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EPA CHEMICAL ACCIDENT INVESTIGATION REPORT

Pennzoil Product Company Refinery Rouseville, Pennsylvania

REPORT

The EPA Accident Investigation Program

EPA has a responsibility under section 112(r) of the Clean Air Act Amendments of 1990 for the prevention and mitigation of accidental chemical releases. One of the fundamental ways to prevent accidents is to understand why accidents occur and to apply the lessons learned to prevent future incidents. Consequently, EPA has a responsibility to investigate and understand why certain chemical accidents have occurred. A key objective of the EPA chemical accident investigation program is to determine and report to the public the facts, conditions, circumstances, and causes or likely causes of chemical accidents that results, or could have resulted in a fatality, serious injury, substantial property damage, or serious off-site impact, including a large scale evacuation of the general public. The ultimate goal of the accident investigation is to determine the root causes in order to reduce the likelihood of recurrence, minimize the consequences associated with accidental releases, and to make chemical production, processing, handling, and storage safer. This report is a result of an EPA investigation to describe the accident, determine root causes and contributing factors, and identify findings and recommendations.

In the EPA accident investigation report preparation process, companies mentioned in the report are provided a draft of only the factual portions (no findings, conclusions or recommendations) for their review for confidential business information. Federal agencies are required by provisions of the Freedom of Information Act (FOIA), the Trade Secrets Act, and Executive Order 12600 to protect confidential business information from public disclosure. As part of this clearance process, companies often will provide additional factual information that EPA considers and evaluates for possible inclusion in the final report.

Chemical accidents investigated by EPA Headquarters are conducted by the Chemical Accident Investigation Team (CAIT) located in the Chemical Emergency Preparedness and Prevention Office (CEPPO) at 401 M Street SW, Washington, DC 20460, 202-260-8600. More information about CEPPO and the CAIT may be found at the CEPPO Homepage on the Internet at http://www.epa.gov/ceppo.

Basis of Decision to Investigate and Scope

An explosion and fire occurred at the Pennzoil refinery in Rouseville, Pennsylvania, on October 16, 1995, resulting in deaths, injuries, public evacuation, and significant plant damage. EPA and OSHA undertook an investigation of this incident because of the seriousness of the consequences and the opportunity for lessons learned to prevent a similar accident from occurring in the chemical and petrochemical industry. The scope of the investigation and this report are solely focused on the conditions and circumstances related to the storage tanks where the explosion and fire occurred. This report is based on information gathered and developed by EPA and OSHA before OSHA reached any settlement agreement with Pennzoil. However, OSHA had no part in writing the report.

Executive Summary/Overview

At about 10:15 a.m., on October 16, 1995, an explosion and fire occurred at Plant No. 1 of the Pennzoil Products Company refinery in Rouseville, Pennsylvania. After the initial explosion, flames quickly engulfed a large area of the refinery, including areas under construction, storage trailers, a trailer where contractors took work breaks, and many storage tanks. The flames ignited several tanks containing naphtha and fuel oil. During the fire, several loud explosions could be heard as compressed gas cylinders and other sealed containers exploded. The explosions hurled some plant debris beyond the fenceline. Thick black smoke spread throughout the area. The fire forced Pennzoil employees and contractors at the plant, residents of the town of Rouseville and an elementary school, and the Pennzoil office across Route 8 from the facility, to evacuate. Firefighters extinguished the fire at about 12:30 p.m. that same day. Three workers were killed in the fire, and three others were injured. Two of the injured died later as a result of their injuries. The fire resulted in extensive damage to the facility. Minor "sheening" was reported on the stream that runs past the refinery, but there were no reports of any materials spilled into the stream or environmental damage.

A welding operation was in progress on a service stairway located between two waste liquid storage tanks (Tanks 487 and 488) at the time of the incident. These tanks contained mixtures of waste hydrocarbons and water. A hot work (welding, cutting) permit had been prepared, as required by Occupational Safety and Health Administration (OSHA) standard, which included combustible gas detection prior to welding to ensure the safety of the work.

The EPA Chemical Accident Investigation Team (CAIT) identified the immediate cause of the fire and the conditions which triggered the serious consequences. The immediate cause of the fire was the ignition of flammable vapors in storage tank 487. Although the CAIT could not determine the exact mechanism, there are at least two likely scenarios: undetected flammable vapors emitted from tank 487 were ignited by an ignition source which then flashed back into the tank; or an electrical discharge in the tank 487, generated by the arc welding, ignited flammable vapors in the tank.

When the flammable vapors in storage tank 487 ignited, its combustion likely caused a rapid pressure increase inside the tank. The tank failed along its bottom seam and shot up into the air, instantaneously releasing its entire contents. The burning liquid released from tank 487 apparently caused the ignition of flammable vapors in the adjacent tank, tank 488. Tank 488 also failed along its bottom seam and shot up, releasing its contents. Since these two storage tanks have no secondary containment, the burning liquid released from these two tanks quickly spread the fire through the refinery.

The CAIT identified the following as root causes and contributing factors in the accident:

- <u>Vessel design, integrity, and maintenance were inadequate.</u> The vessels did not have fire protection capability and had no provision for either emergency venting or frangible roof seams. Following the explosion of vapors, the vessels failed along their corroded bottom seams, releasing their contents.

- Preparation for hot work in the storage tank area was inadequate. The tanks containing combustible or flammable vapors were not thoroughly isolated from the hot work site and, in addition to the welding itself, several ignition sources were present.

- There was a lack of awareness of the impact of changing conditions at the hot work site. Although combustible gas testing prior to the start of hot work early in the morning indicated that vapors were not present, gradual warming could make the presence of combustible vapors more likely.

- Equipment siting and containment was inadequate. Burning liquid released from the tanks was not contained or impounded, impacting other areas of the facility. In addition, tool and work break trailers were spotted within a general containment area near the tanks. These trailers were destroyed by the liquid and fire.

The CAIT developed the following recommendations that address the root causes and contributing factors to prevent a reoccurrence or similar event at this and other facilities:

- Process safety management systems and process hazards analysis techniques should include waste handling operations to ensure that all chemical and process hazards are identified and controlled and equipment integrity is maintained;

- Pennzoil and other facilities should examine hot work permit processes and consider development of management systems to ensure that all vapor and ignition sources are identified and controlled;

- Facilities need to recognize the impact of changing conditions on hot work and other hazardous work tasks. Industry should consider the value of continuous or periodic work permit rechecks and the application of process hazard analysis techniques to ensure greater control over possible changes in routine work situations;

- Facilities should use hazard assessment techniques to address the hazards associated with vehicular access and location of temporary work trailers in the vicinity of storage vessels; and

- The potential for catastrophic vessel failure, no matter how remote, should be evaluated along with other likely spill and leak scenarios, to determine the need for secondary containment or other impoundment as a means of preventing impact on other site areas.

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1.0 Background

1.1 Facility Information

The Pennzoil facility in Rouseville, Pennsylvania has been in existence for about 100 years. The first U.S. oil well was drilled near Titusville, about 10 miles north of the refinery, in 1859. The refinery sits in a river valley along the eastern banks of the Oil Creek. The town of Rouseville, with approximately 750 residents, is located next to the refinery. The facility refines crude oil into a number of hydrocarbon products and has been expanded and modified many times over the years. A new wax plant was under construction at the time of the incident.

Exhibit 1 is a map showing the location of Rouseville in Pennsylvania. A map of the Pennzoil refinery site is shown in **Exhibit 2**. The area of the explosion and fire is indicated by a box on the map in **Exhibit 2**. **Exhibit 3** shows in more detail the area near storage tanks 487 and 488 where the explosion and fire occurred.

About 20 other large storage tanks were located in the same area as tanks 487 and 488. Next to tanks 487 and 488 were a naphtha tank, two number 6 fuel oil tanks, and several other tanks being serviced (see **Exhibit 3**). To the west and north of the tanks was a concrete wall, about five feet tall, separating the plant area from the Oil Creek on the west side and a stream to the north. Along the wall were four trailers, including three tool trailers where contractors working on site kept their tools and a trailer where the contractors took their breaks. Within this walled section is a maintenance road used by facility personnel and contractors.

The EPA Chemical Accident Investigation Team (CAIT) focused its attention on the conditions and circumstances related to the storage tanks where the explosion and fire occurred. The sections below describe the equipment, operations and activities occurring at the time of the explosion and fire.

1.2 Process Information

Tanks 487 and 488, where the incident started, were used for storing waste mixtures of water and oil or other hydrocarbons, some of which were recovered from spills. The purpose of the tanks was to hold waste water and control its release into the water treatment facility through gradual drainage, thereby preventing overload of the water treatment facility. The waste mixtures were pumped into the tanks from vacuum trucks, which collected the waste liquids from drains, equipment, or other locations around the site. Over time, water and hydrocarbons will naturally separate and form distinct liquid phases based on density and polarity of the material. Following separation, the hydrocarbon layer could be returned for use as feedstock or reprocessing, while the water layer is gradually drained to wastewater treatment. Tanks 487 and 488 were not connected by pipes to any other tanks.

