale machine shop and specialty thermal spray coatings, particularly High Velocity Oxygen Fuel (HVOF) coating[b] [1, 2].

Watson Grinding later added a robotic thermal spray facility and an on-site metallurgical laboratory to apply thermal spray coatings that extend the service life of metal parts used in highly corrosive environments [1]. The company serviced parts for a variety of industries, including chemical, mining, offshore oil production, hydraulic fracturing, oil refining, power generation, pulp and paper, and aerospace [3].

Figure 1 identifies the property boundary (yellow dashed line) and shows the pre-incident condition of the Watson Grinding facilities, including the coating building, where the coating activities took place. In 2014, Watson Grinding built a 19,000-square-foot valve repair and manufacturing facility, established as Watson Valve Services, Inc. The valve facility included a fitness facility (Watson Gym) on the second floor, which was made available to Watson employees. **Figure 2** shows a photo of the Watson Gym, taken before the incident.

At the time of the incident, Watson Grinding had approximately 130 employees.

[a] The Watson Grinding facility was bounded, on its east and west sides, primarily by Gessner Road and Steffani Lane, respectively. An additional facility, the Watson Grinding Metallurgical Laboratory (the Watson Lab) was located across Steffani Lane from the coating building and backed up to Brickhouse Gully. Brickhouse Gully is a concrete-lined channel and part of the Harris County Flood Control District [28].

[b] HVOF coating is a thermal spray process in which a fuel and oxygen are mixed, fed into a combustion chamber, and ignited. The gas produced in the combustion chamber has an extremely high temperature and pressure and is ejected through a nozzle at high speeds [40]. HVOF spray coating applies carbides and metal or alloy coatings to provide corrosion protection and wear resistance in specific applications.

Figure 1. Watson Grinding. (Source: Watson Grinding, annotations by CSB)

Figure 2. Watson Gym. (Source: Watson Grinding)

1.2 Watson Grinding HVOF Coating Operations

On October 31, 2008, Watson Grinding experienced a propylene gas leak in one of its coating booths, which resulted in a fire and explosion that injured two workers and significantly damaged its existing coating building. As a result, Watson Grinding constructed a new coating building in 2009. The new coating building had eight coating booths; six of these booths used HVOF spray coating [2]. The other two booths used another type of spray coating called plasma coating.[a]

In Watson Grinding's HVOF coating process, propylene and oxygen gases were fed into a combustion chamber, which exited into the spray gun through a nozzle. The HVOF spray guns had a combustion chamber that combusted the propylene and oxygen mixture under pressure and accelerated the resulting high-velocity flame through a water-cooled nozzle. Pure metals, ceramics, metallic alloys, or composites in powder form were fed into the nozzle by mixing with nitrogen, where particles became entrained in the flame, and were deposited on the surface of the item being coated. The coating material is applied in successive layers until it reaches the desired thickness.

Watson Grinding conducted thermal spray coating operations in separate coating booths, each staffed with a coating booth operator who reported to the Coating Department Supervisor. Watson Grinding coating booth operators performed the HVOF coating both manually and by using industrial robotic arms. **Figure 3**, a photo taken before the incident, shows the interior of an HVOF coating booth (Booth 8) during the spray coating of a ball valve component. The spray gun was attached to the robotic arm. Six of the booths (including Booth 4) were equipped with a gas detector, similar to what is shown on the right side of the figure. The purpose of the gas detection system was to continually monitor the propylene and oxygen concentration inside the coating booths and, in instances of dangerous concentrations, provide local alarms when the prescribed parameters were exceeded, start up the booth's exhaust fan (if not already operating), and stop the flow of these gases (both locally in the booth and remotely at the propylene and oxygen storage tanks located north of the coating building).

[a] Plasma spray coating, like HVOF spray coating, is a thermal spraying process. In a plasma spraying process, an inert gas (rather than fuel), typically argon or an argon-hydrogen or argon-helium mixture, is superheated and ionized by an electrical arc, generating a gas plasma. At Watson Grinding, plasma coating used helium and argon, whereas HVOF coating used propylene.

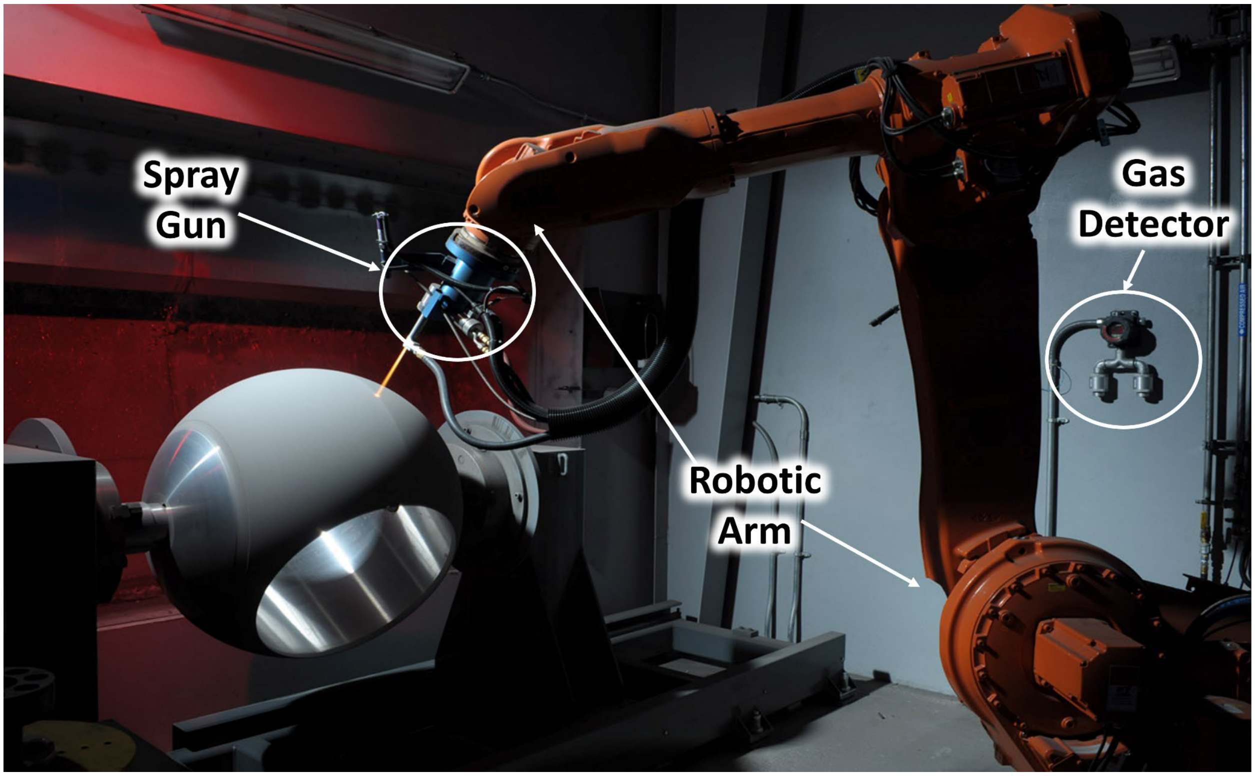

Figure 3. HVOF Booth. (Source: Watson Grinding, annotations by CSB)

Eight of Watson Grinding's ten coating booths (Booths 1 through 8) were located inside the coating building, as shown in **Figure 4**. Booths 1 and 2 were not equipped for HVOF spray coating; instead, these booths contained equipment for plasma spray coating. The other six coating booths in the coating building (Booths 3 through 8) were equipped for HVOF spray coating. **Figure 5** shows a photo of the interior of the coating building, taken soon after construction was completed (circa 2010). In addition to the eight coating booths, the large open space of the coating building, referred to as the common area, was used to conduct other metal shop work activities.

In addition to the eight booths in the coating building, Watson Grinding had two HVOF spray booths (Booths 9 and 10) located separately in other buildings. Booths 9 and 10 could coat metal parts using both plasma spray and HVOF spray. Therefore, these two booths were supplied with helium, argon, propylene, oxygen, nitrogen, and cooling water. The locations of these two booths are shown in **Figure 8**.

All eight coating booths inside the coating building were equipped with blue double access doors located at the front of the booth. These booths had concrete walls that were four to six inches thick.[a]

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[a] Each booth had a rear concrete wall that included a ventilation exhaust system consisting of a large exhaust fan, and either a water wash filter (Booths 1 through 7) or a dry exhaust filtration system (Booth 8). The booths' exhaust was designed to recover high-value metallic coating powder that did not adhere to the item being coated (often referred to as overspray) and to vent to the outside atmosphere, through the exhaust stack, each booth's non-combusted process gases (propylene, oxygen, and nitrogen) and products of combustion.

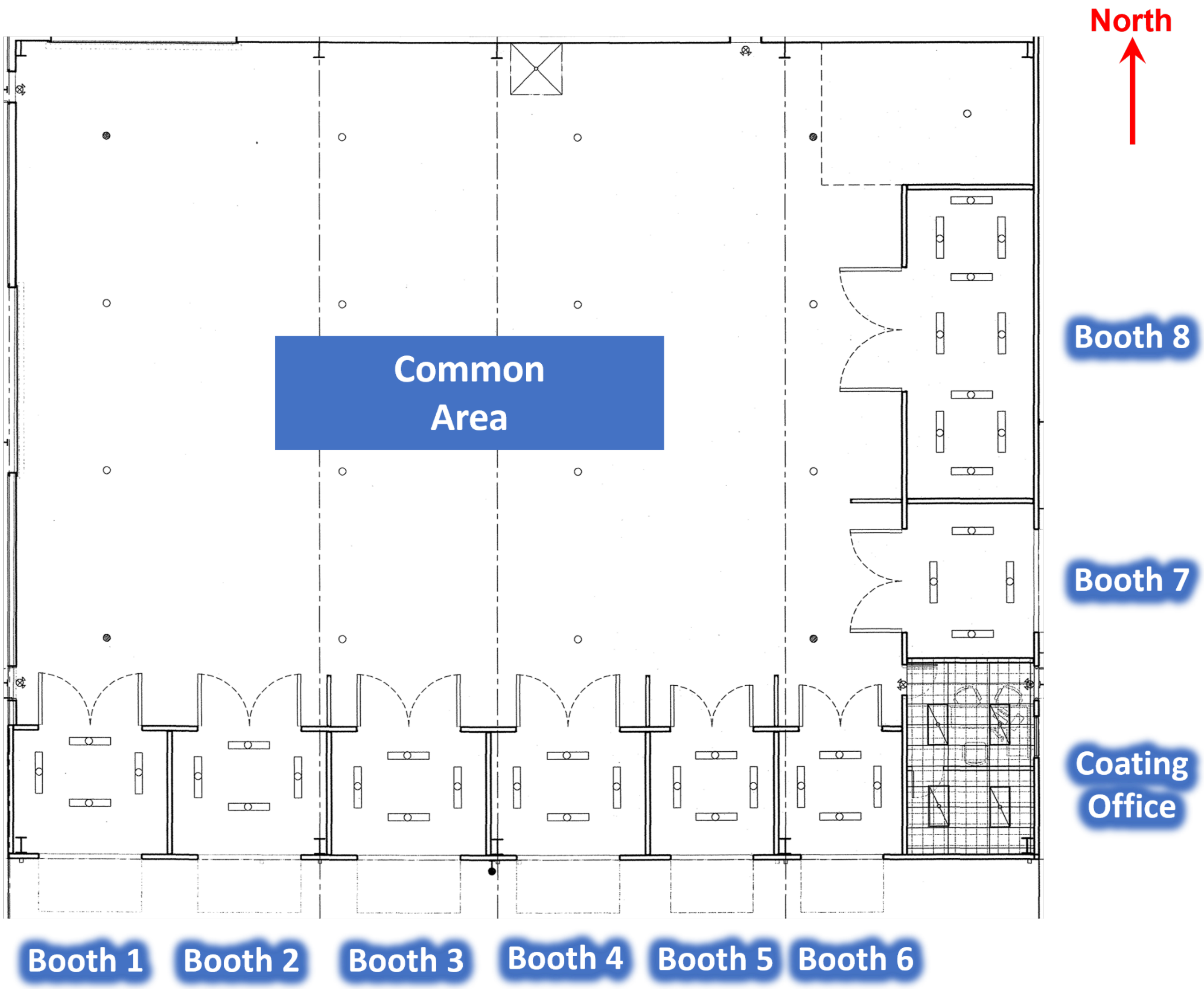

Figure 4. Coating Building Diagram. (Source: Watson Grinding; annotations by CSB)

Figure 5. Inside the Coating Building. (Source: Watson Grinding, annotations by CSB)

1.3 Watson Grinding Propylene System

1.3.1 Propylene Properties and Safety Information

Propylene (C_3H_6) is an extremely flammable[a] and colorless gas, with a petroleum odor [4, 5, 6]. Under certain temperature and pressure conditions, propylene can be a liquid. Propylene vapor is heavier than air and tends to accumulate near the floor of rooms or buildings [2, 6].[b, c]

Propylene is typically transported and stored in its liquefied form. Watson Grinding received propylene shipments as a liquid and stored the liquid propylene on-site in a 2,000-gallon bulk tank (the propylene storage tank). Watson Grinding directed propylene vapor from this storage tank to each of the HVOF coating booths. The propylene used at Watson Grinding was not odorized.[d]

Per the requirements of the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 C.F.R. § 1910.1200 (g)(7)(i), Watson Grinding was supplied with propylene Safety Data Sheets, one of which stated:

- Accidental releases pose a serious fire or explosion hazard;

[a] Propylene's lower explosive/flammable limit in the air is 2 percent and its upper explosive/flammable limit is 11.1 percent [6].

[b] In some parts of Texas, including Harris County, propylene is listed as a Highly Reactive Volatile Organic Compound [31].

[c] Propylene is a gas at atmospheric pressure and typical outdoor air temperatures. Liquefying propylene takes increased pressure, cooling, or a combination of both. At atmospheric pressure, propylene will be a liquid if it is colder than its boiling range/point of -54 degrees Fahrenheit. Liquefying propylene at 70 degrees Fahrenheit requires pressures greater than 133 pounds per square inch gauge. Liquefying propylene requires more pressure at warmer temperatures and less pressure at cooler temperatures. Propylene vapor has a specific gravity of 1.45 at 70 degrees Fahrenheit and atmospheric pressure (air = 1), making it heavier than air [6].

[d] Odorants such as ethyl mercaptan are sometimes added to gases to help detect a gas leak. Such odorants are more commonly added to natural gas and propane because the fuel gases are odorless [42]

- No action shall be taken involving any personal risk or without suitable training;
- Evacuate surrounding areas;
- Keep unnecessary and unprotected personnel from entering; and
- Close valve after each use.