Exhibit 1
Location of Rouseville, Pennsylvania

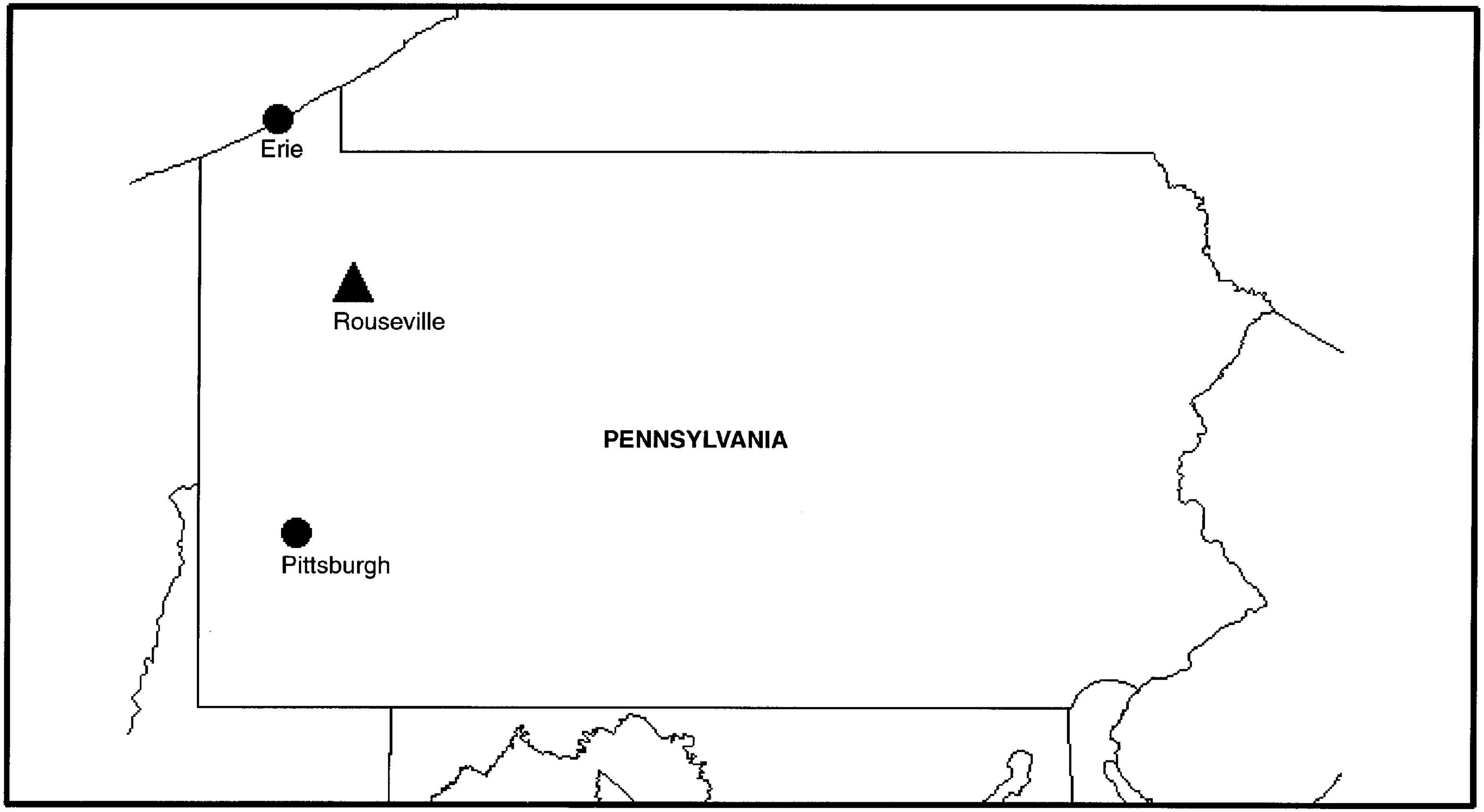


Exhibit 2
Rouseville Refinery Site Map

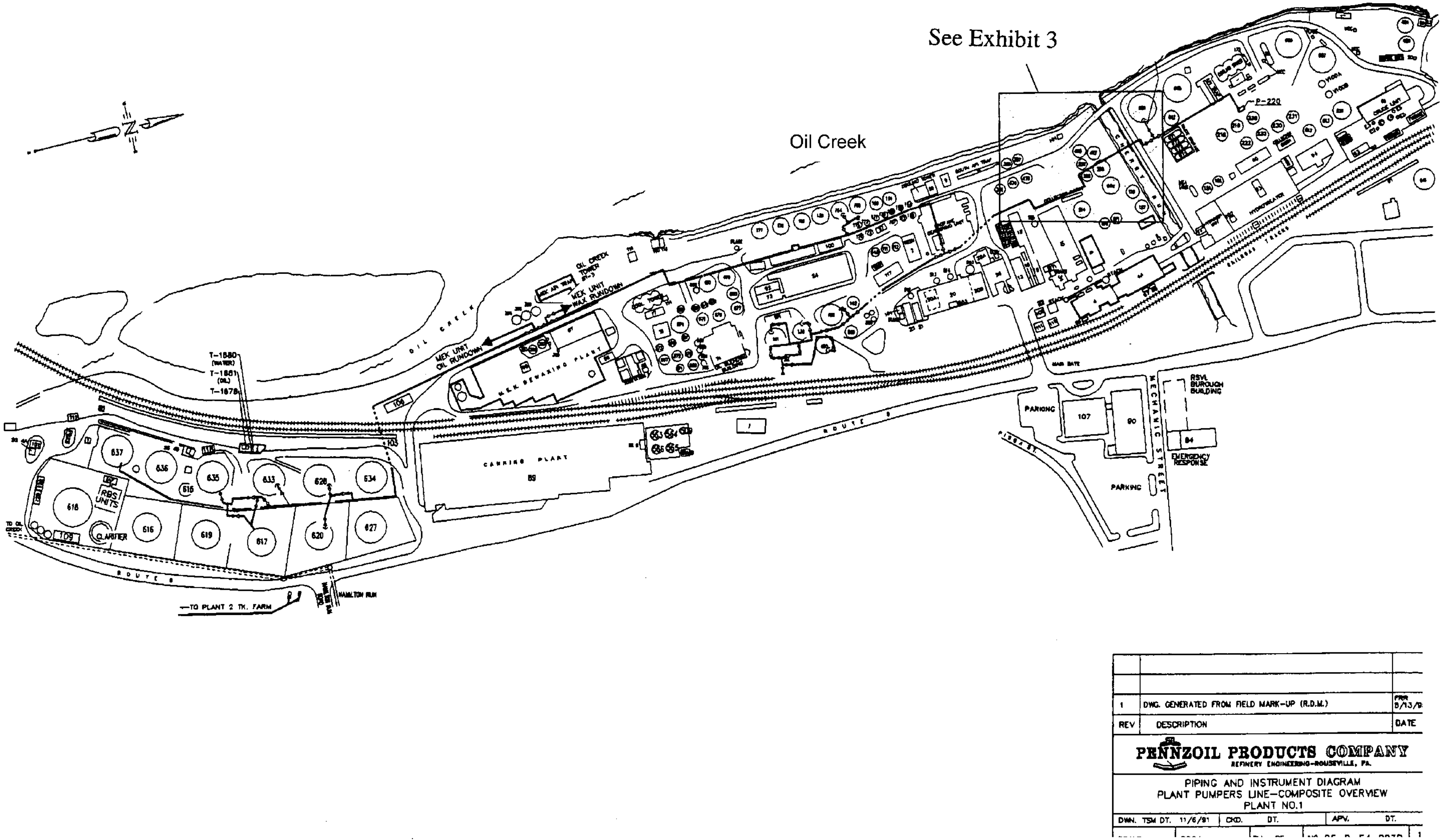
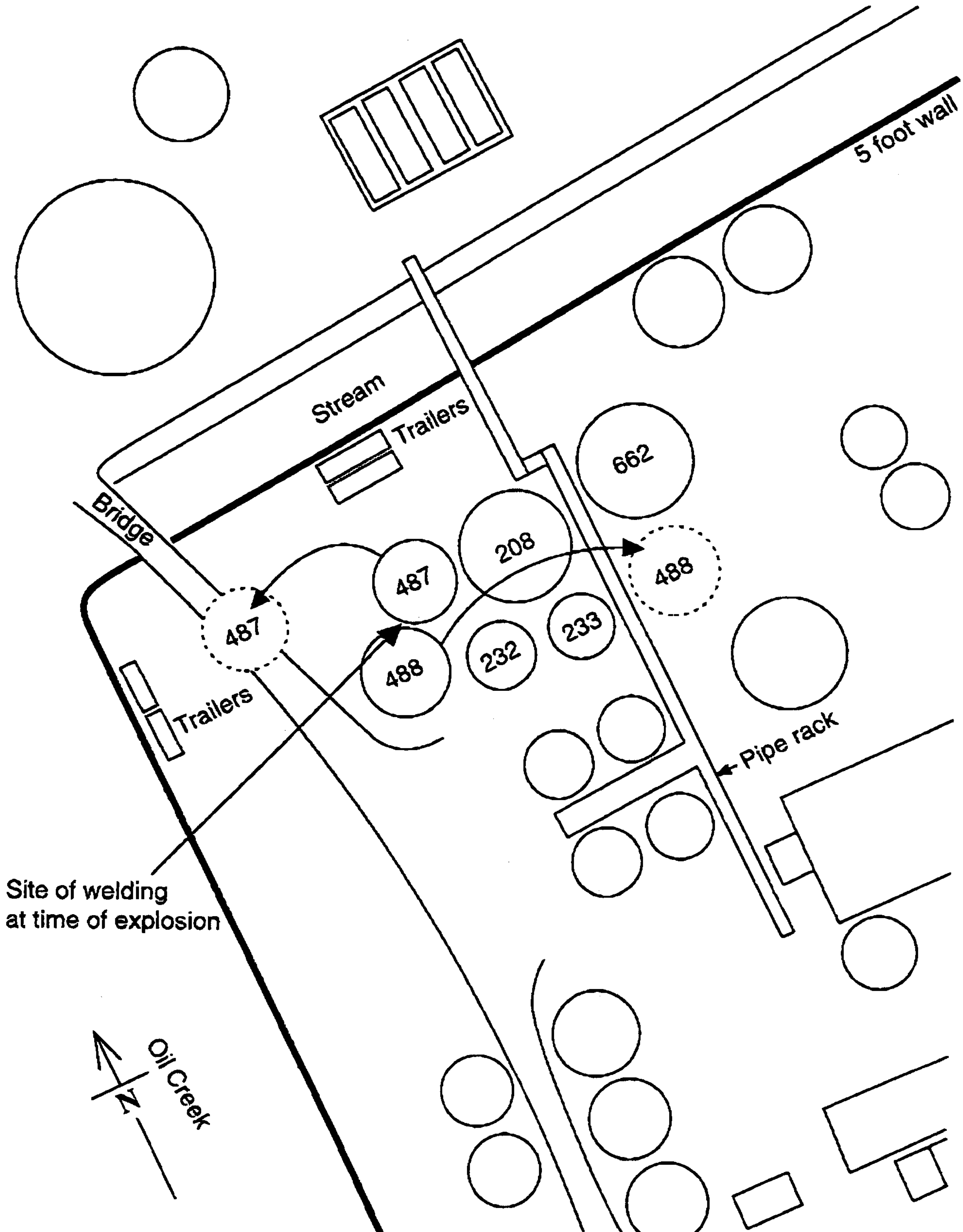


Exhibit 3
Area of Explosion and Fire at Pennzoil Refinery



Notes
Curved lines indicate trajectory of tanks 487 and 488
Tanks 487 and 488: Oil and water mixture
Tank 208: Naptha; burned in place