1.3.2 Propylene Supply

Watson Grinding's propylene supplier was Western International Gas and Cylinders, Inc., a subsidiary of Matheson Tri-Gas Inc. (Matheson) [7]. Matheson is an industrial gas and equipment company with over 4,500 employees at over 300 locations in the United States [8]. Matheson owned the propylene storage tank at Watson Grinding, which could hold up to approximately 8,600 pounds of liquid propylene. Matheson is a member of the Compressed Gas Association (CGA), an industry association that publishes a number of safety standards for its more than 130 member companies worldwide [9, 10]. As discussed in Section 4.1.2, neither OSHA's Process Safety Management (PSM) standard nor the U.S. Environmental Protection Agency's (EPA) Risk Management Program (RMP) rule was applicable to Watson Grinding's propylene operations.

1.3.3 Propylene Storage, Equipment, and Piping

A simplified flow diagram showing the main equipment from the propylene storage tank to the exemplar Booth 6 is shown in **Figure 6**.[a]

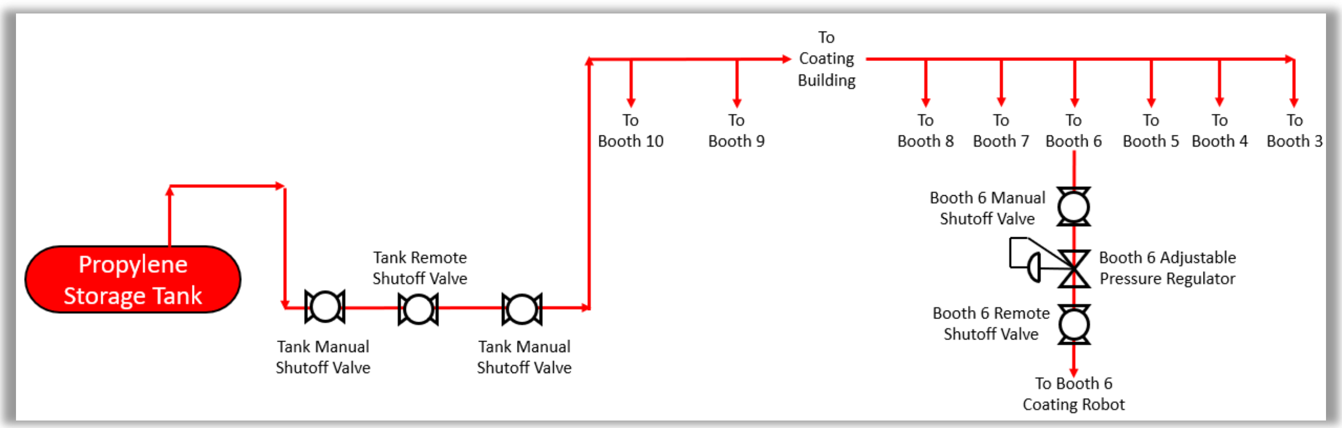

Figure 6. Simplified Propylene Flow Diagram. (Credit: CSB)

In Watson Grinding's coating operations, propylene vapor exited from the top of the propylene storage tank and continued through piping to three shutoff valves (quarter-turn ball valves): two manually operated valves, and one remote shutoff valve (**Figure 7**). These shutoff devices could isolate the propylene storage tank from the

[a] The destructive nature of the explosion resulted in significant damage to the coating booths. However, Booth 6 piping was observed to be primarily intact and is being used as the exemplar for this report.

propylene supply piping to the coating booths (Booths 3 through 10). When these valves in **Figure 6** are open, the propylene vapor flows through the piping to supply propylene fuel to the coating booths.

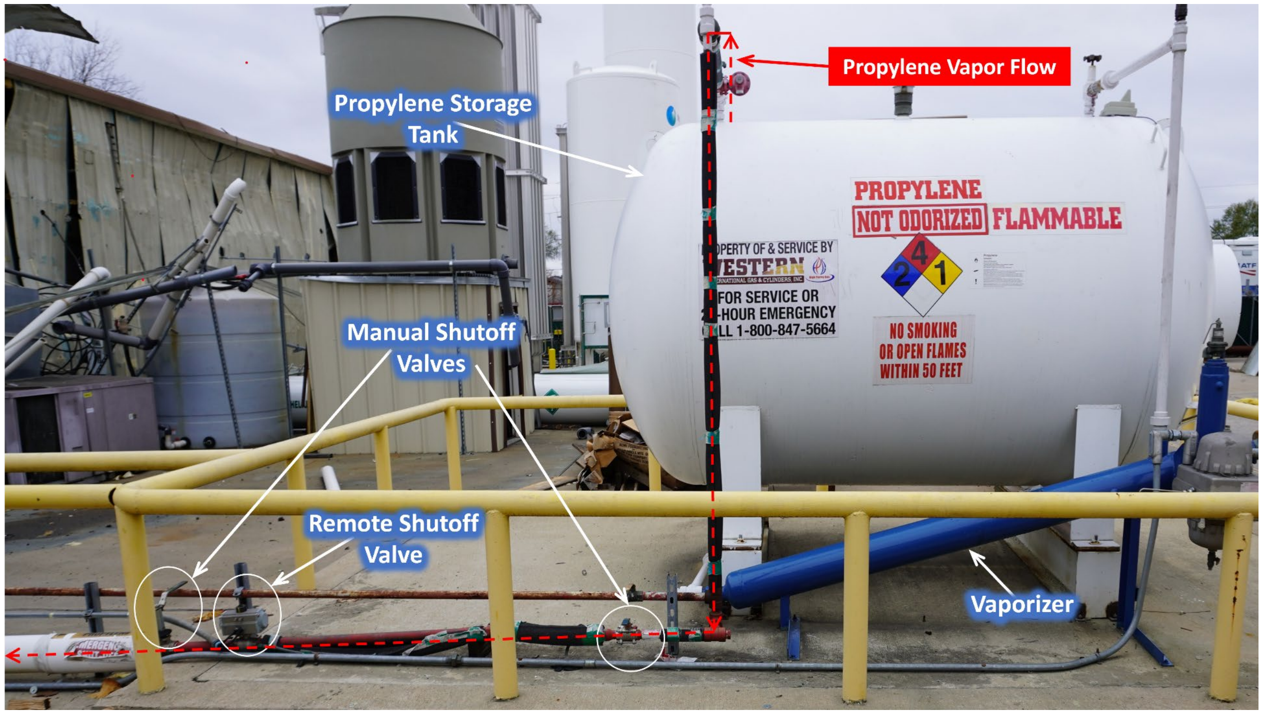

Figure 7. Post-Incident Photo of Propylene Storage Tank. (Source: CSB)

After the second manual shutoff valve, propylene vapor was routed through the propylene supply piping (see the red dashed line in **Figure 8**, which was mounted along the buildings' exterior, where it ran to the eight propylene-fueled HVOF coating booths (Booths 3 through 10). The propylene supply piping was located approximately 15 feet above the ground. At each coating booth, the propylene supply piping branched off and entered near the top of each coating booth. The piping was then routed down towards ground level, through pressure and controlling equipment, and connected to the robotic arm. Each robotic arm was equipped with a spray gun to apply the HVOF spray coating (as shown in **Figure 3**).

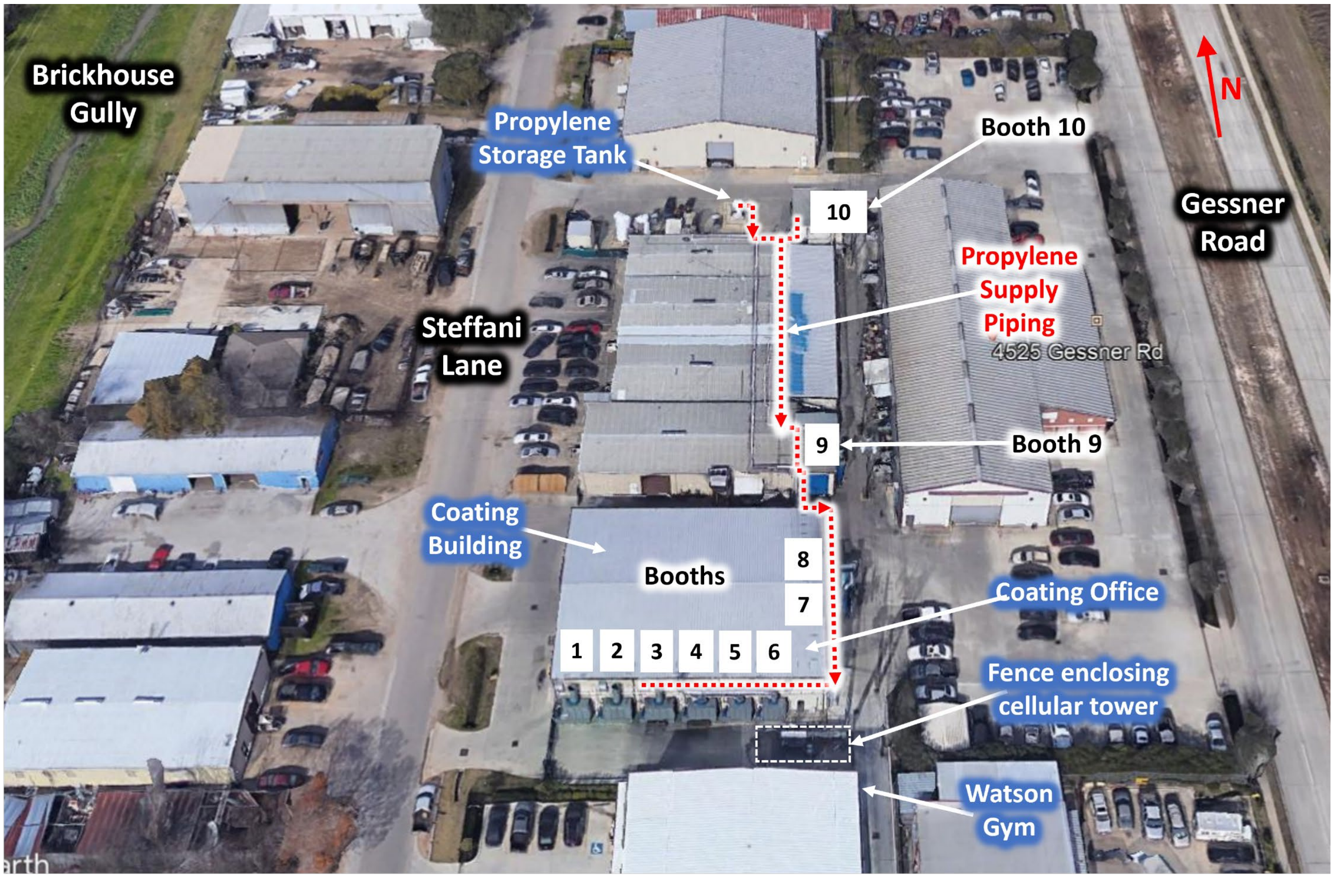

Figure 8. Propylene Supply Piping. (Source: Photo Google Earth Pro, annotations by CSB)

Located next to the propylene storage tank was a blue heater (the vaporizer) that vaporized the liquid propylene. The propylene was piped as a liquid from the bottom of the propylene storage tank, heated in the vaporizer, and returned to the top of the propylene storage tank in the vapor state. The purpose of the vaporizer was two-fold: (1) to vaporize the propylene because the spray guns were designed to burn vaporized propylene; and (2) to maintain a sufficient propylene pressure to operate each spray gun.

Figure 9, a photo of Booth 6 taken after the incident, shows the propylene piping (see red dashed line) after it entered the inside of each HVOF coating booth (Booths 3 through 10). The propylene pressure was controlled inside each booth by a pressure regulator. **Figure 10** shows the Booth 6 gas equipment. The propylene flowed from the pressure regulator and other equipment to the robotic arm (which directed the coating spray gun) and into the spray gun, where it fueled the HVOF spray coating. The propylene equipment in the six HVOF coating booths (Booths 3 through 8) in the coating building was observed to be similarly arranged but was not equipped identical to one another.

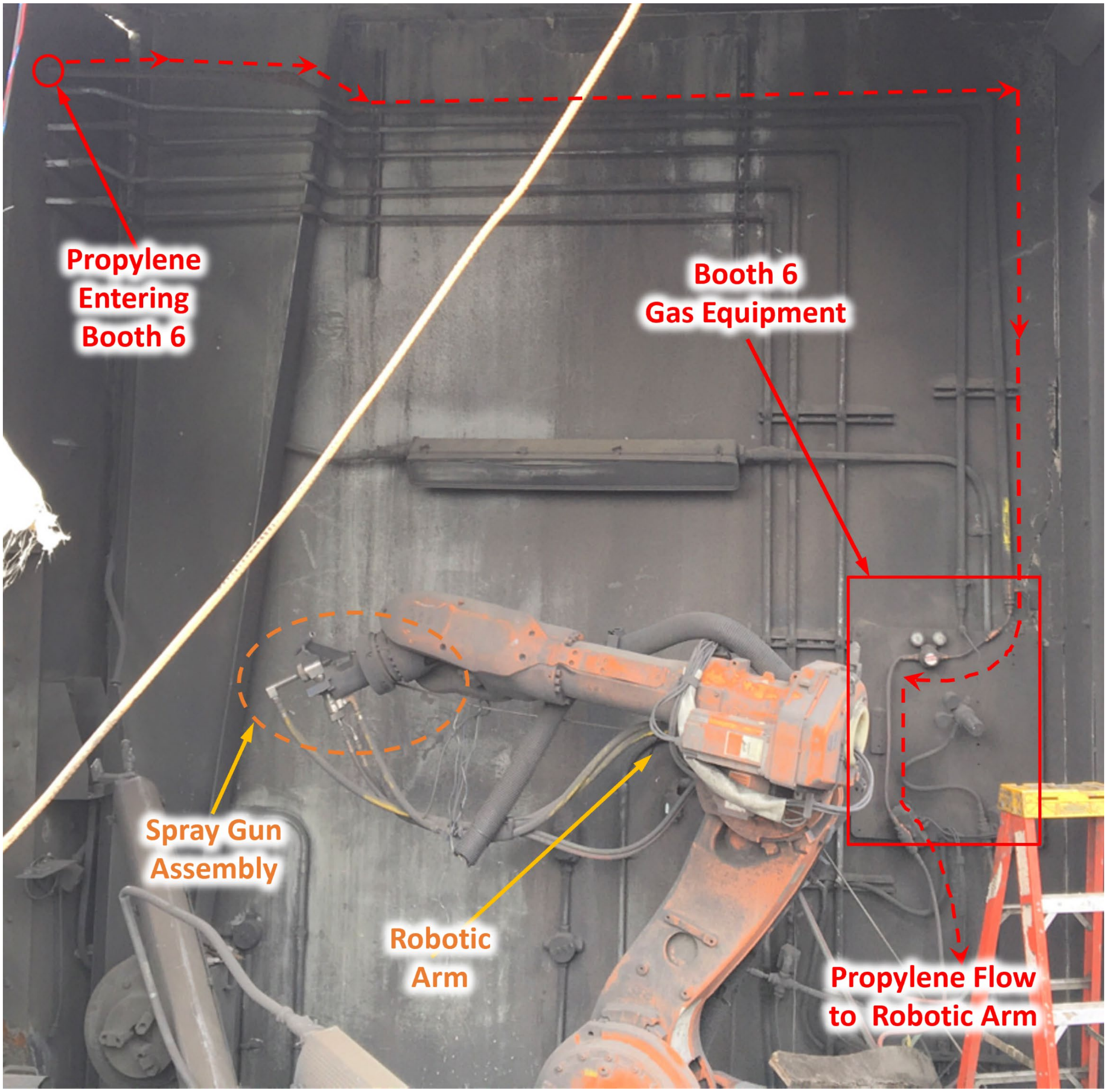

Figure 9. Interior of Coating Booth 6. (Source: Watson Grinding, annotations by CSB)

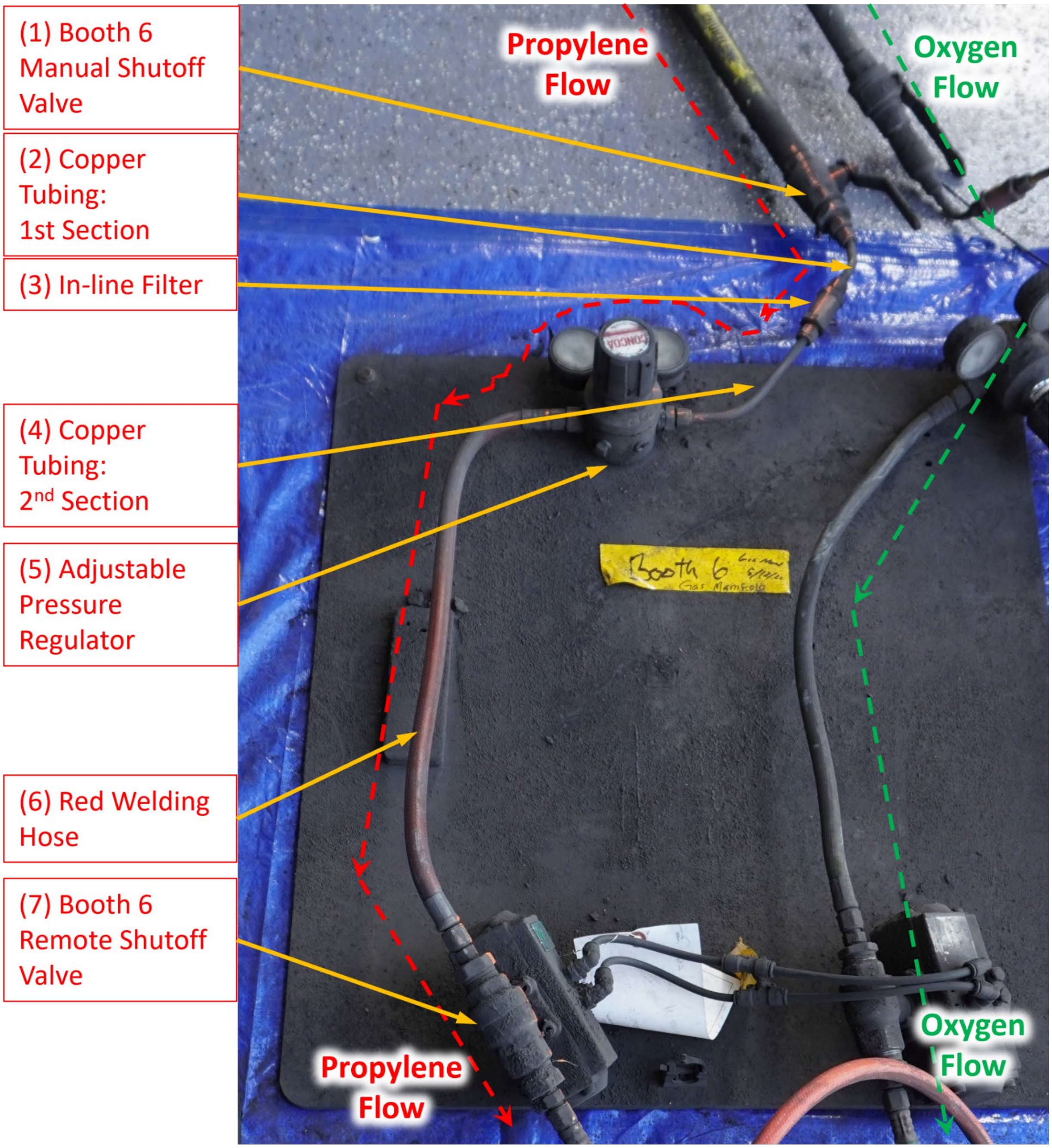

Figure 10. Booth 6 Gas Equipment. (Source: CSB)

Booth 4, the likely location of the propylene leak, differed from Booth 6 in that rather than using the rigid copper tubing located at numbers (2), (3), and (4), as shown in **Figure 10**, these items were substituted with a single section of Grade R flexible red rubber welding hose. This change is further discussed in Sections 3 and 4.1.5. When shutting down at the end of the workday, each booth’s remote shutoff valve would automatically close to isolate each booth's robot and spray gun.

In addition to controlling propylene pressure and flow, Watson Grinding also controlled the oxygen pressure and flow using a similar control system. While propylene hoses were red, oxygen hoses were green.

1.3.4 Propylene Safety Practices

Watson Grinding used different approaches to detect propylene releases and mitigate their effects.

These included:

1. **Daily Leak Checks**

   Daily checks were conducted manually by operators in their assigned booths at the beginning of each workday to ensure there were no propylene leaks. The methods included a visual inspection and spraying soapy water solution on the fittings.

2. **Detection through Sense of Smell**

   Watson Grinding relied on the ability of employees to smell propylene in the atmosphere. While the propylene used by Watson Grinding was not odorized, it had a naturally occurring distinct odor. While each worker's olfactory ability to "smell propylene" varied, several prior "minor" propylene piping leaks were found using this approach. At times, this method resulted in false positives.

3. **End-of-Day Shutoff**

   Following the 2010 rebuild of the coating building, Watson Grinding's practice was to isolate the propylene storage tank at the end of each workday. Over time, however, Watson Grinding developed inconsistent practices concerning isolating the propylene storage tank at the end of the workday. The Coating Supervisor, who was normally responsible for shutting down the facility at the end of each workday, would sometimes close at least one of the two propylene manual shutoff valves at the storage tank at the end of the workday. He would typically do so, however, only on days when the workers did not plan to be at the facility for over the next 24 hours (or longer). The Coating Supervisor felt that closing the manual shutoff valve after the end of each workday and then having to open the valve the following workday prevented a quicker morning startup.

4. **Manual Shutoff**

   If a propylene release was detected, the coating booth operators or the Coating Supervisor could close one of the two manual shutoff valves at the propylene tank, thereby shutting off the source of the propylene.

5. **Remote Shutoff**

   Emergency gas shutoff switches were located at every exit door of the coating building in the form of emergency stop buttons (E-Stops). These buttons were designed to close the remote shutoff valve located at the propylene tank, thereby shutting off the source of the propylene.

6. Coating Booth Ventilation

A large exhaust fan continually operated during coating booth operations to remove process gases and provide ventilation for the spray operations in each booth. See **Figure 11**.

Figure 11. Booth Ventilation Exhaust System. (Source: Google Street View, annotations by CSB)

7. Automated Gas Detection Alarm, Exhaust Fan Startup, and Gas Shutoff System

Six of the eight HVOF coating booths (Booths 4, 6, 7, 8, 9, and 10) were equipped with a wall-mounted gas detector,[a] as shown in **Figure 12** below. These were installed in 2010 during the coating building rebuild following the 2008 incident. Each gas detector was originally configured to transmit a signal to the programmable logic controller (PLC), a type of computer control system, when its gas sensor(s) detected the pre-set concentration level of flammable gas or oxygen. Upon the receipt of a signal from one of the gas detectors, the PLC was originally configured to:

- Trigger alarms notifying employees that propylene had been detected inside a coating booth and to take appropriate action (evacuate);

[a] Also known as an atmospheric monitor.

- Automatically start up the booth's exhaust fan to help remove flammable gas from inside the booth, if the fan was not already running;

- Automatically close the remote shutoff valve inside the individual coating booth where gas is detected; and

- Automatically close the remote shutoff valve at the propylene storage tank, thus shutting off the flow of propylene (see **Figure 7**).[a]

The alarms were both audible and visual (see **Figure 13**). The audible alert consisted of a verbal message alerting employees of the hazard and directing employees to evacuate, alternating with a siren. Meanwhile, the visual alarm consisted of a flashing red beacon located outside of alternating coating booths. At the time of the incident, the automated gas detection alarm, exhaust fan startup, and gas shutoff system was not functional.

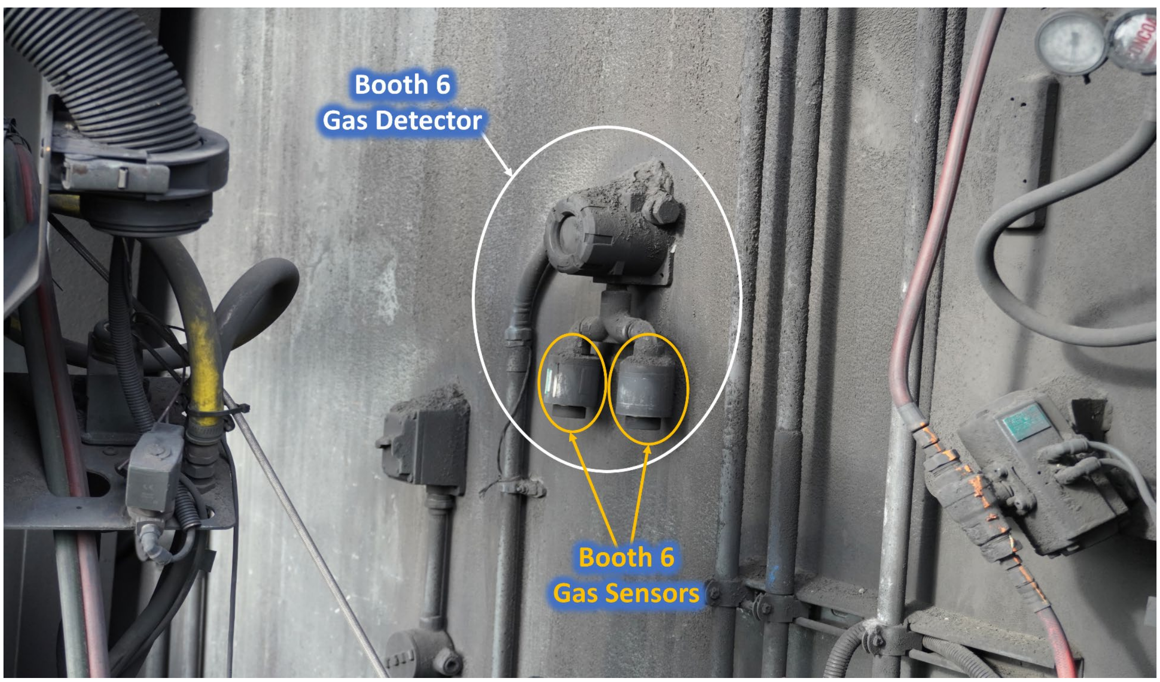

Figure 12. Booth 6 Gas Detector, Including Flammable Gas and Oxygen Sensors. (Source: CSB)

[a] In addition to closing the propylene remote shutoff valve, this system was also designed to close remote shutoff valves for the other gases, including oxygen, argon, and nitrogen.

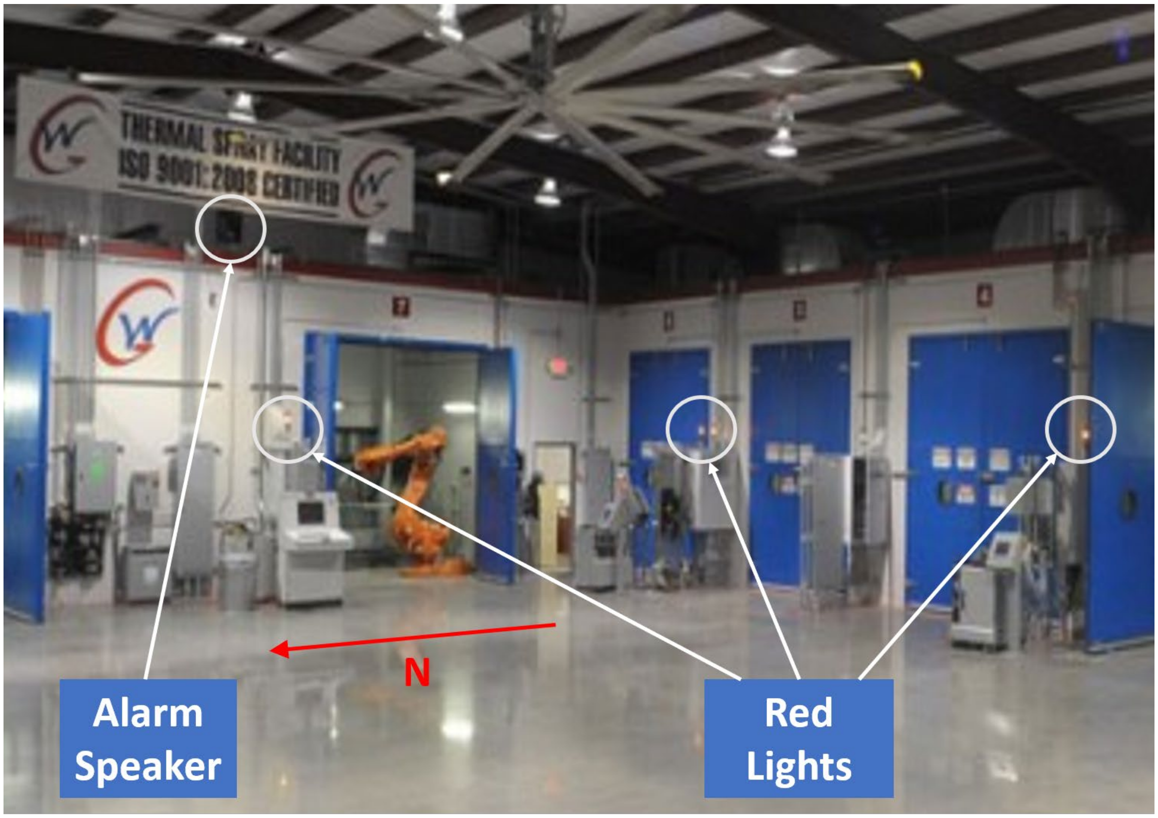

Figure 13. Alarm Locations Inside the Coating Building. (Source: Watson Grinding, annotations by CSB)

8. Other Safety Systems

The HVOF system in Booths 3 through 8 included a sensor that detected whether a flame was present on the spray gun. If a flame was not detected for a specified time, then that booth's remote shutoff valve would automatically close to prevent a release of propylene into the coating building. In addition, the automation required each booth's blue double access doors to be closed for the spray system to operate to prevent gas from leaking into the common area of the coating building.