Tank 662: Empty, being cleaned
Tanks 232, 233: No. 6 fuel oil (thick, heavy oil)

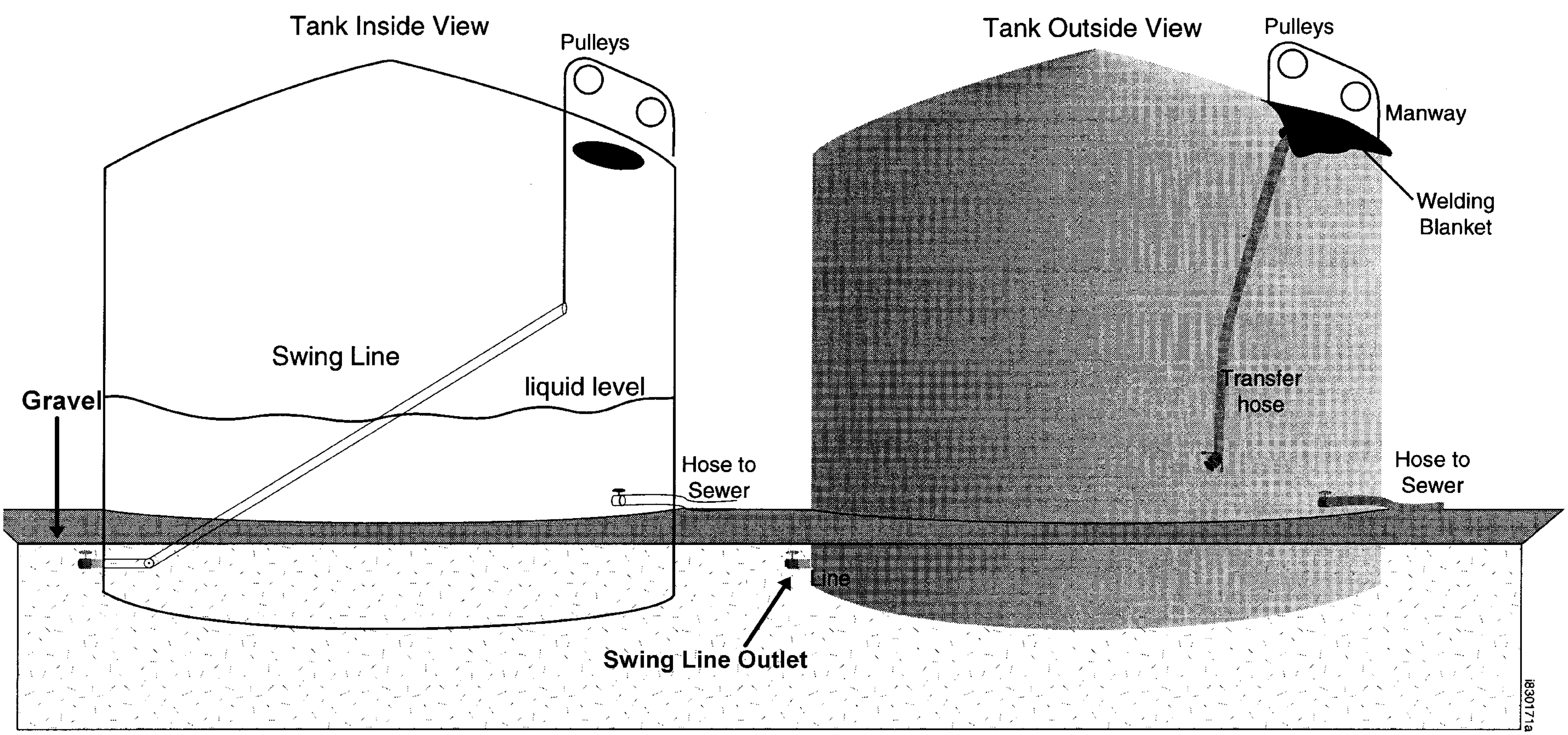
Tanks 487 and 488, which were similar in size and design, were 30 feet in diameter with 25-foot high sidewalls and five-foot high domes. The tanks, built in 1937, were constructed of steel plates riveted together. The riveted "umbrella" domes were replaced in 1950. The tanks were about four feet apart and shared a common set of stairs leading to the top for employee activities such as gauging the volume of liquid in the tank or inspections. These tanks were not individually diked; i.e., they did not have a secondary containment wall around them. However, they were located in a general tank farm area that had walls and berms to prevent any spilled materials from reaching the Oil Creek.

At the time of the incident, a three-inch transfer hose was draped over the side of tank 487. One end of the hose extended a few feet through the manway (a large opening in the top of the tank for access) into the top of the tank while the other end extended to the ground outside. The hose was held in place under the stairway structure with wire. This hose was used for transferring liquids from vacuum trucks into the tank. Inside the tank was also a moveable pipeline ("swingline") that connected to a valve outside the tank near the base. The swingline was used to drain liquids from various levels within the tank, e.g. at the bottom, water could be drawn off; near the top, hydrocarbons. The elevation of the swingline was adjusted using a cable and pulley arrangement on the side of the tank. At the time of the accident, the swingline opening inside tank 487 was positioned above the liquid level in the vapor space of the tank. Finally, a drain valve and hose were fitted to the side of the tank near the base. The hose extended from the side of the tank to a sewer located near the naphtha storage tank (#208). The drain valve and hose were used to drain water from the bottom of the tank to wastewater treatment. **Exhibit 4** shows inside and outside views of tank 487 with the transfer hose, swingline and pulley, and drain valve.

1.3 Chemical Information

The specific chemicals in the tanks where the explosions took place, and the quantity in the tanks, are not precisely known. The hydrocarbon content of the tanks could vary widely in composition from day to day because of the nature of the process (i.e., storage of waste liquids from drains, equipment cleaning and spills). The volume in the tanks also varied. On July 16, 1995, the last time the tanks were gauged, tank 487 had 19 feet of liquid (approximately 100,000 gallons), and tank 488 had 22 feet of liquid (approximately 116,000 gallons); no information is available on the volume of the hydrocarbon and water layers. A few days before the incident, a vacuum truck reportedly discharged an unknown quantity of methyl ethyl ketone (MEK) to one or both of the tanks. MEK is flammable (NFPA 3 out of 4), only partially miscible with water, has a low fire point (lower flammable limit is 1.8%) and its vapors are denser than air (Lees, 1996). The flash point of MEK is 20 F. A Material Safety Data Sheet (MSDS) for MEK is provided in **Appendix B**.

Exhibit 4
Inside and Outside Views of Tank 487



2.0 Description of the Accident

On the morning of October 16, 1995, about 100 people were working at the plant. About 50 of the workers were contractors, including many pipe fitters and welders. The weather was clear and cool.

At 7:40 a.m., a Pennzoil safety officer prepared and issued a hot work permit, valid from 7:40 a.m. to 3:30 p.m., for two Pennzoil employees to weld a handrail to the stairs on storage tanks 487 and 488. The safety technician had inspected the setup before giving the final approval for the welding. The hot work permit required that all manways at the top of the tanks be covered, that the welding machine be grounded as close as possible to the points being welded, and that a fire watch be present at all times on the ground. (A fire watch is a person designated to watch for small fires that might occur when welding slag or spatter drips from the work area; the fire watch must have fire extinguishing equipment readily available and be trained in its use.) The permit stated that there must be no welding near the top of the tank (the manways were located at the top of the tanks). It also required measurement of the area for combustible vapor. All of these precautions were taken to minimize the occurrence of fire.

The area was prepared for hot work by spotting a welding machine near the work location, setting up welding and grounding cables, rigging the stairway in place and placing welding blankets around the work area. The welding blankets, generally made of heavy canvas, collect sparks, slag or spatter emitted from the welding operation and serve to reduce the potential for fire. The Pennzoil safety technician took combustible vapor measurements around the welding area with a combustible gas detector before approving the hot work permit to allow welding. The combustible gas detector indicated that no combustible vapors were present in the welding area.

One welder began arc welding on the stairs, using a welding machine with an internal combustion engine-driven generator. The second welder served as the fire watch on the ground. The welder was instructed not to weld on the handrail closest to the roof of the tanks, because it was too close to the openings on the tank.

At around 9:30 a.m., the welder and fire watch took a break after having tack welded the handrail in place with the aid of riggers (tack welding is an initial welding step). The riggers assisted in positioning the handrail in its proper location for tack welding.

The welder and fire watch returned to work at 10:00 a.m. They were unable to restart the engine on their welding machine. At about 10:10 a.m., two employees in a maintenance truck gave the welding machine a jump start.

At 10:15, an explosion occurred in tank 487, followed in less than a minute by a second explosion in tank 488. It is not precisely known whether the welders had actually started welding following the jump start at the time the explosion occurred. Witnesses reported seeing one welder on the platform between the two flights of stairs and the other at the bottom of the stairs shortly before the incident. No one reported seeing welding taking place at that time.

As a result of the explosions, each tank failed catastrophically at the bottom seam where the vertical sidewall of the tank was connected to the bottom horizontal floor plate, lifting the tanks up in opposite directions. Tank 487 lifted off its base and landed about 20 feet to the west. Tank 488 landed about 50 feet to the east after clearing a storage tank and a pipe rack. The burning contents of the tanks, released when the tanks failed, created a wave of burning hydrocarbon that engulfed the entire area.

Employees nearby reported hearing a whooshing sound followed by a low boom and seeing a tide of flame spreading through the site. Some employees reported hearing two sets of whooshing sounds followed by a boom. One nearby employee reported seeing flames on the southwest side of tank 487; according to the employee, the flames continued around the base of the tank, then reached and swept over the top, followed by the explosion. Other employees did not report seeing flames until after the explosion. No witness interviewed had an unobstructed continuous view of the entire event.

The welder who had been welding the railing was found on the bank of the Oil Creek with burns over 60 percent of her body. The welder who had been acting as the fire watch was killed in the fire. Two contractor employees also were killed in the fire; they were found in the remains of the trailers located near the tanks. Three employees (two contractor employees and the Pennzoil welder) were seriously burned; the welder and one contractor employee later died from their injuries.

Thirteen liquid storage tanks, piping, and electrical lines in the area and some parts of the new wax plant under construction were damaged. The fire ignited the contents of a number of liquid storage tanks; it consumed one tank (70,434 gallons) of naphtha solvent, two tanks (1,605 gallons) of Stoddard solvent, and two tanks (21,057 gallons) of No. 6 fuel oil. These tanks burned in place; they did not rupture and spill their contents, which limited the spread of the fire. A number of loud explosions were reported during the fire. These are believed to have been the result of gas cylinders and sealed piping rupturing during the fire.