1.4 Description of the Surrounding Area

Figure 14 depicts the area within one mile of the Watson Grinding facility. Summarized demographic data for the approximately one-mile vicinity of the Watson Grinding facility are shown below in **Table 1**. There are over 15,000 people residing in over 6,000 housing units, most of which are single units, within one to two miles of the Watson Grinding facility. Detailed demographic data are included in **Section 4.2**. In addition to residences, the one-mile vicinity includes hotels, businesses, a warehouse and distribution center, a medical institute, several churches, and two parks.

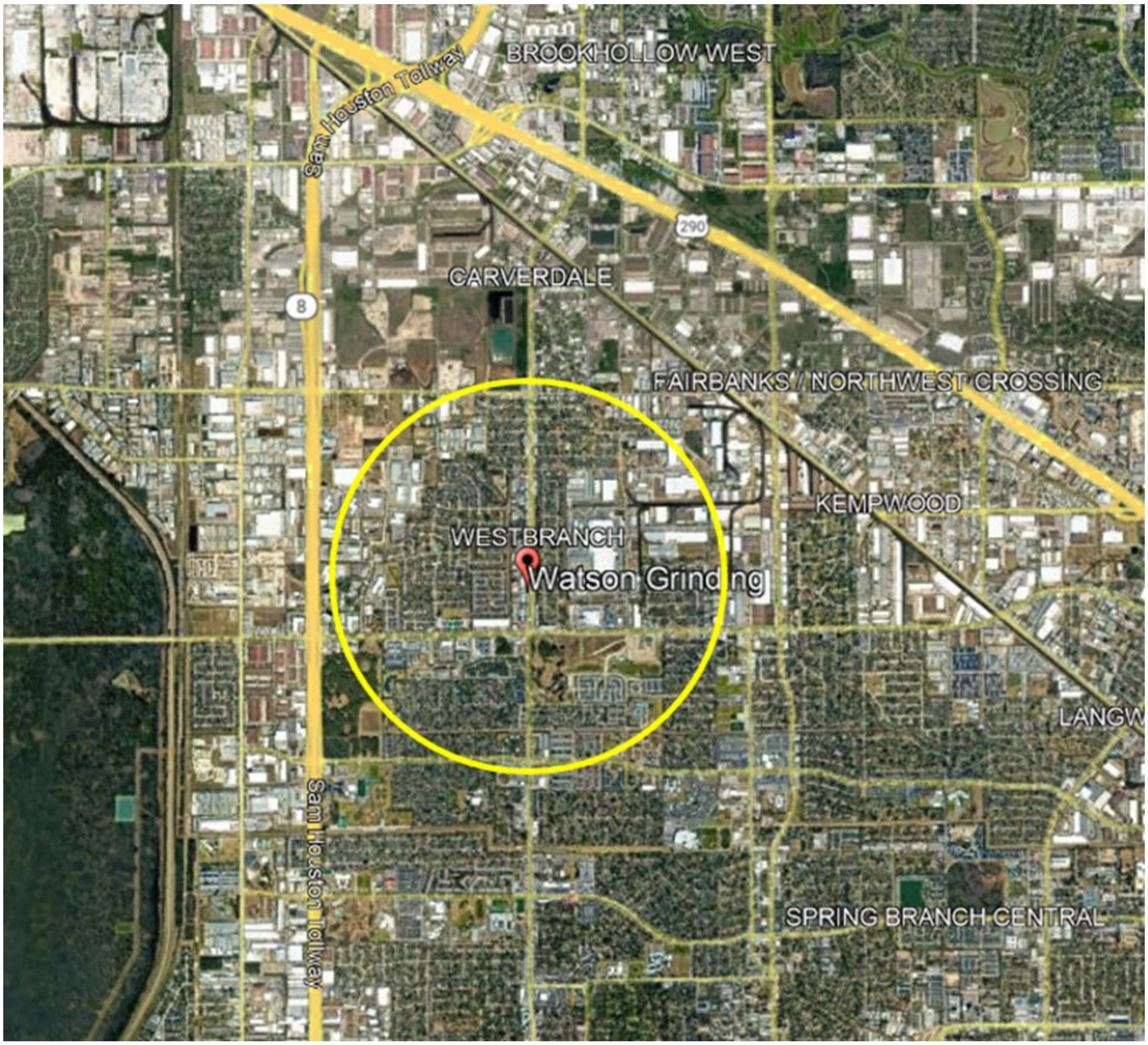

Figure 14. Overhead Satellite Image of the Area Surrounding the Watson Grinding Facility. (Source: Google, annotations by CSB)

Table 1. Summarized demographic data for approximately one-mile vicinity of Watson Grinding.

Population	Race and Ethnicity		Per Capita Income	% Persons Below Poverty Line	Number of Housing Units	Types of Housing Units	
16,589	White	29%	$32,225[a]	10%	6,608	Single Unit	70%
	Black	10%				Multi-Unit	29%
	Native	0%				Mobile Home	1%
	Asian	10%				Boat, RV, Van, etc.	0%
	Islander	0%					
	Other	0%					
	Two+	2%					
	Hispanic	49%					

[a] Census Reporter reports that Harris County's per capita income was $35,037 [37]. The Census Bureau reports that the 2021 per capita income for the United States was $41,285 [38].

2 Incident Description

2.1 Propylene Storage Tank Shutdown

On the day prior to the incident, January 23, 2020, the coating booth operators shut down the individual booths following a normal workday, and the Coating Supervisor closed and locked the coating building. On this day, the Coating Supervisor did not close either of the two manual shutoff valves located at the propylene storage tank, which should have isolated the propylene storage tank from the piping that supplied propylene vapor to the coating building.

2.2 Propylene Leak and Response

At some point overnight, the propylene hose in Booth 4 disconnected from its fitting, creating a propylene release from the propylene storage tank through piping into the booth. This flammable propylene then accumulated within the coating building.

On Friday morning, January 24, 2020, at approximately 3:37 a.m., Employee One arrived at Watson Grinding to exercise at the Watson Gym. At about 3:55 a.m., Employee Two arrived at the Watson Gym and detected a chemical odor consistent with that of propylene outside the building. Upon entering the Watson Gym, Employee Two asked Employee One if he also smelled propylene. Although Employee One replied that he did not, Employee Two insisted that they investigate the source of the odor.[a]

At approximately 4:00 a.m., the two employees left the Watson Gym and walked to the coating building. While standing outside the coating building in the area directly behind Booth 4, they smelled a "strong" propylene odor and heard a "really loud hissing" noise coming from inside the coating building. After smelling the propylene and hearing the sound of leaking gas, both employees returned to the Watson Gym and resumed exercising. At 4:04 a.m., Employee Two texted the Coating Supervisor with the following message: "I think there's gas leaking out of Booth 4. You can hear it and smell it. Please be careful."

At 4:07 a.m., Employee Two called the Plant Manager, notifying him of the propylene leak. The Plant Manager told Employee Two he was on his way to the site. Neither the Coating Supervisor nor the Plant Manager directed Employee Two to evacuate himself and others from the facility. After alerting these two supervisors, Employee Two left the gym to investigate the propylene leak.

2.3 Coating Building Explosion and Fire

At 4:19 a.m., the Coating Supervisor sent a text to all coating booth operators, stating, "Booth 4 has a potential leak. Do no[t] start up yet." At approximately 4:23 a.m., Employee Three arrived at Watson Grinding and parked his car just outside the door on the west side of the coating building. Employee Three, a coating booth operator,

[a] Employee One did not work in the coating building and was unaware of the smell or danger of a propylene leak. However, Employee Two was a maintenance technician, who had worked throughout the Watson Grinding facility, and was familiar with the odor of propylene having previously repaired a propylene leak.

had a key to the coating building[a] and, in his supervisor's absence, would unlock the door of the coating building, turn on the lights, and clock in.

At around 4:24 a.m., another Watson Grinding coating booth operator (Employee Four) arrived. As he stopped and prepared to park his truck, he noticed Employee Three's car parked just outside the coating building and saw him enter the coating building through the open west door. As Employee Four backed his truck into a parking space, the flammable propylene vapor ignited, and the coating building exploded. The explosion was captured by a nearby residential camera (**Figure 15**). The explosion fatally injured Employees Two and Three and injured Employees One and Four.

[a] This area was described as "pitch dark." Therefore, when first arriving to the coating building, employees would position their car headlights to illuminate the area, allowing them to unlock the door and turn on the lights.

Figure 15. Explosion. (Source: Residential Camera [11])

Figure 16 shows a pre-incident photo of the coating building and identifies the approximate locations of the four employees at the time of the incident.

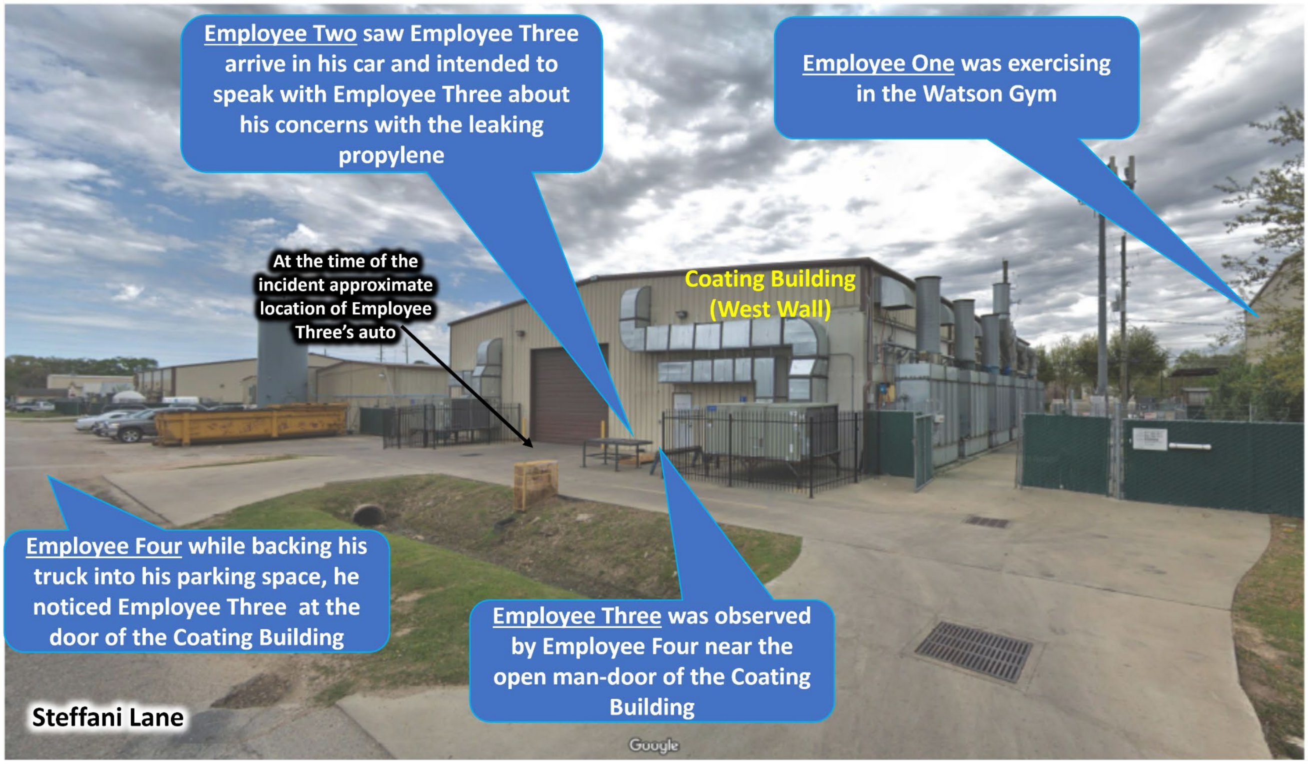

Figure 16. Employee Locations at the Time of the Incident. (Source: Google Street View, annotations by CSB)

2.4 Post-Incident Response

Following the incident, Employees One and Four were able to self-evacuate and were later transported by ambulance to area hospitals for examination and treatment of their injuries.

The first emergency notification sent to emergency responders occurred at approximately 4:26 a.m. from a residential smoke detector located approximately 600 feet from Watson Grinding's coating building. The Houston Emergency Center quickly dispatched the first City of Houston Fire Department (HFD) engine to the scene. At 4:28 a.m., Employee Four texted all the coating booth operators to "Call 911." At 4:34 a.m., the first HFD fire engine arrived on the scene and requested additional firefighting resources. Based on the request for assistance, a significant number of other firefighting resources were dispatched to the scene, including HFD's Hazardous Materials Response Team (HMRT), often referred to as the HazMat team.

Figure 17 shows a drone image of the devastation from the explosion.

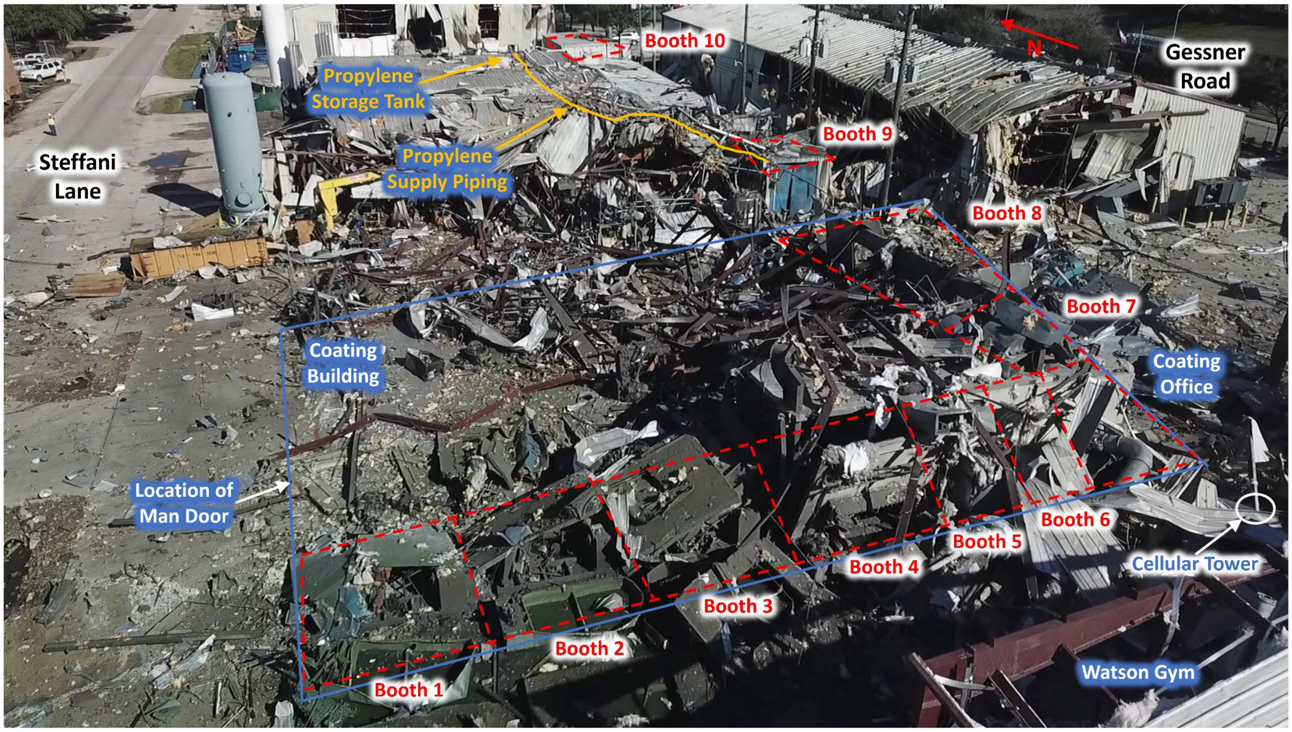

Figure 17. Post-Explosion Image of Coating Building and Adjacent Area. (Source: HFD, annotations by CSB)

At approximately 7:30 a.m., HMRT members closed one of the manual shutoff valves adjacent to the propylene storage tank, thus stopping any further release of propylene from the tank. The CSB estimated that approximately 2,600 pounds of propylene were released.

2.5 Incident Consequences

Injuries

The explosion fatally injured Employees Two and Three and injured Employees One and Four, who were transported to nearby hospitals by ambulance. A nearby resident died two weeks later due to injuries sustained in his house caused by the explosion [12].

Surrounding Community

The City of Houston's Office of Emergency Management subsequently reported that the incident damaged numerous nearby structures (see **Figure 18**). Some homes, located to the west of the Watson Grinding facility, experienced major damage.

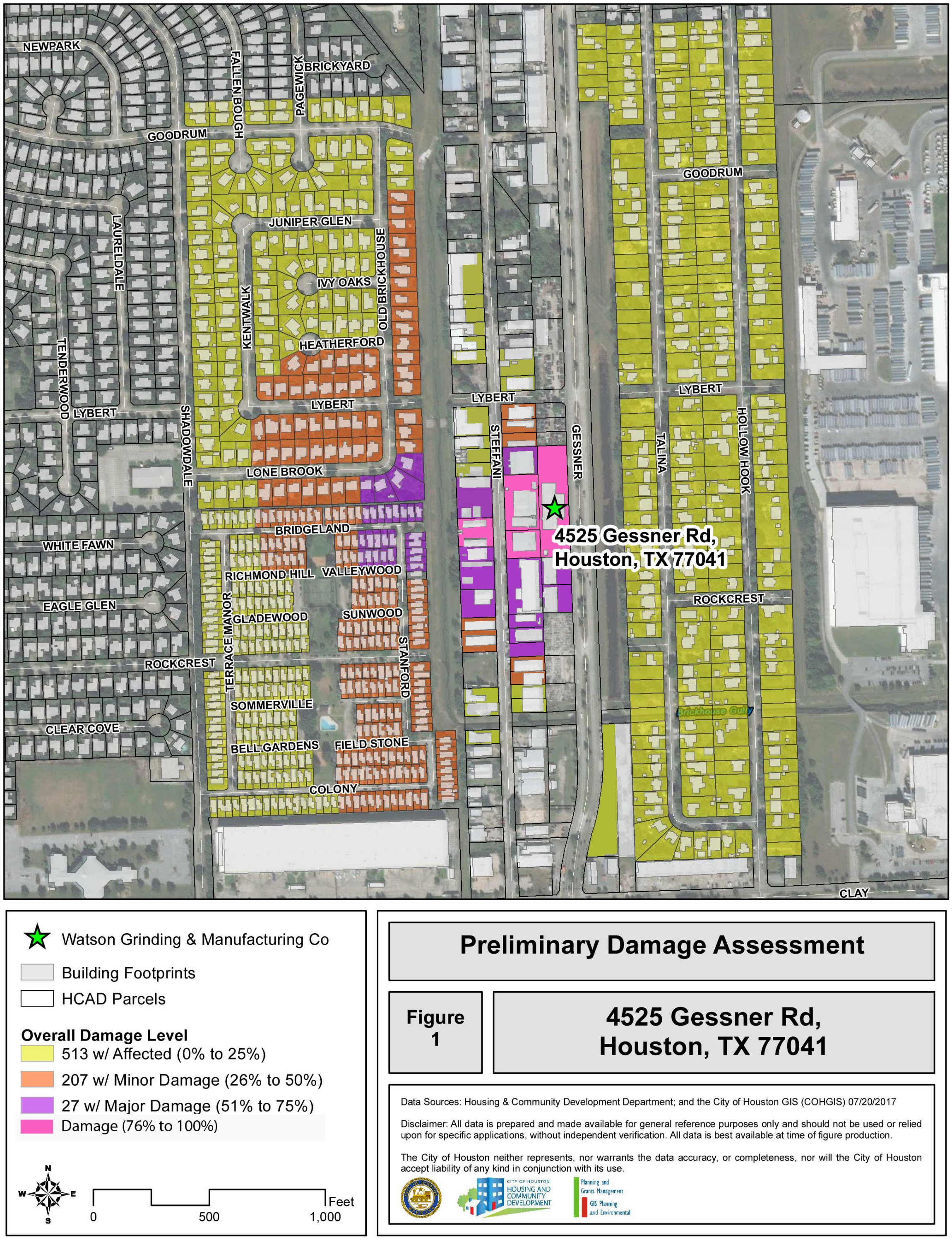

Figure 18. Damage Assessment. (Source: City of Houston Office of Emergency Management)

Some homes were located within a few hundred feet of the Watson Grinding facility. Due to the close proximity of the Watson Grinding facility to so many homes and facilities, over 450 structures were affected by the explosion, with some sustaining major damage. A resident died due to injuries sustained in his house caused by the explosion. An aerial view of the damage is shown in **Figure 19.**

Figure 19. West-facing aerial view of Watson Grinding. (Source: The New York Times [13])

In the aftermath of the explosion at the Watson Grinding facility, in December 2020, the Houston City Council adopted an ordinance tightening regulations on businesses storing hazardous materials within city limits and restricting the location of such facilities within 1,000 feet of a public park, community center, school, library, church, licensed day care center, licensed group day-care home, licensed family home, hospital, licensed continuing care facility, licensed convalescent and nursing facility, or any related institution. The ordinance also provided that the permit for a facility storing hazardous materials cannot be modified unless the facility has established appropriate mitigation and safeguards so the manufacturing, processing, generation, storage, or use of the hazardous material at the facility will not pose a risk to hazard to human health or the environment, and that the modification would not have an increased impact on residents of surrounding neighborhoods, in addition to other requirements. The preamble to the ordinance stated that the City Council's intent is "to regulate all locations in the city that utilize, store, process, manufacture, convert, transport, repackage, or handle in any manner certain hazardous materials that could present an immediate and extreme danger to adjacent residences and other special occupancies located nearby."[a]

Facility Impact

On February 6, 2020, Watson Grinding filed a petition for voluntary Chapter 11 reorganization bankruptcy with the U.S. Bankruptcy Court of the Southern District of Texas, leading to an initial layoff of 80 of the company's 130 employees.

The explosion destroyed the coating building and caused heavy damage to the administration building and valve shop. The company was later liquidated under bankruptcy proceedings, and Watson Grinding is no longer in business [14]. The CSB did not issue any safety recommendations to Watson Grinding, because the company is no longer in operation. However, if such recommendations were made, they would address the identified safety issues.

[a] City of Houston, Texas, Ordinance No. 2020-1092 (adopted Dec. 16, 2020), amending Houston Code of Ordinances Chapter 28, Article VII.

3 Technical Analysis

At the end of the workday on the evening before the incident, neither of the manual shutoff valves nor the remote shutoff valve located at the propylene storage tank were closed.[a] The CSB found that there was no established policy or procedure for isolating the propylene storage tank at the end of the workday.

The CSB concludes that by not closing one of the two manual shutoff valves, the propylene storage tank was not isolated from the piping that supplied propylene vapor to the coating building. When the propylene leak began overnight in Booth 4, the lack of isolation allowed propylene gas to continue to flow into Booth 4 and accumulate inside the coating building.

The coating booths inside the coating building were designated as Class I, Division 2 locations, one of the hazardous classified locations under the National Fire Protection Association (NFPA) 70, *National Electric Code*, where the possibility of fire or explosion hazards may exist under abnormal conditions because of the presence of volatile flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors [15, p. 353]. The remaining areas of the coating building, including the common area (**Figure 4**) and coating office, however, were designated as unclassified locations, meaning hazardous materials such as propylene vapor should not be present. The CSB concludes that a Watson Grinding worker entered the coating building and likely turned on the internal lights near the main entrance, igniting the flammable propylene vapor and triggering the explosion. The electrical devices located in the coating building's common area, including the lights, were not designed to be safe in a flammable atmosphere, making any of them a potential ignition source if activated.

Post-incident evaluation of the coating building determined that the source of the propylene release was the rubber welding hose located inside Booth 4,[b] which disconnected from its fitting sometime after the previous workday ended. The hose that failed was found to be degraded and poorly crimped (**Figure 20 and Figure 21**).[c]

Post-incident testing revealed that the hose had lost its flexibility and elasticity (indicating deterioration), which likely contributed to its detachment. Where the hose disconnected from its fitting is shown in **Figure 20**. In addition, several years prior to the January 2020 incident, Watson Grinding went from using factory-crimped hose within each coating booth to having the coating booth operators crimp each replacement hose for their assigned booth. The post-incident inspection of the propylene welding hose that disconnected in Booth 4 revealed that the hose was not properly crimped to its fitting. Had the hose been properly crimped to its fitting, it should not have disconnected. **Figure 21** shows both the improper crimp that disconnected and a more effectively crimped hose from another location in Booth 4.

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[a] Among other good practice safety guidance, both the American Welding Society and the Association for Rubber Products Manufacturers (ARPM) recommend closing the fuel gas supply source valves after completion of the activity [18, p. 3, 33, p. 15].

[b] The rubber welding hose was located between the manual shutoff valve and the pressure regulator within Booth 4. The point where the hose disconnected was on the outlet of the Booth 4 manual shutoff valve.

[c] The rubber welding hose was crimped to secure the hose to its fitting. Crimping involves bending metal parts to lock them into place [36, p. 327].

Figure 20. Disconnected Welding Hose from Booth 4. (Source: CSB)

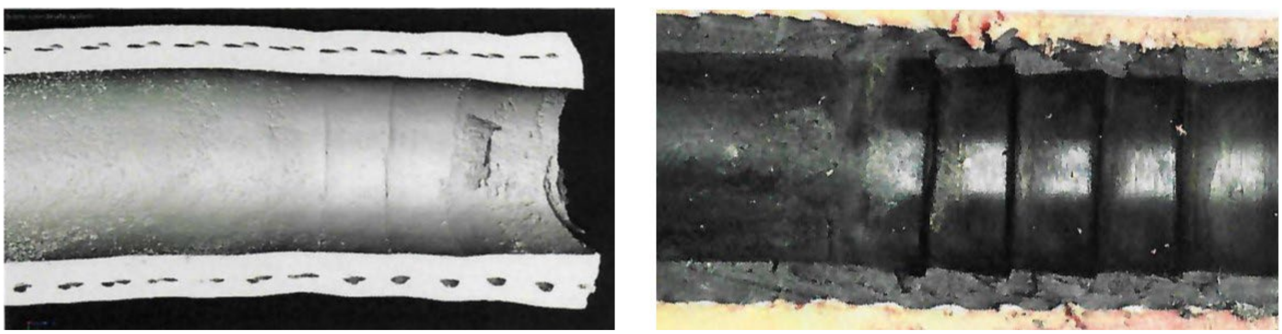

Figure 21. Booth 4 Crimping Comparison: The image on the right shows a different welding hose in Booth 4 with distinct lines that highlight where it was properly crimped; the image on the left shows a computerized tomography scan of the hose that disconnected in Booth 4, leading to the incident. The minimal crimp lines are evidence that the incident hose was not effectively crimped [16].

The CSB concludes that the propylene leak began when a rubber welding hose, which was degraded and poorly crimped, disconnected from its fitting overnight in Booth 4. Propylene gas continued to flow into Booth 4 and accumulated inside the coating building.

The CSB also concludes that the Booth 4 automated gas detection alarm, exhaust fan startup, and gas shutoff system was not functional at the time of the propylene leak. Had the system been functional, it would have alarmed to alert employees, started up the exhaust fan, which would have removed the leaking propylene from inside the booth, and remotely shut off the propylene storage tank, stopping the flow of propylene vapor and likely preventing the dangerous accumulation of propylene from Booth 4. Evidence indicated that Watson Grinding did not effectively respond to reports in 2013, 2016, 2019, and two weeks before the January 2021 explosion, of the gas detection alarm, exhaust fan startup, and gas shutoff system not being connected to the computer control system (a PLC).

4 Safety Issues

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

1. **Process Safety Management.** Had Watson Grinding developed and implemented an effective process safety management program to identify and control hazards, the incident could have been prevented. Several elements of a process safety management program, if implemented, could have helped prevent this incident, including process safety information, process hazard analysis, management of change, mechanical integrity, and operating procedures.

2. **Emergency Preparedness.** Watson Grinding's emergency response plan did not address responding to a propylene gas leak. Watson Grinding also did not train its employees to recognize or respond to a propylene gas release. As a result, on the day of the incident, employees did not evacuate the area after suspecting a propylene leak, did not prevent others from entering the area, and did not contact emergency responders for help.

An Accident Map for this event is provided in **Appendix A**.