Exhibit 5 presents photographs of the area following the explosion and fire (refer to **Exhibit 3** for a diagram of this area with tank numbers). **Photograph A** is an overhead view with arrows indicating the locations of tanks 487 and 488 after the explosion. The Oil Creek can be seen at the top of this photograph. **Photograph B** shows dips in the ground at the locations of the bases of tanks 487 and 488; this photo also shows the remains of tank 487. Tank 488 after the explosion is shown in **Photograph C**.

Some plant debris, including charred pipe insulation, landed on the hill across the road from the refinery. The explosions also hurled pieces of a small fuel container into the business and residential area beyond the fenceline. The five-foot walls separating the area from the river and stream apparently prevented any released liquid from spilling into the water.

About 140 firefighters responded to the incident. At 12:30 p.m., the fire was extinguished. A fire drill had been held the day before, with participation by area fire departments, the refinery's fire brigade, hazardous materials specialists on site, local and state police, and the Pennsylvania Emergency Management Agency. The response to the incident was considered successful and very quick, and response personnel suffered no significant injuries; the success was attributed in part to the fire drill.

The sequence of events is summarized as follows:

7:40 a.m.	Hot work permit issued for stairway handrail welding at Tanks 487 and 488.
7:45-9:30 a.m.	Tack welding work commences and continues without incident;
9:30 a.m.	Welders take break after tack welding the hand rail;
10:00 a.m.	Welders return to work after break; welding machine won’t start;
10:10 a.m.	Welding machine is jump started;
10:15 a.m.	Explosion and fire occur at tank site. Wave of flame observed spreading throughout plant. Emergency response commences.
12:30 p.m.	Fire extinguished.

Exhibit 5
Photographs of Explosion Area

A. Overhead view of explosion area.

B. Dips in ground showing the original site of tanks 487 & 488. Tank 487 in background.

C. Tank 488, after explosion.

3.0 Analyses and Facts

3.1 Analyses

After the accident, CAIT investigators photographed the fire location, tanks and piping and interviewed employees to determine the process and operations involving the storage tanks and the sequence of events leading to the explosions and fire. In addition, several pieces of equipment, such as the tanks and swinglines, were examined as closely as possible. However, much of the area and equipment were heavily damaged or destroyed including portions of the tanks and piping, hoses, the welding machine, welding cables, etc. and could not be thoroughly tested or examined. The exact condition of this equipment prior to the incident is not precisely known.

The CAIT used the information collected to develop an Event and Causal Factors Chart (described below). The Event and Causal Factors Chart combined with the factual information collected in addition to professional and engineering judgement were used to determine the causes of this accident.

3.2 Facts

The CAIT assembled the following facts using the information collected:

- Tanks 487 and 488 were intended to function as waste water tanks - holding up waste water and hydrocarbon mixtures to reduce load on waste water treatment;

- Handrails needed to be secured by welding to stairs installed between the tanks;

- Precautions were taken to control flammable vapor and eliminate ignition sources. These included covering the storage tank manway and preparation of a hot work permit;

- Welders were instructed to keep hot work away from manways on the tanks and to secure the electric arc grounding lead close to the work;

- Combustible gas testing was conducted prior to the start of welding work. Test results indicated that no combustible vapors were present in the welding area;

- Initial welding work proceeded without incident from about 7:30 a.m. to 9:30 a.m.;

- Combustible gas testing was conducted only once, early in the morning. It does not appear that the area was retested for combustible gases prior to the restart of work following the midmorning break;

- Following ignition of vapors, the storage tanks failed along their bottom seam and lifted off their base, releasing their contents.

- Once released, the burning liquid flowed without restriction to other areas nearby involving trailers, storage tanks and other equipment in the fire; and

- Tool and work break trailers were spotted in the vicinity of storage tanks 487 and 488.

4.0 Causes of the Accident

The immediate cause of the fire was the ignition of flammable vapors in storage tank 487. Although the CAIT could not determine the exact mechanism, there are at least two likely scenarios: undetected flammable vapors emitted from tank 487 were ignited by an ignition source which then flashed back into the tank; or an electrical discharge in the tank 487, generated by the arc welding, ignited flammable vapors in the tank.

When the flammable vapors in storage tank 487 ignited, its combustion likely caused a rapid pressure increase inside the tank. The tank failed along its bottom seam and shot up into the air, instantaneously releasing its entire contents. The burning liquid released from tank 487 apparently caused the ignition of flammable vapors in the adjacent tank, tank 488. Tank 488 also failed along its bottom seam and shot up, releasing its contents. Since these two storage tanks have no secondary containment, the burning liquid released from these two tanks quickly spread the fire through the refinery.

The accident investigation identified several possible sources of vapor and ignition in the storage tank area and reasons why vapors may not have been detected. The investigation team also sought to identify root causes and contributing factors to the incident and its severity. These are presented in Section 4.6.

Exhibit 6 is an Event and Causal Factors Diagram for the accident. This diagram presents the sequence of events, with the description of each event enclosed in a rectangle, and factors that may have contributed to the occurrence of each of the events.

Four potential vapor sources along with three potential ignition sources are described below. Each of the causal factors discussed in these potential sources is shown graphically in the Event and Causal Factors Diagram. Possible reasons that an undetected combustible atmosphere occurred are presented next. Additional vapor and ignition sources are also discussed. Finally, factors that may have contributed to the severity of the consequences of the incident are discussed at the end of this section.

Exhibit 7 shows tanks 487 and 488 with the approximate positions of the welders at the time of the accident. This exhibit also indicates potential sources of combustible vapor and potential sources of ignition, as discussed below.

4.1 Potential Vapor Sources

Vapor Escaping from Open Manway. Placement of a hose for discharge of liquids from vacuum trucks through the open manway into tank 487 prevented the manway cover from completely sealing the opening. Although a welding blanket was draped over this opening, vapor could have escaped into the surrounding area because the blankets are not designed to provide a vapor-tight seal. This potential vapor source is shown in Exhibit 7. The escape of vapor could have been aggravated by ambient conditions, since the outdoor temperature rose from early to mid-morning. The effect of ambient conditions is discussed in more detail under Section 4.3 below.

Additionally, the potential presence of MEK in the tank likely provided sufficient vapor for ignition. Although MEK is "appreciably soluble" in water, the amount of water present in the tank is unknown along with the amount of hydrocarbon which may have affected MEK solubility and vapor pressure. MEK vapors are denser than air and it is not known if sufficient driving force was present to have pushed vapors up and out the open manway. In addition, the vapors may have been diluted before reaching ignition sources.

Vapor Escaping from Swingline. The swingline could have provided a route for vapor release (see Exhibit 7). The swingline portion inside the tank was raised above the liquid level in the tank vapor space. Investigators found after the accident that the outside valve near the base of the tank connected to the swingline inside the tank was open. As above, as the tank warmed, if sufficient driving force was present, undiluted heavier-than-air flammable vapors could have been pushed out through the swingline and open valve. If there was little or no wind, these dense vapors could have collected at grade level near ignition sources (see below). After ignition, the flame front could have flashed back through the swingline, igniting vapors in the tank. However, the end fitting on the swingline valve outside the tank was buried under the soil. Further, inspection of the inside of the swingline, after the accident, revealed no evidence of burn or scorch marks.

Vapor Escaping from Transfer Hose. Vapor from the tanks could have exited through the open, three-inch transfer hose leading from inside the storage tank through the manway to the ground outside the tank, as shown in Exhibit 7. The hose remained after transfer of liquid from a vacuum truck and was wired in-place under the stairway near the welding operation. As for the swingline described above, the hose could have provided a route for vapor to be emitted and for flame to flash back into the tank. However, as for the manway, it is not known if sufficient driving force was present to have pushed vapors up and out the hose. In addition, investigators found no evidence of burn or scorch marks inside the hose upon examination after the accident.

Vapor Escaping from Holes in Tank. After the explosion and fire, investigators discovered some holes up to a quarter inch in diameter, presumed to be from corrosion, near the top of the tank. If these holes were present before the explosion, they could have provided a route for vapor release and flame front flashback (see Exhibit 7). However, ignition sources would need to be very close to ignite the small amount of diluted vapor expected from this

Exhibit 6
Event and Causal Factors Diagram
October 16, 1995 Explosion of Tanks 487 & 488 at Pennzoil Refinery - Rouseville, PA