4.1 Process Safety Management

4.1.1 OSHA Citations

In 2008, Watson Grinding experienced a catastrophic explosion of propylene gas that injured two workers and led to a rebuild of the coating building. OSHA investigated this incident and issued Watson Grinding four citations; two were deleted during settlement. One of the remaining citations was for violation of the General Duty Clause, and the other was related to medical services and first aid.[a] The General Duty Clause citation involved welding hose and connecting joints that were not inspected for signs of deterioration, leaks, and wear. This is notable because the January 24, 2020, incident occurred when a deteriorated rubber welding hose disconnected from its fitting, filling the building with an explosive concentration of propylene gas.

As part of the rebuild following the 2008 incident, Watson Grinding made a number of safety-related changes in using propylene gas as the fuel for the HVOF coating process. At that time, Watson Grinding adopted the safety systems described in Section 1.3.4 to specifically prevent future incidents. These safety systems included the automated gas detection alarm, exhaust fan startup, and gas shutoff system.

Following the January 24, 2020, incident, OSHA issued two citations to Watson Grinding. The first citation was for failure to provide effective information and training on the hazards of chemicals, including propylene. The second citation was for a violation of the General Duty Clause, stating the following:

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[a] Under the Occupational Safety and Health Act of 1970, Section (5)(a)(1), known as the General Duty Clause, states, "Each employer…shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to the employees…" See 29 U.S.C. § 654.

- Watson Grinding did not prevent explosive concentrations of propylene from accumulating inside the coating building;
- Watson Grinding did not ensure that equipment in the coating booths was always maintained gas-tight; and
- Watson Grinding did not ensure the propylene manual shutoff valve at the propylene storage tank was closed at the end of each workday.

4.1.2 Application of PSM Standard and RMP Rule

The propylene storage tank at Watson Grinding could hold up to approximately 8,600 pounds of liquid propylene. As a result, the OSHA PSM standard did not apply to Watson Grinding's coating process because the amount stored was below the threshold quantity of 10,000 pounds.[a] Propylene is listed as a regulated substance under EPA's RMP rule, but because the amount of propylene that Watson Grinding stored on-site did not meet the threshold quantity of 10,000 pounds, the RMP rule also did not apply.[b] In addition, neither the OSHA PSM standard nor the EPA RMP rule cover hazardous substances, such as propylene, when the material is used as a fuel.[c]

Because neither the OSHA PSM standard nor the EPA RMP rule applied at Watson Grinding, a process safety management system was not specifically required for Watson Grinding's propylene coating process. The CSB concludes that Watson Grinding could have prevented the incident by developing an effective process safety management program and implementing process safety management system elements for its propylene process, such as process safety information, process hazard analysis, management of change, mechanical integrity, and operating procedures. The following sections discuss how the lack of implementation of these safety elements at Watson Grinding contributed to the January 24, 2020, catastrophic explosion.

4.1.3 Process Safety Information

In its book *Guidelines for Risk Based Process Safety,* the Center for Chemical Process Safety (CCPS) created a broadly accepted framework for process safety management consisting of 20 elements to help organizations design and implement more effective process safety management systems. Throughout the book, CCPS illustrates how each of the 20 elements correlates to current OSHA PSM standard elements [17, p. 13]. CCPS states that the

[a] The PSM standard applies to "(i) A process which involves a chemical at or above the specified threshold quantities listed in appendix A to this section; (ii) A process which involves a Category 1 flammable gas (as defined in §1910.1200(c)) or a flammable liquid with a flashpoint below 100°F (37.8°C) on-site in one location, in a quantity of 10,000 pounds (4,535.9 kg) or more except for: (A) Hydrocarbon fuels used solely for workplace consumption as a fuel (e.g., propane used for comfort heating, gasoline for vehicle refueling), if such fuels are not a part of a process containing another highly hazardous chemical covered by this standard; (B) Flammable liquids with a flashpoint below 100°F (37.8°C) stored in atmospheric tanks or transferred which are kept below their normal boiling point without benefit of chilling or refrigeration." 29 C.F.R. § 1910.119(a)(1)(ii).

[b] See 40 C.F.R. § 68.130, List of Substances. Table 1 – List of Regulated Toxic Substances and Threshold Quantities for Accidental Release Prevention.

[c] The OSHA PSM standard exempts "Hydrocarbon fuels used solely for workplace consumption as a fuel (e.g., propane used for comfort heating, gasoline for vehicle refueling), if such fuels are not a part of a process containing another highly hazardous chemical covered by this standard." See 29 C.F.R. § 1910.119(a)(1)(ii)(A). While under the EPA RMP rule, "A flammable substance listed in Tables 3 and 4 of § 68.130 is nevertheless excluded from all provisions of this part when the substance is used as a fuel or held for sale as a fuel at a retail facility. See 40 C.F.R. § 68.126.

OSHA PSM element of Process Safety Information correlates to its element known as *Process Knowledge Management.* CCPS describes *knowledge* as:

> …information that can easily be recorded in documents, such as (1) written technical documents and specifications, (2) engineering drawings and calculations, (3) specifications for design, fabrication, and installation of process equipment, and (4) other written documents such as material safety data sheets… [17, p. 170].

CCPS' term *process knowledge* refers to this collection of information. CCPS also notes that knowledge implies understanding, not simply compiling data [17, p. 170].

Following the 2010 installation of the propylene automated gas detection alarm, exhaust fan startup, and gas shutoff system, Watson Grinding did not maintain engineering drawings and additional documentation on the system, did not maintain this system in working order, and did not train its employees on effectively using or maintaining the system. The CSB concludes that deficiencies in process knowledge and documentation at Watson Grinding significantly contributed to the incident.

In 2016, the individual who originally designed and installed this system visited Watson Grinding to conduct repair work on one of the robotic arms in a coating booth and noted that he found the gas detection system to be dismantled and disabled. The designer recommended that Watson Grinding conduct a proper assessment of all the coating booths to ensure safe operation. Watson Grinding did not follow the designer's recommendation to conduct a hazard assessment of the coating booths.

In 2016, Watson Grinding hired a company, different from the original system designer, to improve the coating process. Engineering drawings were developed for the robotic coating system within certain booths. This effort did not include developing drawings for the automated gas detection alarm, exhaust fan startup, and gas shutoff system. In addition, this company did not conduct work to reconnect this system to ensure the automated alarms, exhaust fan, and gas shutoff would function in the event of a release. The CSB concludes that Watson Grinding did not maintain critical process safety information for the automated gas detection alarm, exhaust fan startup, and gas shutoff system. Such documentation is necessary to maintain the reliability of this critical safety system. The lack of this information contributed to this system not being functional on the day of the incident. Had the system worked, it should have prevented the accumulation of flammable propylene gas within the coating building.

4.1.4 Process Hazard Analysis

CCPS states that the OSHA PSM element of Process Hazard Analysis correlates to its element known as *Hazard Identification and Risk Analysis* [17, p. 13]. According to CCPS, the term Hazard Identification and Risk Analysis encompasses all activities involved in identifying hazards and evaluating risk at a facility, throughout the facility's life cycle, to ensure that risks to workers, the public, and the environment are consistently controlled. The three main risk questions the CCPS recommends are:

- Hazard – What can go wrong?
- Consequences – How bad could it be?

- Likelihood – How often might it happen [17, p. 210]?

The understanding of risk developed from these exercises helps form the basis for establishing most of the other process safety management activities undertaken by the facility [17, p. 211]. At Watson Grinding, to ensure safe operations, the company should have identified the hazards of a propylene leak and considered the critical safeguards necessary to control the hazards and reduce the risk.[a] However, the CSB was unable to identify instances in which Watson Grinding employees identified or analyzed hazards related to its propylene coating process. In addition, after the gas detection alarm, exhaust fan startup, and gas shutoff system was installed in 2010, there was no evidence that Watson Grinding effectively maintained that system. As a result, this system was not functioning at the time of the incident. The CSB concludes that had Watson Grinding performed an effective process hazard analysis on its propylene process, it should have identified the hazards of a propylene leak and considered the critical safeguards necessary to control the hazards. Such an analysis should have identified the fact that the gas detection system was no longer capable of automatically triggering alarms, starting up the exhaust fan, or shutting off the propylene supply if a dangerous concentration of propylene accumulated in a coating booth. Action items to restore the functionality of the system should have then been promptly developed and implemented.

4.1.5 Management of Change

CCPS notes that the OSHA PSM element of Management of Change correlates to its element also known as *management of change* [17, p. 13]. CCPS describes management of change as an element of process safety management that helps ensure that changes to a process do not inadvertently introduce new hazards or increase the risk of existing hazards [17, p. 424]. If a proposed modification is made to a hazardous process without the necessary review, the risk of a process safety incident potentially increases significantly. According to CCPS, the following principles should be addressed for the management of change element:

- Maintain a dependable practice;
- Identify potential change situations;
- Evaluate possible impacts;
- Decide whether to allow the change; and
- Complete follow-up activities [17, p. 425].

In this case, the hose that disconnected and led to the propylene leak was a Grade R rubber welding hose that replaced a more robust copper tubing connection.[b] **Figure 22** shows the Booth 4 gas equipment, as originally installed in 2010 using copper tubing (left image), and again in 2020 (post-incident) with rubber hoses. **Figure 23** also shows the 2010 installation and post-incident Booth 4 gas equipment in the form of a simplified flow diagram.

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[a] Because of the involvement of robots in the coating process at Watson Grinding, additional safety standards applied that required a risk assessment and functional testing of safeguards, such as the American National Standard for Industrial Robots and Robot Systems – Safety Requirements [35].

[b] A Grade R rubber welding hose is not suitable for propylene, is not oil-resistant, and does not have a flame-resistant rubber tube and cover. A Grade T hose is suitable for propylene and has a flame and oil-resistant rubber tube and cover [34].

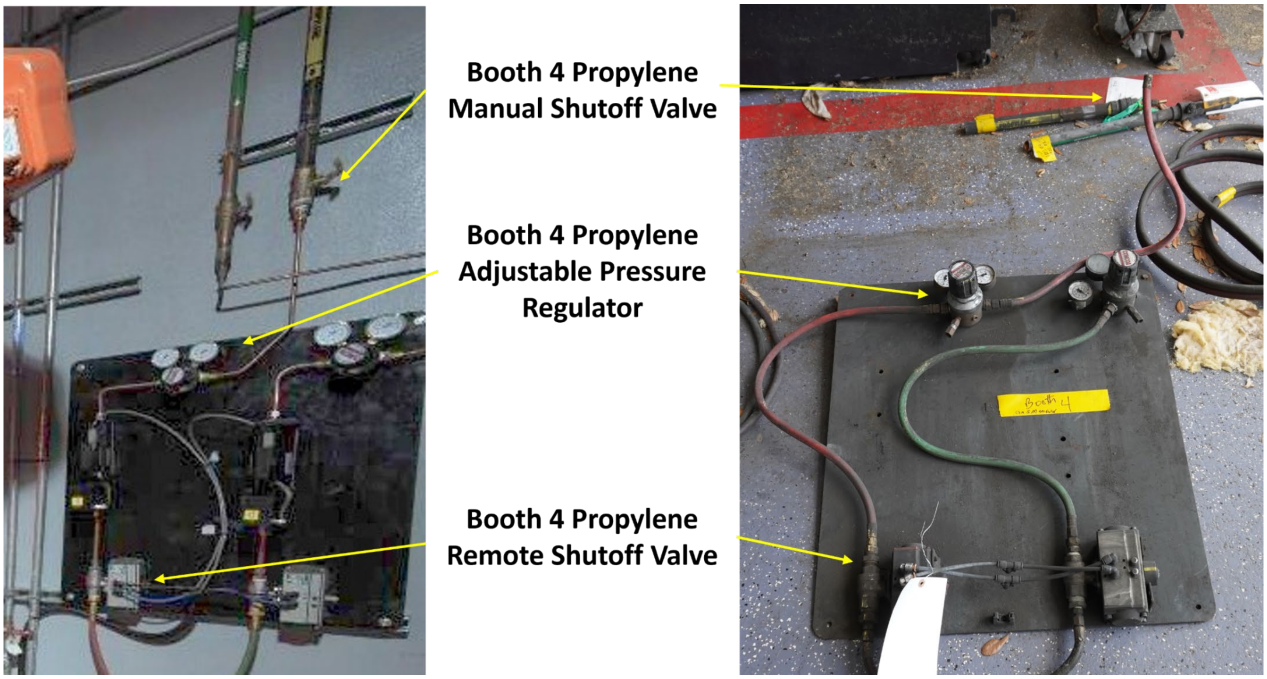

Figure 22. Booth 4 Gas Equipment. At left from 2010; at right from post-incident. (Source: Automation Plus (left), CSB (right), annotations by CSB)

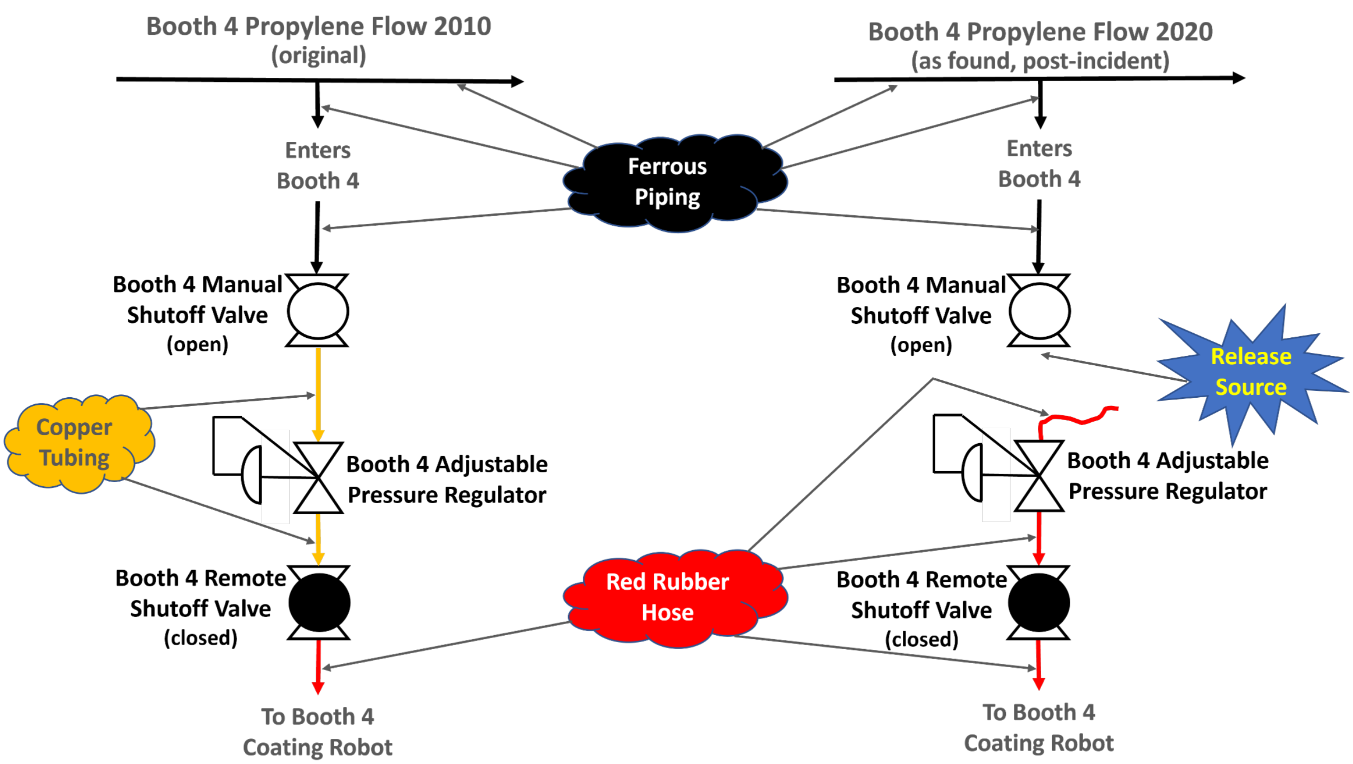

Figure 23. Simplified Propylene Flow Diagram of the Booth 4 Gas Equipment. (Source: CSB)

The Grade R rubber welding hose that Watson Grinding used is a less expensive type of hose that is designed for acetylene and oxygen service only and is not recommended by the hose manufacturer for use with any other gases, such as propylene. The hose manufacturer recommends a Grade T hose for propylene service because the oils found in fuel gases such as propylene can dry rot a Grade R hose[a] in a reasonably short amount of time, causing the hose to form cracks and lose pliability. In addition, the Association for Rubber Products Manufacturers[b] (ARPM) states that the use of a Grade R rubber welding hose in propylene service may reduce its life and present a safety hazard [18, p. 3].[c] The hose that failed was found to have lost its flexibility and elasticity. This likely contributed to its detachment, leading to the incident.

The CSB could not identify documentation showing that the potential hazards associated with the change from copper tubing to rubber hose were identified or evaluated. The CSB concludes that Watson Grinding could have reduced the likelihood of an incident by performing a management of change review prior to replacing rigid copper tubing with a less robust Grade R flexible rubber welding hose in its propylene process.

4.1.6 Mechanical Integrity

CCPS refers to the OSHA PSM element of Mechanical Integrity as *Asset Integrity and Reliability* [17, p. 13]. This element helps ensure that equipment is properly designed, installed in accordance with specifications, and remains fit for use until it is retired. Work activities related to this element focus on ensuring high availability and dependability of critical safety or utility systems that prevent or mitigate the effects of loss of containment events. According to CCPS, two primary responsibilities for any chemical facility are maintaining containment of hazardous materials and ensuring that safety systems work when needed [17, p. 318].

Several years prior to the incident, Watson Grinding disabled the safety function of its automated gas detection alarm, exhaust fan startup, and gas shutoff system, essentially disconnecting it from the computer control system (a PLC), that should have automatically triggered the closure of the remote shutoff valve at the propylene storage tank. Gas sensor calibration contractors visited the Watson Grinding coating building in 2013, 2016, and 2019, and raised concerns in writing that the gas detection system was disconnected from the PLC. Watson Grinding management also had a discussion two weeks prior to the incident that the booths' gas detectors were not connected and needed to be fixed. Watson Grinding did not address these issues prior to the incident.

In addition, Watson Grinding had no testing program in place to ensure the functional integrity of the automated gas detection alarm, exhaust fan startup, and gas shutoff system. As a result, once the propylene leak began inside Booth 4, the alarms did not activate, the exhaust fan did not start up, and the remote shutoff valve at the propylene storage tank did not close, allowing propylene to accumulate to explosive levels inside the coating building. The CSB concludes that a robust mechanical integrity program would have ensured that an effective inspection, testing, and preventive maintenance system was in place to maintain the integrity of the automated gas detection alarm, exhaust fan startup, and gas shutoff system. Such a program should have ensured a prompt response to reports and inspections about the non-working conditions of those systems.

[a] Dry rot in the hose appears cracked on the surface, with a loss of pliability.

[b] ARPM maintains and monitors hose, sealing and belt standards for the rubber industry [32].

[c] For all oxy-fuel applications, CGA recommends the "exclusive use of Grade T hose because of its gas compatibility, oil resistance, and flame resistance…" [39, p. 17].

As discussed above, the disconnected hose was found to be degraded. In part, this is because it was not the appropriate grade of material for a hose in propylene service. In addition, several years prior to the incident, Watson Grinding went from using factory-crimped hose within each coating booth to crimping its own hose for that application on-site. Watson Grinding did not have a procedure for crimping, nor were its employees formally trained on how to properly crimp fittings onto the rubber welding hose.[a] The CSB found that prior to the incident, the rubber welding hose inside Booth 4 disconnected from its fitting and resulted in the propylene leak. The CSB concludes that a robust mechanical integrity program, which would have ensured the proper crimping of the fitting to the recommended grade of rubber welding hose, as well as effective inspection and testing of the hose, would have helped prevent the propylene release.[b]

4.1.7 Operating Procedures

CCPS defines "operating procedures" as "written instructions that (1) list the steps for a given task and (2) describe the way the steps are to be performed. Good procedures describe the process, hazards, tools, protective equipment, and controls in enough detail that operators understand the hazards, can verify that controls are in place, and can confirm that the process responds in an expected manner" [17, pp. 245-246].

The CSB found that Watson Grinding lacked a written coating system shutdown procedure that should have included effectively isolating the propylene supply by, for example, closing a manual shutoff valve at the propylene storage tank at the end of each workday. Closing one of the two manual shutoff valves at the propylene storage tank at the end of the workday should have prevented the continued release of propylene within the coating building during non-business hours.[c, d] Instead, Watson Grinding did not implement consistent work practices, which resulted in the manual shutoff valves remaining open overnight. The CSB concludes that Watson Grinding could have reduced the likelihood of an incident if it had developed and effectively trained its workers on operating procedures that included a requirement to effectively isolate the propylene storage tank from the coating building at the end of each workday.

4.1.8 Process Safety Management for Industrial Gases

The CSB noted above that Watson Grinding's propylene supplier was Western International Gas and Cylinders, Inc., a subsidiary of Matheson. Matheson is a member of CGA, an industry association that publishes a number of safety standards for its more than 130 member companies worldwide [9, 10].

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[a] An operator testified that he was told how to perform the crimping by a senior operator. The CSB is not aware of any formal training on crimping.

[b] The CSB previously investigated an incident in which the appropriate type of hose was not used in a service involving highly hazardous chemicals and then ruptured. On January 23, 2010, an operator walked into the phosgene cylinder storage area in the Small Lots Manufacturing unit at the DuPont plant in Belle, West Virginia (DuPont Belle). The worker was fatally injured when he was sprayed in the face and upper torso with phosgene when a flexible hose suddenly ruptured. The CSB investigated the incident and found that the stainless-steel hose that failed was not a hose that was recommended for any service involving highly toxic materials such as phosgene, as it is susceptible to chlorides corrosion. In its final investigation report on the incident, the CSB made recommendations to CGA, among other organizations, to update its guidance on compressed gas cylinders and flexible stainless steel braided hoses [41].

[c] CGA provides the following guidance to its members: "DO NOT leave pressure in hoses when equipment is not being used (i.e., lunchtime, overnight, weekends, etc) …" [39, p. 17].

[d] ARPM states that "[u]pon completion of the welding/cutting activity the user should first close the torch valves and then the supply source valves…" [18, p. 3].

On August 28, 2016, a nitrous oxide trailer truck exploded at the Airgas manufacturing facility in Cantonment, Florida. The explosion killed the only Airgas employee present and heavily damaged the facility. In the CSB's final investigation report entitled *Nitrous Oxide Explosion: Airgas Investigation Report*, the CSB recommended that CGA develop and implement a safety management system to manage process safety hazards for nitrous oxide manufacturing, including nitrous oxide decomposition, which includes appropriate elements based on chemical industry good practice guidance, such as CCPS' *Guidelines for Risk Based Process Safety, Essential Practices for Managing Chemical Reactivity Hazards,* and *Guidelines for Implementing Process Safety Management* [19, p. 127].

In response to this recommendation, in May 2020, just four months after the Watson Grinding incident, CGA published *CGA P-86, Guideline for Process Safety Management* (CGA P-86), an industry standard that was developed specifically for the processes within the industrial and medical gases industry. The document has 21 elements of a process safety management system to manage known process safety hazards and to identify, assess, and manage other hazards. The 21 elements are:

Element 1 - Leadership commitment and responsibility

Element 2 - Compliance with legislation and industry standards

Element 3 - Employee selection, training, and competency

Element 4 - Workforce involvement

Element 5 - Communication with stakeholders

Element 6 - Hazard identification and risk assessment

Element 7 - Documentation, records, and knowledge management

Element 8 - Process and operational status monitoring and behavior

Element 9 - Operating procedures

Element 10 - Management of operational interfaces

Element 11 - Standards and practices

Element 12 - Management of change

Element 13 - Operational readiness and process startup

Element 14 - Emergency and crisis management

Element 15 - Inspection and maintenance

Element 16 - Management of safety critical devices

Element 17 - Work control, permit to work, and task risk management

Element 18 - Contractors and suppliers – selection and management

Element 19 - Incident investigation

Element 20 - Audit, management review, and intervention

Element 21 - Measures and metrics [20].

CGA states that the intent of this document is to make process safety management understandable beyond the OSHA PSM standard. CGA P-86 also allows users to develop process safety management systems following the CCPS model that has been discussed throughout this section.

The American Chemistry Council (ACC) is a trade organization in the United States that represents chemical companies and requires its members to adhere to its Responsible Care program, a program developed by the chemical industry to help guide companies toward safe and responsible operation [21, 22]. According to ACC, Responsible Care companies are committed to a culture of continual improvement in product safety and product stewardship for each stage of a product's life cycle. As part of this, ACC developed the Product Safety Code, which provides a set of practices to manage chemical product safety and enhance it as part of its industry's health, safety, security, and environmental management system. The Product Safety Code requires that companies include product safety and product stewardship as part of their management systems. According to ACC, product safety includes exchanging information regarding product hazards, intended uses, handling practices, exposures, and risks. The ACC describes product stewardship as the responsibility to understand, manage, and communicate the health and environmental impacts throughout the life cycle of chemical products. The customers of member companies and users of the members' products are an important focus of product stewardship [23, 24].

Unlike ACC, CGA does not implement a similar program for its member companies, such as Matheson, to encourage the sharing of safety information with customers. Based on post-incident Watson Grinding employee statements, there was minimal interaction between Matheson and Watson Grinding employees regarding the safe use and handling of propylene, even though Matheson owned the propylene storage tank and supplied the propylene to Watson Grinding.

The CSB concludes that had CGA required or otherwise urged its members like Matheson to share information with their customers such as Watson Grinding on the need for a process safety management program to manage the hazards associated with hazardous chemicals such as propylene, Watson Grinding may have developed and implemented an effective process safety program, which could have prevented the incident.

The CSB recommends that CGA urge member companies that handle hazardous chemicals to share information with their customers about (1) the safety issues described in this report and (2) why their customers should develop and implement effective process safety management systems as part of their own internal safety programs, including informing member companies' customers about CGA P-86, *Guideline for Process Safety Management*, CCPS' *Guidelines for Risk Based Process Safety*, or an equivalent approach.

The CSB also recommends that Matheson provide its customers with information about (1) the safety issues described in this report and (2) why its customers should develop and implement effective process safety management systems as part of their own internal safety programs, including informing its customers about CGA P-86, *Guideline for Process Safety Management*, CCPS' *Guidelines for Risk Based Process Safety*, or an equivalent approach.

4.2 Emergency Preparedness

CCPS refers to Emergency Planning and Response, an element of OSHA's PSM standard, as *Emergency Management.* According to CCPS,

> Emergency Management includes 1) planning for possible emergencies, 2) providing resources to execute the plan, 3) practicing and continuously improving the plan, 4) training or informing employees, contractors, neighbors, and local authorities on what to do, how they will be notified, and how to report an emergency, and 5) effectively communicating with stakeholders in the event an incident does occur [17, p. 510].

The CSB found that Watson Grinding had a written emergency response plan in place at the time of the incident that identified propylene as a major fire hazard. However, the plan did not address any additional hazards of propylene or discuss how to respond to a leak. Watson Grinding also did not formally train its workers to recognize or respond to a propylene gas release. As a result, on the day of the incident, workers did not evacuate the area after suspecting a propylene leak, did not prevent others from entering the area, and did not contact emergency responders for help.

The CSB concludes that had Watson Grinding developed and implemented an effective emergency response plan for potential propylene leaks, and effectively trained workers on the plan, no workers should have been harmed once a propylene leak was suspected. When the propylene leak was detected, Watson Grinding workers should have been able to evacuate to a safe distance, notified emergency responders, and prevented other workers from approaching the facility.

5 Conclusions

5.1 Findings

Technical Analysis

1. By not closing one of the two manual shutoff valves, the propylene storage tank was not isolated from the piping that supplied propylene vapor to the coating building. When the propylene leak began overnight in Booth 4, the lack of isolation allowed propylene gas to continue to flow into Booth 4 and accumulate inside the coating building.

2. A Watson Grinding worker entered the coating building and likely turned on the internal lights near the main entrance, igniting the flammable propylene vapor and triggering the explosion. The electrical devices located in the coating building's common area, including the lights, were not designed to be safe in a flammable atmosphere, making any of them a potential ignition source if activated.

3. The propylene leak began when a rubber welding hose, which was degraded and poorly crimped, disconnected from its fitting overnight in Booth 4. Propylene gas continued to flow into Booth 4 and accumulated inside the coating building.

4. The Booth 4 automated gas detection alarm, exhaust fan startup, and gas shutoff system was not functional at the time of the propylene leak. Had the system been functional, it would have alarmed to alert employees, started up the exhaust fan, which would have removed the leaking propylene from inside the booth, and remotely shut off the propylene storage tank, stopping the flow of propylene vapor and likely preventing the dangerous accumulation of propylene from Booth 4. Evidence indicated that Watson Grinding did not effectively respond to reports in 2013, 2016, 2019, and two weeks before the January 2021 explosion, of the gas detection alarm, exhaust fan startup, and gas shutoff system not being connected to the computer control system (a PLC).

Process Safety Management

5. Watson Grinding could have prevented the incident by developing an effective process safety management program and implementing process safety management system elements for its propylene process, such as process safety information, process hazard analysis, management of change, mechanical integrity, and operating procedures.