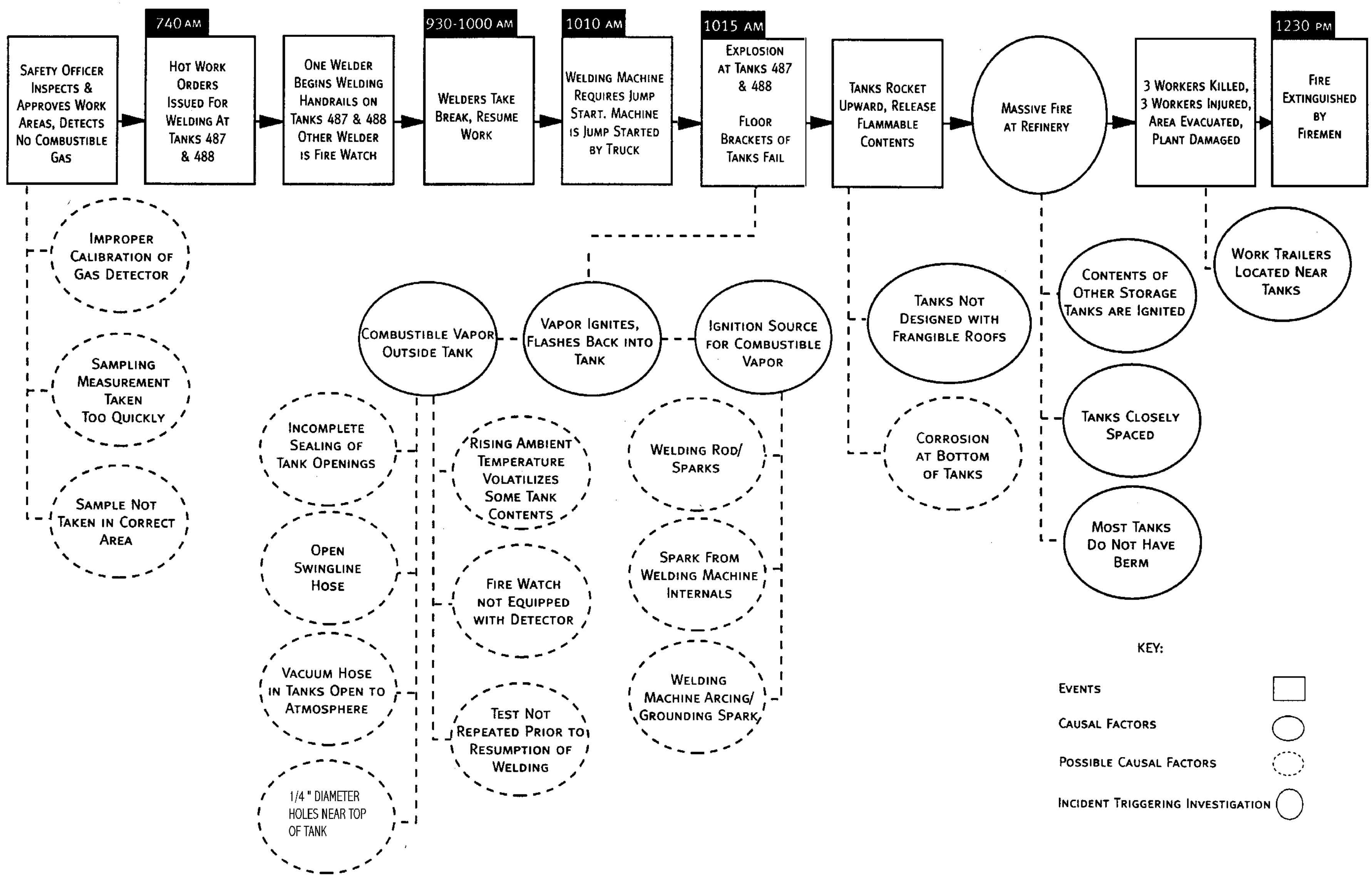
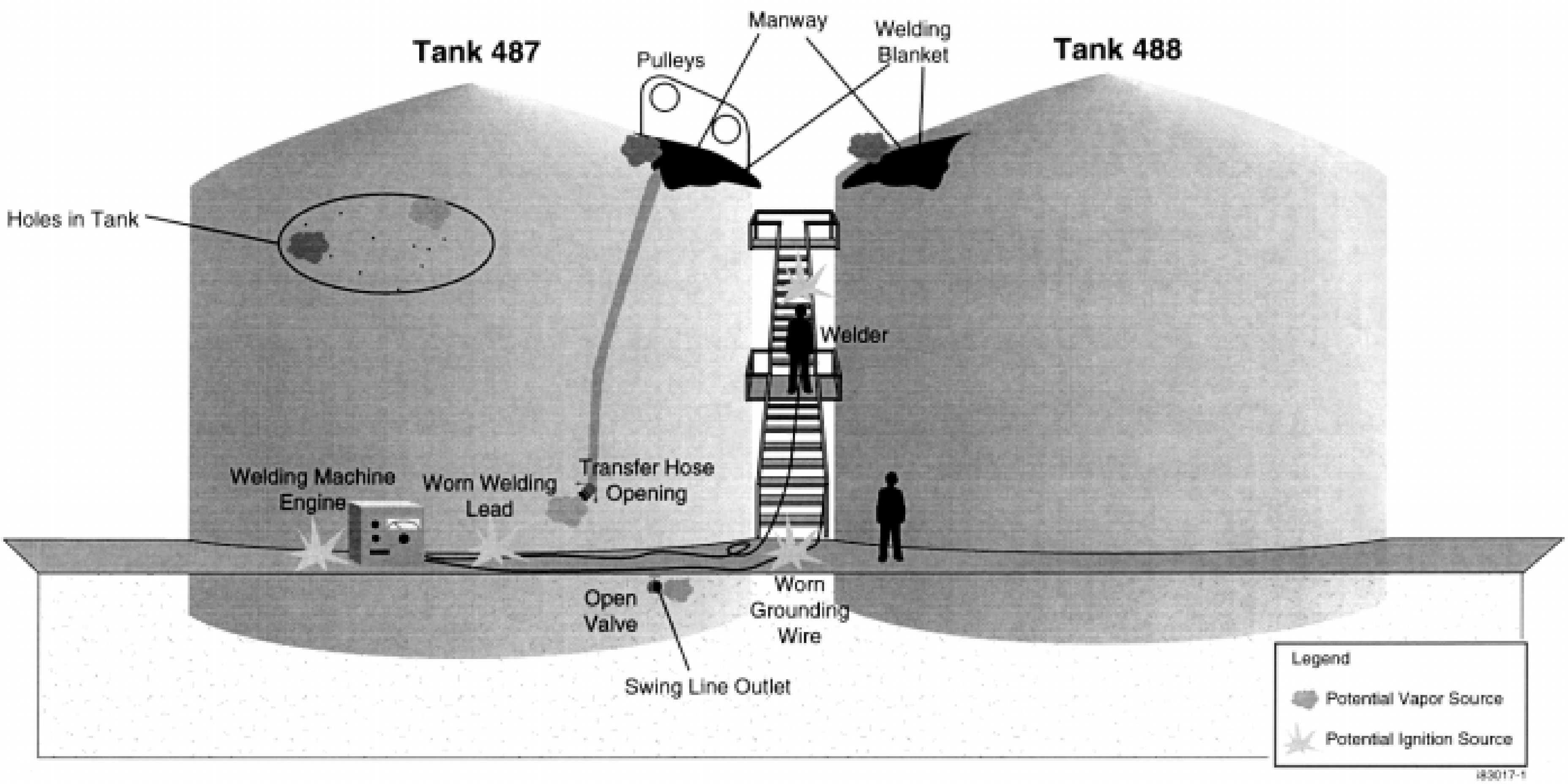


Exhibit 7
Pennzoil Tank Explosion:
Potential Vapor and Ignition Sources at Tanks 487 & 488



source in comparison to the undiluted vapor emitted by the other sources described above. Further, welders were instructed to not weld near the top of the tank.

4.2 Possible Ignition Sources

The most likely ignition sources were provided by the welding operation, the welding machine's internal combustion engine, and electrical arcing from the welding machine or grounding cables:

- The welding rod or sparks from hot slag or spatter possibly could have caused ignition of vapors present, if welding had been started (see Exhibit 7 for employee accounts of the position of the welder). During welding, flux coating the welding rod burns off. The welding rod being used by the welder was found after the accident and inspection revealed that flux on the tip was not burned off; however, there could have been an instantaneous arc, which could have caused ignition, but could have been of such short duration that the flux was not burned off. Or, the welding gun may have been dropped or kicked against the stairway causing an arc. However no evidence was discovered (e.g. arc marks) to support this scenario. Flammable and combustible materials are often ignited during hot work; generally, the material ignited is in the equipment being worked on. It is relatively rare for hot work to ignite a vapor cloud (Lees, 1996).

- The welding machine (see Exhibit 7), which provided power from an internal combustion engine generator, also could be a source of ignition because of arcing in the generator, the heat of the internal combustion engine, exhaust gases, or emission of hot particles from the engine exhaust system. The welding machine power generator that was near the tanks at the time of the incident was not equipped with an exhaust spark arrestor. Welding machines or internal combustion engines used in hydrocarbon processing facilities are often equipped with an arrestor on the exhaust to prevent sparks or hot particles from being emitted (Lees, 1996). Engine exhaust piping and gases can be hot and because of turbulent mixing, can ignite flammable vapor mixtures at lower temperatures than expected (Lees, 1996).

- Alternatively, electrical grounding or arcing from welding or the welding machine could have caused stray currents that may have contacted the tank, causing ignition. For example, a worn or frayed welding lead or grounding cable resting against the side of the tank or structure could short out. More importantly, arcing to ground can occur if the grounding cable from the arc welder is connected to a location that is not well grounded to earth (Lees, 1996). The site investigation confirmed that the grounding lead was attached close to the components to be welded and appeared to be properly connected. The condition of the welding cables at the time of the incident is not known. However, the grounding lead was connected to the stairway which also connected to the tank. Grounding leads should not be connected to equipment containing flammable materials (Pankratz, 1997). In addition, the presence of corrosion at the bottom of the stairs and tank may have prevented a good connection to earth causing current flow instead to the tank. This condition may have led to a buildup of a large charge that can accumulate in the liquid and on the container (Lees, 1996). If the charge then finds a path to ground, there could have been an arc in the vapor space of the tank which subsequently ignited any vapors present.

4.3 Possible Reasons for Not Detecting Combustible Vapors

As per standard safety and hot work practices, the safety technician tested the area where the welding was to be performed using a combustible gas detector. Testing was conducted early in the morning before welding operations began. The gas detector found no combustible vapor in the locations tested. There are several possible reasons why combustible vapors were not detected:

- Early in the morning, the tanks, the waste liquids, and vapors were cold. There were less flammable vapors present. Changes in temperature later in the morning may have increased the concentration of flammable vapors near the welding operation. The measurement for flammable vapors took place at around 7:40 a.m. (just after sunrise), before the welding began, and was not repeated. As the ambient temperature increased during the morning, it could have raised the vapor concentration in the area around the tanks to a combustible level. According to National Oceanic and Atmospheric Administration (NOAA) weather data, on October 16, the sun rose in Rouseville, Pennsylvania, at 7:31 a.m. and skies were clear. Between 7:00 a.m. and 10:00 a.m., the air temperature at Pittsburgh International Airport (about 75 miles south of Rouseville) increased about 9°F, from 39° F to 48° F. The ambient temperature in Rouseville most likely increased by a similar amount. In addition, sun shining directly on the storage tanks likely raised vapor temperatures in the tanks, and the resulting thermal expansion could have pushed flammable vapors out from tank openings.

- The combustible gas indicator may not have been calibrated, or may have been improperly calibrated, leading to inaccurate readings. The four-gas detector used to detect combustible gas needs to be calibrated, and regularly checked to ensure its accuracy. It is not precisely known whether the instrument was properly calibrated or whether the training and procedures provided by the company and experience of the user are sufficient to ensure that the instrument will be properly calibrated and used. However, the CAIT assumes that there were not significant amount of flammable vapors present since the early morning portion of the welding operation occurred without incident.