6. Deficiencies in process knowledge and documentation at Watson Grinding significantly contributed to the incident. Watson Grinding did not maintain critical process safety information for the automated gas detection alarm, exhaust fan startup, and gas shutoff system. Such documentation is necessary to maintain the reliability of this critical safety system. The lack of this information contributed to this system not being functional on the day of the incident. Had the system worked, it should have prevented the accumulation of flammable propylene gas within the coating building.

7. Had Watson Grinding performed an effective process hazard analysis on its propylene process, it should have identified the hazards of a propylene leak and considered the critical safeguards necessary to control the hazards. Such an analysis should have identified the fact that the gas detection system was no longer

capable of automatically triggering alarms, starting up the exhaust fan, or shutting off the propylene supply if a dangerous concentration of propylene accumulated in a coating booth. Action items to restore the functionality of the system should have then been promptly developed and implemented.

8. Watson Grinding could have reduced the likelihood of an incident by performing a management of change review prior to replacing rigid copper tubing with a less robust Grade R flexible rubber welding hose in its propylene process.

9. A robust mechanical integrity program would have ensured that an effective inspection, testing, and preventive maintenance system was in place to maintain the integrity of the automated gas detection alarm, exhaust fan startup, and gas shutoff system. Such a program should have ensured a prompt response to reports and inspections about the non-working conditions of those systems.

10. A robust mechanical integrity program, which would have ensured the proper crimping of the fitting to the recommended grade of rubber welding hose, as well as effective inspection and testing of the hose, would have helped prevent the propylene release.

11. Watson Grinding could have reduced the likelihood of an incident if it had developed and effectively trained its workers on operating procedures that included a requirement to effectively isolate the propylene storage tank from the coating building at the end of each workday.

12. Had CGA required or otherwise urged its members like Matheson to share information with their customers such as Watson Grinding on the need for a process safety management program to manage the hazards associated with hazardous chemicals such as propylene, Watson Grinding may have developed and implemented an effective process safety program, which could have prevented the incident.

Emergency Preparedness

13. Had Watson Grinding developed and implemented an effective emergency response plan for potential propylene leaks, and effectively trained workers on the plan, no workers should have been harmed once a propylene leak was suspected. When the propylene leak was detected, Watson Grinding workers should have been able to evacuate to a safe distance, notified emergency responders, and prevented other workers from approaching the facility.

5.2 Cause

The CSB determined the cause of the accidental release of propylene was a degraded and poorly crimped rubber welding hose that disconnected from its fitting inside a coating booth, combined with two other circumstances (1) not closing the manual shutoff valve at the propylene storage tank at the conclusion of production operations the previous workday; and (2) the inoperative automated gas detection alarm, exhaust fan startup, and gas shutoff system. The CSB concluded that the propylene vapor likely ignited when an employee entered the coating building and turned on the lights.

Contributing to the cause of the incident was the lack of a comprehensive process safety management program, including the absence of critical process safety information, a hazard assessment of the propylene process, a mechanical integrity program, a management of change review, and written operating procedures. Contributing to the severity of the incident was the lack of an effective emergency response plan that should have instructed workers to evacuate from the area, prevented others from entering the area, and notified emergency responders when the flammable propylene gas leak was suspected or detected.

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 Compressed Gas Association (CGA)

2020-03-I-TX-R1

Urge member companies that handle hazardous chemicals to share information with their customers about (1) the safety issues described in this report and (2) why their customers should develop and implement effective process safety management systems as part of their own internal safety programs, including informing member companies' customers about CGA P-86, *Guideline for Process Safety Management*, the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*, or an equivalent approach.

6.2 Matheson Tri-Gas Inc.

2020-03-I-TX-R2

Provide your customers with information about (1) the safety issues described in this report and (2) why your customers should develop and implement effective process safety management systems as part of their own internal safety programs, including informing customers about CGA P-86, *Guideline for Process Safety Management*, the Center for Chemical Process Safety's *Guidelines for Risk Based Process Safety*, or an equivalent approach.

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. Companies have a duty of care to ensure the safety of workers at their facilities who handle flammable gases or other hazardous materials and protect surrounding communities and the environment regardless of whether the chemical(s) on-site meet the threshold quantity under OSHA's PSM standard or EPA's RMP rule. To prevent catastrophic incidents, a company should apply a process safety management system such as CGA P-86 *Guideline for Process Safety Management*, CCPS' *Guidelines for Risk Based Process Safety*, or CCPS' *Guidelines for Implementing Process Safety Management.* The harm to Watson Grinding workers and to members of the surrounding community occurred because Watson Grinding did not develop and implement an effective process safety management program for its coating process.

2. At facilities that handle flammable gases or other hazardous materials, gas detection, alarm, exhaust, and shutdown systems must 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 chemicals. Inspections should identify disassembled or bypassed preventive measures as well as deterioration of equipment. Testing should go beyond system maintenance, such as sensor calibration, and ensure the functional integrity of the system. Alarms should clearly alert to the hazard through visual and audible indications. Shutoff valves should effectively isolate the flammable material. Facilities should promptly and effectively respond to reports of non-functional safety systems.

3. Facilities that handle flammable gases or other hazardous materials should ensure that there is a comprehensive written emergency response plan that adequately addresses all actions to be taken in the event of a chemical release. Workers must be trained on the plan, and periodic drills should be conducted to ensure the plan can be effectively implemented.

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Appendix A — Accident Map

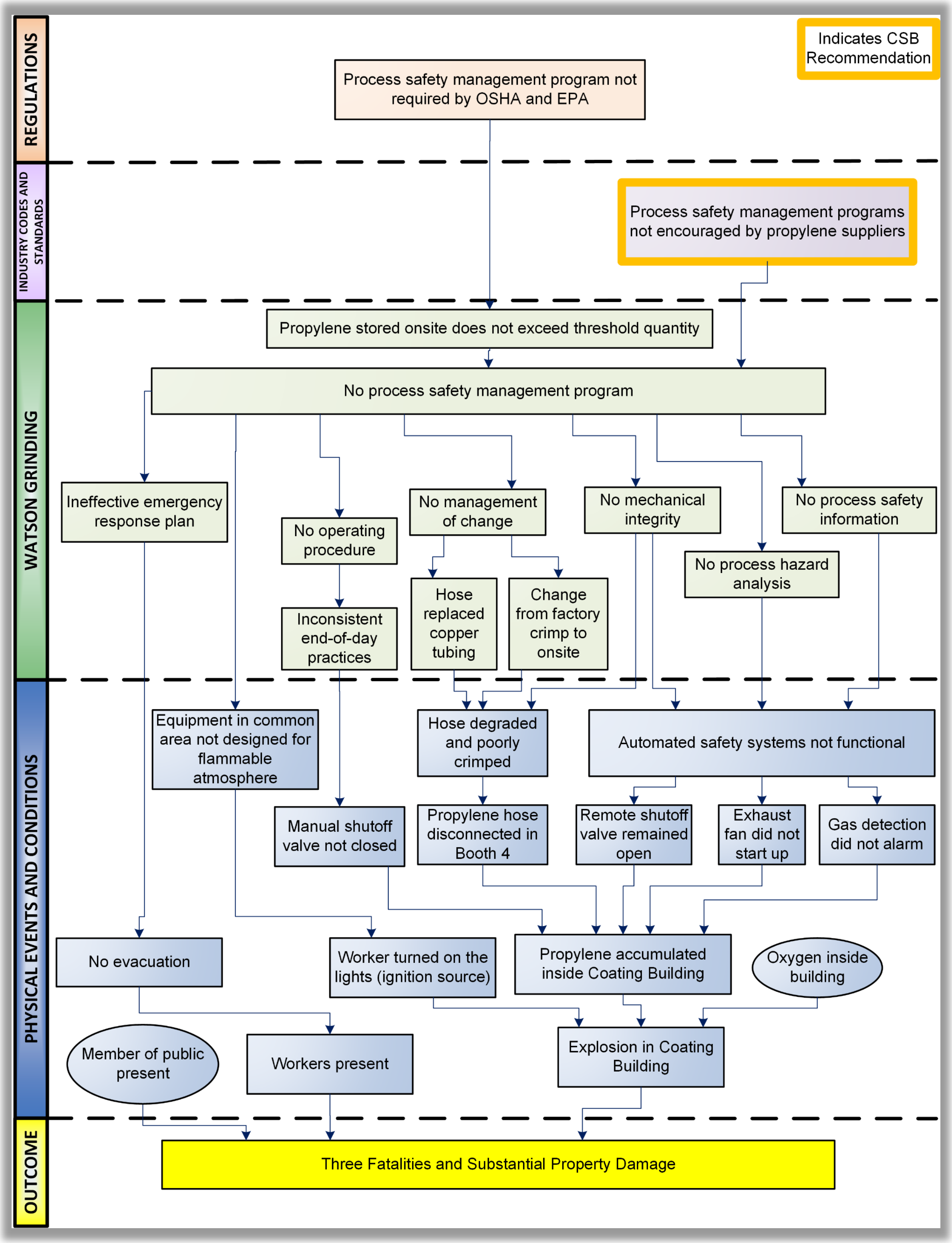

Figure 24. Accident Map. (Credit: CSB)

Appendix B—Description of Surrounding Area

There are four census tracts that are located within approximately one mile of the Watson Grinding facility (**Figure 25**). **Table 2** provides more detailed demographics for each census tract. Note that some of the demographic data cover areas outside of the approximately one-mile radius of the facility.[a]

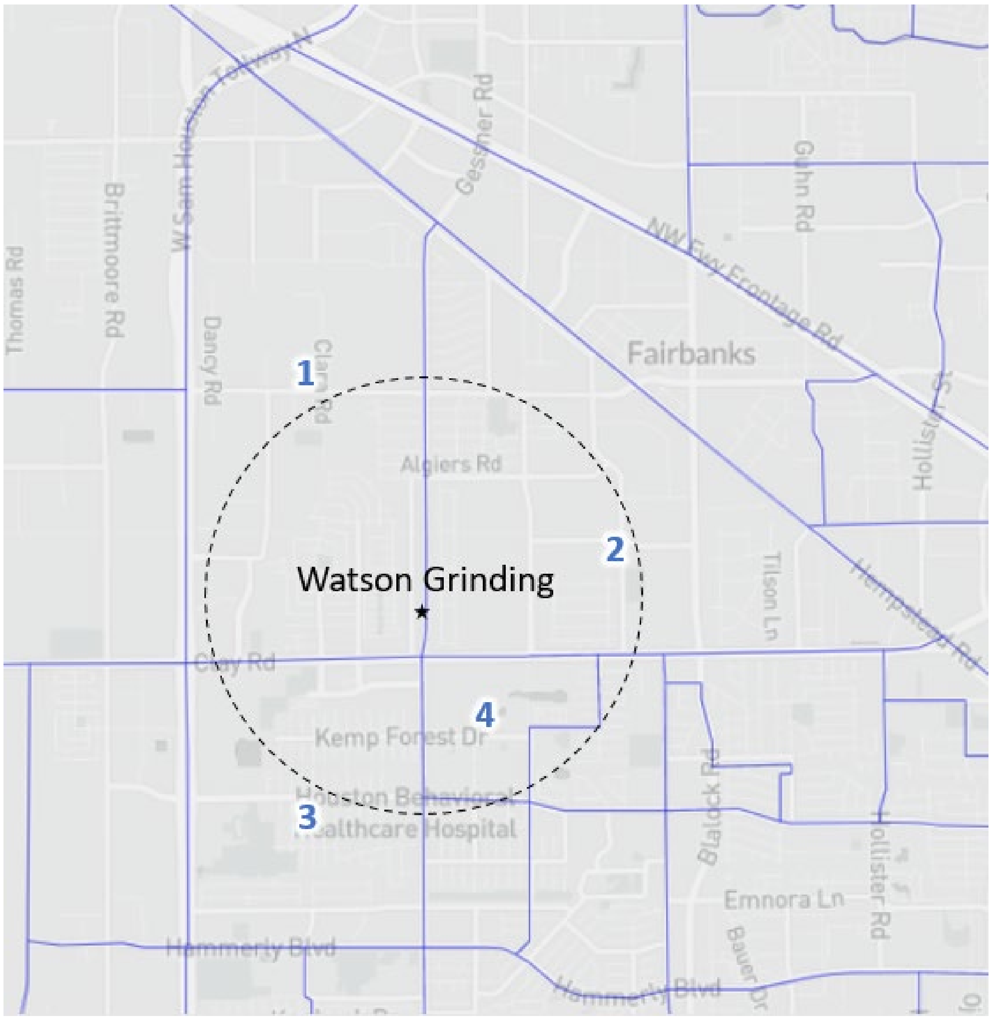

Figure 25. Census tracts within approximately one-mile vicinity of Watson Grinding facility. (Credit: CSB using data obtained from Google and Census Reporter)

[a] This information was compiled using 2020 Census data as presented by Census Reporter [30]. "Census Reporter is an independent project to make data from the American Community Survey easier to use. [It is] unaffiliated with the U.S. Census Bureau. A News Challenge grant from the Knight Foundation funded the initial build-out of the site. … Support for [Census Reporter's] 2020 Decennial Census features was provided by the Google News Initiative. … [T]he Medill School of Journalism at Northwestern University, home of the Knight Lab, [] provides in-kind support for some of Census Reporter's ongoing development. Most of [Census Reporter's] server hosting infrastructure is [] provided by the Oregon State University Open Source Lab [29]."

Table 2. Tabulation of the demographic data for the populations within the census tracts shown in **Figure 25**.

Tract Number	Population	Median Age	Race and Ethnicity		Per Capita Income	% Persons Below Poverty Line	Number of Housing Units	Types of Structures	
1	5,409	43.4	17%	White	$24,094	8.2%	1,838	88%	Single Unit
			8%	Black				10%	Multi-Unit
			1%	Native				2%	Mobile Home
			17%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			57%	Hispanic					
2	3,046	38.6	11%	White	26,724	14.8%	1,072	99%	Single Unit
			13%	Black				1%	Multi-Unit
			0%	Native				0%	Mobile Home
			1%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			1%	Two+					
			74%	Hispanic					
3	6,263	41.3	45%	White	40,315	2.8%	2,660	59%	Single Unit
			12%	Black				41%	Multi-Unit
			0%	Native				0%	Mobile Home
			11%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			4%	Two+					
			28%	Hispanic					
4	1,871	37.9	42%	White	$37,603	32.8%	1,038	37%	Single Unit
			2%	Black				63%	Multi-Unit
			0%	Native				0%	Mobile Home
			1%	Asian				0%	Boat, RV, van, etc.
			0%	Islander					
			0%	Other					
			0%	Two+					
			55%	Hispanic					

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