- Combustible gas sampling technique, training and procedures may have been inadequate. In particular, insufficient time may have been taken for sampling to allow an accurate reading. Sampling of gases may have missed areas where combustible vapors were present. It is not precisely known what gas sampling techniques were used, whether the user was trained, and the adequacy of training. However, as above, the CAIT assumes that there were not significant amount of flammable vapors present since the early morning portion of the welding operation occurred without incident.

4.4 Other Vapor and Ignition Sources

The CAIT examined the areas around the welding operation for other potential sources of flammable vapor or ignition that may have contributed to this incident:

- The open wastewater drain in the area of the storage tanks is a possible source of flammable vapor. If waste water containing flammable substances or flammable liquids are spilled into an inadequately sealed sewer, vapors can migrate in interconnected sewer channels to other plant locations where hot work may be taking place. A sealed sewer is designed to prevent vapors from traveling from one sewer to another (e.g., by use of water seals). It is not precisely known if flammable substances were present in sewer drains near the welding work or whether combustible gas measurements were made at sewer openings. Regardless, the likelihood that vapors originated and ignited from this source was judged to be low because a site visit indicated that the sewers were properly sealed and covered. The Pennzoil sewer system included a new collection basin that was sealed and vented to prevent accumulation of vapors and to prevent vapors from traveling throughout the sewer system. The catch basin by tanks 487 and 488 was connected to only one other catch basin, which was covered with a welding blanket at the time of the incident, before it entered the sealed collection basin. Some of the older catch basins did not have liquid seals; however, investigators found evidence at several locations that the sewers were covered with wooden covers or welding blankets to minimize vapor escape. These measures also serve to reduce the possibility that hot work in other plant locations ignited vapors that propagate back to the tank 487 and 488 location, triggering the explosions and fire.

- Arcing from static electric discharge can provided an ignition source. Liquids, including hydrocarbons, may generate static electricity when transferred. Hoses, piping and liquids can retain an electrical charge even after pumping or transfer has ceased. In addition, splash loading (liquids discharged above the liquid level rather than beneath) can generate static charge; the hose was well above the surface of the liquid in the tank (Lees, 1996). However, no liquids were transferred into, or out of, the tanks shortly before the incident, and any static charge from the last loading or unloading is believed to have dissipated by the time of the incident.

- Cathodic protection systems, which are sometimes used to protect underground piping and tank bottoms from corrosion, have the potential to create an electrical charge. This electrical charge could be a potential source of ignition. Reportedly, the Pennzoil site had no cathodic protection system in use; therefore, such a system could not be the ignition source.

- Several trailers in the vicinity of the incident site had electrical components and fixtures that did not meet the requirements for Class 1, Division 2, locations; i.e., they were not considered "explosion-proof" or "intrinsically safe." An electrical panel for some pumps and motors in the area was in a similar category. These electrical components could be a potential ignition source in the presence of combustible vapor. Evidence suggests, however, that ignition occurred at tanks 487 and 488, not in the area of the trailers. Further, sufficient vapor would have to have been emitted from the tank to support this scenario.

- A service road is located adjacent to the tanks, and four trailers used for tool storage and contractors taking breaks were also located in the area. Either a passing vehicle or some activity at one of the trailers possibly could have ignited the vapor. As above, there is no supporting evidence for these scenarios.

4.5 Factors that Contributed to the Consequences

Once the flammable vapors were ignited and exploded in tanks 487 and 488, the tanks failed at their bottom seam between the base and the sidewall, lifted off their bases, and released their entire contents. If the pressure of the explosion could have been sufficiently vented either by emergency vents or by failing the roof-to-shell seam, the fire likely would have been confined within the tank walls. Contents of tank 208, located next to tank 487, also ignited. Tank 208's wall folded inward under the heat of the fire but did not lift like tanks 487 and 488. The material in the tank burned in-place. Other nearby storage tanks containing naphtha and fuel oil also were damaged during the fire but did not fail at the bottom and release their contents. Factors that may have contributed to the failure of tanks 487 and 488 at the bottom include:

- The tanks were not equipped with sufficient emergency venting and the roofs of the tanks were not sufficiently frangible to act as an emergency vent; i.e., the roof-to-shell side seam did not yield and fail readily to internal pressure buildup. (See Appendix C).

- The bottoms of the tanks at the shell wall seam may have been weakened through corrosion. The tanks generally contained water at the bottom. Gravel was also built up around the bottoms and sides of the tanks, which may have allowed moisture to collect on the outside, on the bottom and tank wall edge, leading to corrosion and weakening of the bottom seam at the shell wall. (Evidence of this gravel can be seen in Exhibit 5-B, which shows the indentations left in the ground by tanks 487 and 488.)

- Although the site had walls and berms to prevent spillage or runoff from reaching the Oil Creek or other offsite locations, tanks 487 and 488 did not have secondary containment or impoundment which may have prevented the spilled liquid and fire from spreading throughout the area triggering fires in other vessels.

- The tool and break trailers were located within a walled area near the storage tanks. Had the trailers been isolated from the storage tank area, the casualties in the trailers may have been prevented.

4.6 Root Causes and Contributing Factors

Root causes are the underlying prime reasons, such as failure of particular management systems, that allow faulty design, inadequate training, or deficiencies in maintenance to exist. These, in turn, lead to unsafe acts or conditions which can result in an accident. Contributing factors are reasons that, by themselves, do not lead to the conditions that ultimately caused the event; however, these factors facilitate the occurrence of the event or increase its severity. Although the CAIT cannot precisely determine the exact cause of this event, there is sufficient information to support several root and contributing causes. The root causes and contributing factors of this event have broad application to a variety of situations and should be considered lessons for industries that conduct similar operations, especially the chemical and petroleum refining industries.

The CAIT uses a variety of analytical techniques to determine the root causes and contributing factors of accidents, and to generate recommendations to prevent a recurrence. The techniques used in this case included Events and Causal Factors charting, engineering and operations management experience and professional judgement. A number of factors involving equipment, facility layout, and procedures may have contributed to this incident, as discussed below. Appendix C presents information on industry standards and regulations that were most likely relevant to tanks 487 and 488, and welding operations at this facility. Based upon the facts and circumstances described above, the CAIT identified the following root causes and contributing factors in this incident:

- <u>Vessel design, integrity, and maintenance were inadequate:</u>

1. Tanks 487 and 488 were primarily intended to store waste water and did not appear to be properly equipped to handle flammable materials; yet a considerable quantity of MEK was transferred into tank 487. The tank manways were allowed to remain open to the atmosphere without fire preventive measures (e.g. pressure-vapor vents, flame arrestors or other means); potentially flammable materials were splash-loaded into the vapor space of the tank without benefit of static discharge prevention, and there did not appear to be a means of emergency venting (vent system or frangible roof); and

2. Tanks 487 and 488 failed along their bottom seams, releasing their entire contents. There was evidence of corrosion along the bottom seam. The roofs of these tanks had been replaced since initial construction but the CAIT has no other information about whether these tanks were properly inspected or maintained on a routine basis.

- <u>Preparation for hot work in the storage tank area was inadequate:</u>

1. Although the CAIT cannot thoroughly assess whether the training, procedures and equipment were adequate for detection of combustible or flammable vapors prior to the start of hot work, evidence suggests that combustible or flammable vapors in the storage tanks closest to the welding operation were not completely isolated (open manways, open swingline valve, open

hose) from the hot work leading to ignition and explosion of vapors in the tanks; and

2. Aside from the welding point, several other electrical or spark ignition sources in the area near the storage tanks were inadequately addressed (electrical equipment classifications and welding machine exhaust spark arrestor). In addition, grounding of the welding equipment may have caused a buildup of charge on the tank. Once conditions were favorable for ignition, these sources may have played a role;

- There was a lack of awareness of the impact of changing conditions at the hot work site:

No action was taken to address the potential for conditions near the hot work area to change over time, affecting the safety of the task. As temperatures rose from early to mid-morning, there was a greater possibility that combustible or flammable vapors were present. Proper retesting with a combustible gas detector before the restart of welding after the break could have addressed this possibility.

- Equipment siting and containment was inadequate:

1. There was no secondary containment or impoundment capacity around tanks 487 and 488 that may have limited the spread of liquid and fire following tank failure; and

2. There did not appear to be a consideration of the hazards associated with the vehicle access road and placement of tool and break trailers within the storage tank area. Greater isolation or relocation of these potential ignition sources and employee work areas likely would have prevented some of the casualties at this location.

5.0 Recommendations

Based on the root causes and contributing factors of this accident described above, the CAIT provides the following recommendations to prevent accidents like this one from happening in the future at this and other facilities:

Equipment Design and Integrity

Although waste water or slop oil tanks may be typically expected to present low chemical or process hazards, Pennzoil and other facilities should still ensure that all chemical and process hazards and the consequences and deviations associated with these hazards are completely understood, evaluated, documented, and appropriately addressed through preventive measures. This assessment should also include accident history, equipment design, and integrity. One way facilities can carry out this evaluation is use of a formal process hazards analysis (PHA) as required under the OSHA Process Safety Management Standard under 29 CFR 1910.119 or the EPA Risk Management Program Rule under 49 CFR part 68. The Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers American Institute of Chemical Engineers (AIChE) has prepared guidance on PHA methodologies. In this case, the PHA could have assisted in the identification of process hazards associated with the introduction of a large amount of volatile hydrocarbon into the waste water tank and appropriate safeguards (fire protection, flammable vapor control, flame arrestors) for such a situation. The hazard evaluation can identify failure areas that need to be addressed by safeguards such as engineering controls, or the need for emergency venting or frangible roofs (also captured by industry codes and standards listed in Appendix C), and ongoing preventive maintenance for vessel integrity (for example, inspection, recognition, and control of corrosion that can lead to vessel failure). EPA has already issued an Alert on Catastrophic Failure of Storage Tanks (Appendix D) that addresses emergency venting (e.g. frangible roofs) and maintenance. Facilities should consider use of PHA techniques for all vessels and processes for control of hazards and unintended situations.

Preparation for Hot Work

Pennzoil and other industries should review their hot work permitting processes and procedures and consider development of a management system or other mechanisms to ensure that all vapor and ignition sources are identified and controlled immediately prior to the start of hot work. For example, an equipment schematic and checklist could serve as a reminder or tool for ensuring that all potential vapor sources (manways, drains, valves) and ignition sources (electrical classifications, spark arrestors, grounds) are isolated or in proper working condition. Facilities should review past hot work incidents, conduct periodic audits or inspections of ongoing hot work, and develop a means to continuously improve or correct possible vapor or ignition source gaps in permitting procedures or processes. In addition, companies need to ensure that welding equipment is properly grounded and provide assurance that electrical current cannot find its way to equipment containing flammable materials.

Awareness of Changing Conditions

Facilities need to be aware that environmental conditions can change over the time. In this case, a retest for combustible gases may have detected their presence prior to the restart of work following a break. Facilities should also consider continuous combustible gas monitoring. Facilities should consider the value of work permit rechecks following work breaks or periodic rechecks as a matter of routine practice for hot work or other high hazard work tasks (such as confined space entry). In addition, facilities should consider application of process hazard analysis methodologies to job task analyses to ensure greater control over possible changes in routine situations. For example, the What-If methodology could be used to evaluate hot work or other permitted jobs to examine the influence of weather or other abnormal situations that might arise in the same area that could affect the safety of the task.

Facility Siting Considerations

As above, PHA techniques can be used to evaluate the hazards associated with siting of equipment and work areas. Pennzoil and the other facilities can make use of these techniques in combination with industry codes and standards and regulatory requirements, to ensure that vehicular traffic is restricted from areas containing flammable materials, the work locations are properly evaluated and isolated from potential process hazards and that these work locations do not impose hazards on the process (ignition sources). Further, accident history, the potential for leaks, spills, and vessel failures should be evaluated to determine the need for secondary containment or other impoundment as a means of preventing impact on other site areas.

Appendix A

EPA personnel who participated in the accident investigation and report development include:

David Speights, Associate Director	EPA Headquarters
Craig Matthiessen, Chemical Engineer	EPA Headquarters
David Chung, Chemical Engineer	EPA Headquarters
Diane Walker, Chemical Engineer	EPA Region 3
Jim Corbitt, Chemical Engineer	EPA contractor
Lawrence McLaughlin, Chemical Engineer	EPA contractor

OSHA personnel involved in the investigation[1] include:

John Morris	OSHA Investigation Team Leader
Michael L. Marshall, Civil Engineer	OSHA Investigation Team Member
Walt Siegfried	OSHA Investigation Team Member
Bob Carol	OSHA Investigation Team Member
Vance Delsignore	OSHA Investigation Team Member
George Yoksas	Region V - PSM Coordinator, OSHA Investigation Team Member

[1] OSHA did not participate in writing the report.

Appendix B

MSDS for METHYL ETHYL KETONE

1. PRODUCT IDENTIFICATION

PRODUCT NAME: METHYL ETHYL KETONE
FORMULA: CH3COCH2CH3
FORMULA WT: 72.11
CAS NO.: 78-93-3
NIOSH/RTECS NO.: EL6475000
COMMON SYNONYMS: 2-BUTANONE; MEK; ETHYL METHYL KETONE; METHYLACETONE
PRODUCT CODES: 9214,9323,9211,5385,9319,Q531
EFFECTIVE: 08/27/86 REVISION #02

PRECAUTIONARY LABELLING BAKER SAF-T-DATA(TM) SYSTEM

HEALTH	- 2	MODERATE
FLAMMABILITY	- 3	SEVERE (FLAMMABLE)
REACTIVITY	- 2	MODERATE
CONTACT	- 1	SLIGHT

HAZARD RATINGS ARE 0 TO 4 (0 = NO HAZARD; 4 = EXTREME HAZARD).

LABORATORY PROTECTIVE EQUIPMENT - SAFETY GLASSES; LAB COAT; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER

PRECAUTIONARY LABEL STATEMENTS

WARNING EXTREMELY FLAMMABLE
CAUSES IRRITATION HARMFUL IF INHALED
KEEP AWAY FROM HEAT, SPARKS, FLAME. AVOID BREATHING VAPOR. KEEP IN TIGHTLY CLOSED CONTAINER. USE WITH ADEQUATE VENTILATION. WASH THOROUGHLY AFTER HANDLING. IN CASE OF FIRE, USE ALCOHOL FOAM, DRY CHEMICAL, CARBON DIOXIDE - WATER MAY BE INEFFECTIVE. FLUSH SPILL AREA WITH WATER SPRAY.

SAF-T-DATA(TM) STORAGE COLOR CODE: RED (FLAMMABLE)

2 - HAZARDOUS COMPONENTS

COMPONENT	%	CAS NO.
METHYL ETHYL KETONE	90-100	78-93-3

3 - PHYSICAL DATA

BOILING POINT: 80 C (176 F) VAPOR PRESSURE(MM HG): 78
MELTING POINT: -87 C (-125 F) VAPOR DENSITY(AIR=1): 2.5

SPECIFIC GRAVITY: 0.81 (H2O=1) EVAPORATION RATE: 5.7 (BUTYL ACETATE=1)

SOLUBILITY (H2O): APPRECIABLE (MORE THAN 10 %) % VOLATILES BY VOLUME: 100

APPEARANCE & ODOR: CLEAR COLORLESS, LIQUID WITH ACETONE-LIKE ODOR.

4 - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (CLOSED CUP -7 C (20 F) NFPA 704M RATING: 1-3-0

FLAMMABLE LIMITS: UPPER - 11.4 % LOWER - 1.8 %

FIRE EXTINGUISHING MEDIA - USE ALCOHOL FOAM, DRY CHEMICAL OR CARBON DIOXIDE. (WATER MAY BE INEFFECTIVE.)

SPECIAL FIRE-FIGHTING PROCEDURES - FIREFIGHTERS SHOULD WEAR PROPER PROTECTIVE EQUIPMENT AND SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN POSITIVE PRESSURE MODE. MOVE CONTAINERS FROM FIRE AREA IF IT CAN BE DONE WITHOUT RISK. USE WATER TO KEEP FIRE-EXPOSED CONTAINERS COOL.

UNUSUAL FIRE & EXPLOSION HAZARDS - VAPORS MAY FLOW ALONG SURFACES TO DISTANT IGNITION SOURCES AND FLASH BACK. CLOSED CONTAINERS EXPOSED TO HEAT MAY EXPLODE. CONTACT WITH STRONG OXIDIZERS MAY CAUSE FIRE.

TOXIC GASES PRODUCED - CARBON MONOXIDE, CARBON DIOXIDE

5 - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE (TLV/TWA): 590 MG/M3 (200 PPM)

SHORT-TERM EXPOSURE LIMIT (STEL): 885 MG/M3 (300 PPM)

PERMISSIBLE EXPOSURE LIMIT (PEL): 590 MG/M3 (200 PPM)

TOXICITY: LD50 (ORAL-RAT)(MG/KG) - 2737
LD50 (IPR-MOUSE)(MG/KG) - 616
LD50 (SKN-RABBIT) (G/KG) - 13

CARCINOGENICITY: NTP: NO IARC: NO Z LIST: NO OSHA REG: NO

EFFECTS OF OVEREXPOSURE - INHALATION OF VAPORS MAY CAUSE HEADACHE, NAUSEA, VOMITING, DIZZINESS, DROWSINESS, IRRITATION OF RESPIRATORY TRACT, AND LOSS OF CONSCIOUSNESS. CONTACT WITH SKIN OR EYES MAY CAUSE IRRITATION. PROLONGED EXPOSURE MAY CAUSE DERMATITIS. LIQUID MAY CAUSE PERMANENT EYE DAMAGE. INGESTION MAY CAUSE NAUSEA, VOMITING, HEADACHES, DIZZINESS, GASTROINTESTINAL IRRITATION.

TARGET ORGANS - NASAL SEPTUM, LUNGS

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE - NONE IDENTIFIED

ROUTES OF ENTRY - INHALATION, INGESTION, EYE CONTACT, SKIN CONTACT

EMERGENCY AND FIRST AID PROCEDURES - CALL A PHYSICIAN. IF SWALLOWED, DO NOT INDUCE VOMITING. IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. IN CASE OF CONTACT,

IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. FLUSH SKIN WITH WATER.

6 - REACTIVITY DATA

STABILITY: STABLE HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

CONDITIONS TO AVOID: HEAT, FLAME, OTHER SOURCES OF IGNITION

INCOMPATIBLES: STRONG OXIDIZING AGENTS, STRONG BASES, CAUSTICS, MINERAL ACIDS, AMINES AND AMMONIA, HALOGENS

DECOMPOSITION PRODUCTS: CARBON MONOXIDE, CARBON DIOXIDE

7 - SPILL AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN THE EVENT OF A SPILL OR DISCHARGE - WEAR SELF-CONTAINED BREATHING APPARATUS AND FULL PROTECTIVE CLOTHING. SHUT OFF IGNITION SOURCES; NO FLARES, SMOKING OR FLAMES IN AREA. STOP LEAK IF YOU CAN DO SO WITHOUT RISK. USE WATER SPRAY TO REDUCE VAPORS. TAKE UP WITH SAND OR OTHER NON-COMBUSTIBLE ABSORBENT MATERIAL AND PLACE INTO CONTAINER FOR LATER DISPOSAL. FLUSH AREA WITH WATER.

J. T. BAKER SOLUSORB(R) SOLVENT ADSORBENT IS RECOMMENDED FOR SPILLS OF THIS PRODUCT.

DISPOSAL PROCEDURE - DISPOSE IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL ENVIRONMENTAL REGULATIONS.

EPA HAZARDOUS WASTE NUMBER: U159 (TOXIC WASTE)

8 - PROTECTIVE EQUIPMENT

VENTILATION: USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLV REQUIREMENTS.

RESPIRATORY PROTECTION: RESPIRATORY PROTECTION REQUIRED IF AIRBORNE CONCENTRATION EXCEEDS TLV. AT CONCENTRATIONS UP TO 1000 PPM, A CHEMICAL CARTRIDGE RESPIRATOR WITH ORGANIC VAPOR CARTRIDGE IS RECOMMENDED. ABOVE SELF-CONTAINED BREATHING APPARATUS IS RECOMMENDED.

EYE/SKIN PROTECTION: SAFETY GOGGLES, UNIFORM, APRON, RUBBER GLOVES RECOMMENDED.

9 - STORAGE AND HANDLING PRECAUTIONS

SAF-T-DATA(TM) STORAGE COLOR CODE: RED (FLAMMABLE)

SPECIAL PRECAUTIONS - BOND AND GROUND CONTAINERS WHEN TRANSFERRING LIQUID. KEEP CONTAINER TIGHTLY CLOSED. STORE IN A COOL, DRY, WELL-VENTILATED, FLAMMABLE LIQUID

STORAGE AREA.

10 - TRANSPORTATION DATA AND ADDITIONAL INFORMATION

DOMESTIC (D.O.T.)

PROPER SHIPPING NAME METHYL ETHYL KETONE
HAZARD CLASS FLAMMABLE LIQUID
UN/NA UN1193
LABELS FLAMMABLE LIQUID
REPORTABLE QUANTITY 5000 LBS.

INTERNATIONAL (I.M.O.)

PROPER SHIPPING NAME METHYL ETHYL KETONE
HAZARD CLASS 3.2
UN/NA UN1193
LABELS FLAMMABLE LIQUID

Appendix C

Industry Standards and Regulations that May Be Applicable to the Aboveground Tanks at the Pennzoil Facility

Pennsylvania Statutes and Regulations

The Storage Tank and Spill Prevention Act, Title 35, requires the Pennsylvania Department of Environmental Resources (DER) to adopt regulations regarding the certification and training of installers and inspectors of aboveground storage tanks. However, the regulations do not include requirements for operators or emergency response personnel. As a result of the Act and Title 35, the Pennsylvania DER must adopt minimum corrosion protection standards for aboveground storage tanks. Title 35 authorizes the DER to establish "methods and procedures for the operation of aboveground storage tanks and the early detection, by owners, of releases or potential releases," and to adopt minimum standards for release prevention, which may include leak detection systems. Sections 902 and 903 of the Act establish the guidelines for preparation of a spill prevention response plan for all facilities with capacities that exceed 21,000 gallons. The plan must include descriptions of the facility, the organization structure for plan implementation, the spill leak prevention, response, and countermeasure programs, the emergency spill network, and any other information as may be required by the DER. Plans must be submitted to DER for approval.

EPA Regulations

Oil Pollution Prevention Regulation (29 CFR 112):

The Oil Pollution Prevention Regulation is intended to prevent discharges of oil into waters of the United States. Facilities drilling, producing, gathering, storing, processing, refining, transferring, or consuming oil or oil products may be subject to the rule if they are non-transportation related, meet certain storage capacity criteria, and are located so that spilled oil could be reasonably expected to reach water. Facilities subject to the regulation must prepare and implement a Spill Prevention Control and Countermeasures (SPCC) Plan. The plan must be prepared in accordance with good engineering practices and be certified by a registered professional engineer. It should detail the equipment, manpower, and steps to prevent, control, and provide adequate countermeasures to an oil spill. The plan is a written description of the facility's compliance with the regulation. The plan must cover:

- The practices devoted to the prevention of oil spills, including:

  -- Minimization of operational errors (e.g., through training and supervision),
  -- Minimization of equipment failures (e.g., through proper construction, maintenance of structural integrity, and frequent inspections);

- The plan of containment should a spill occur (e.g., through dikes, retaining walls, curbing, spill diversion ponds, sumps); and

- The plan for removal and disposal of oil.

The facility must maintain a copy of the plan and make it available to EPA for on-site review. If one discharge of more than 1,000 gallons occurs, or if two discharges of harmful quantities occur in a 12-month period, copies of the plan must be submitted to EPA and the state. In such cases, EPA may require an amendment to the plan to prevent future discharges.

American Petroleum Institute Standards, Recommended Practices, and Other Publications

API Standard 12A, *Specification for Standard Tanks with Riveted Shells* (published from 1936 through 1941):

This standard (currently out of print) probably would have applied to tanks 487 and 488.

API Standard 620, *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*:

This standard covers the design and construction of large, welded, low pressure, carbon steel, aboveground tanks. The rules cover only those tanks that are shaped such that they can be generated by the rotation of a suitable contour around a single vertical axis. API Standard 620 covers tanks that operate at metal temperatures not exceeding 200ºF and with pressures in their gas or vapor spaces exceeding those permissible under API Standard 650, but not exceeding 15 pounds per square inch gauge. The basic rules provide for installations in areas where the lowest recorded one-day mean atmospheric temperature is as low as -50ºF. These rules may be used for tanks intended either for holding or storing liquids with gases or vapors above the surface of the liquid or for holding or storing gases or vapors alone. These rules do not apply to "lift-type" gas holders. Although this Standard does not cover horizontal tanks, it is not intended to preclude the application of appropriate portions to the design and construction of horizontal tanks.

API Standard 650, *Welded Steel Tanks for Oil Storage*:

API Standard 650 covers material, design, fabrication, erection, and testing requirements for vertical, cylindrical aboveground, closed- and open-topped, welded steel storage tanks in various sizes and capacities with internal pressures approximating atmospheric pressure. Higher internal pressure is permitted when certain additional requirements are met. This Standard covers only tanks with uniformly supported bottoms and tanks in non-refrigerated service that have a maximum operating temperature of 200ºF.

API Recommended Practice (RP) 651, *Cathodic Protection of Above-Ground Petroleum Storage Tanks*:

API RP 651 provides recommended practices to limit potential corrosion problems common to steel aboveground tanks. It contains a description of corrosion problems and methods for evaluating the need for cathodic protection. This publication also describes the design, installation, and maintenance of various types of cathodic protection systems.

API RP 652, *Lining of Above-Ground Petroleum Storage Tank Bottoms*:

API RP 652 presents procedures and recommended practices to improve corrosion control in aboveground storage tanks by the addition of linings to tank bottoms. It includes a description of the various types of corrosion that may affect tank bottoms, and factors that should be considered when evaluating the need for and suitability of different types of linings. It also provides general guidance on application of linings.

API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*:

The recently adopted API Standard 653 is applicable to carbon and low-alloy steel tanks built to API Standard 650 and its predecessor, 12C. It provides minimum standards to maintain the integrity of aboveground, non-refrigerated, atmospheric tanks that are already in service. Some of the topics cover suitability for service, brittle fracture, repair and alteration, reconstruction, and inspection and testing.

API RP 575, *Inspection of Atmospheric and Low-Pressure Storage Tanks*:

This recommended practice covers the inspection of atmospheric storage tanks designed to operate at atmospheric pressure through 0.5 psig and low-pressure storage tanks designed to operate above 0.5 psig to below 15 psig. It includes reasons for inspection, frequency and time of inspections, methods of inspection and repair, and records and reports.

API Publication 2009, *Safe Welding and Cutting Practices in Refineries, Gasoline Plants, and Petrochemical Plants*:

This publication outlines suggested precautions for the protection of persons from injury and the protection of property from damage by fire that might arise during the operation of gas and electric cutting and welding equipment in and around petroleum operations.

API RP 2000, *Venting Atmospheric and Low Pressure Storage Tanks: Non Refrigerated and Refrigerated:*

This publication outlines major considerations for design and arrangement of emergency venting and pressure relief of above ground storage tanks.

API Standard 2610, *Design, Construction, Operation, Maintenance, and Inspection of Terminal and Tank Facilities:*

This publication provides specific guidance for prevention of ignition of flammable vapors in the vicinity of storage tanks.

American Society of Mechanical Engineers (ASME) and American National Standards Institute (ANSI)

ASME/ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*:

ASME/ANSI B31.3 is a section of the ASME/ANSI B31 Code for Pressure Piping. It is applicable to piping systems that handle most types of fluids, including oil and other petroleum products. It includes requirements for materials, design, fabrication, assembly, erection, examination, and inspection of piping systems.

National Fire Protection Association (NFPA) Codes and Standards

NFPA 30, *Flammable and Combustible Liquids Code*:

The Flammable and Combustible Liquids Code (NFPA 30) applies to operations that require the use of flammable and combustible liquids. Its provisions are intended to reduce the hazard to a degree consistent with reasonable public safety, without undue interference to public convenience and necessity, for activities that require the use of flammable and combustible liquids. It includes requirements for aboveground, underground, and portable tanks. Requirements concerning design and construction of buildings that contain tanks are also discussed.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*:

This standard covers provisions to prevent loss of life and property from fire in the use of oxy-fuel gas and electric arc cutting and welding equipment. Topics covered included the responsibilities of management, supervisors, and cutters and welders; and fire prevention precautions, including permissible areas for cutting and welding, permits, and fire watchers.

NFPA 77, *Recommended Practice on Static Electricity*:

This recommended practice is intended to assist in reducing the fire hazard of static electricity. It includes a general discussion of static charges, general methods for mitigation, and recommendations for dissipation of static electricity in certain specific operations. Flammable and combustible liquids are discussed, including recommendations regarding storage tanks and piping systems.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*:

NFPA 780 presents lightning protection standards for structures containing flammable vapors and gases, as well as liquids that give off flammable vapors.

Occupational Safety and Health Administration (OSHA) Regulations

OSHA Standard for Flammable and Combustible Liquids (29 CFR 1910.106):

This standard includes a variety of provisions for safe storage and handling of flammable and combustible liquids, including design, construction, and installation of tanks, piping systems, and containers; and storage and handling of flammable and combustible liquids in various types of industries.

OSHA Standard for Process Safety Management of Highly Hazardous Chemicals (29 CFR 1910.119):

OSHA's Process Safety Management (PSM) standard contains requirements for the management of hazards associated with processes using highly hazardous chemicals, including flammable chemicals. It does not apply to flammable liquids stored in atmospheric tanks at temperatures below their normal boiling points (without refrigeration). Requirements included are related to: process safety information, process hazard analysis, operating procedures, training, contractors, pre-startup safety review, mechanical integrity, hot work permits, management of change, incident investigations, emergency planning, compliance safety audits, employee participation, and trade secrets.

OSHA Standard for Welding, Cutting and Brazing (29 CFR 1910 Subpart Q)

This standard includes requirements for fire prevention and protection for welding, cutting, and brazing, including fire extinguishing equipment, fire watch, and protective equipment.

Appendix D

Chemical Safety Alert for Catastrophic Failure of Storage Tanks

United States Environmental Protection Agency | Office of Solid Waste and Emergency Response (5104) | EPA 550-F-97-002b May 1997

EPA
CEPPO

CATASTROPHIC FAILURE OF STORAGE TANKS

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment by preventing chemical accidents. Under CERCLA, section 104(e) and Clean Air Act (CAA), EPA has authority to conduct chemical accident investigations. Additionally, in January 1995, the Administration asked the Occupational Safety and Health Administration (OSHA) and EPA to jointly undertake investigations to determine the root cause(s) of chemical accidents and to issue public reports containing recommendations to prevent similar accidents. EPA has created a chemical accident investigation team to work jointly with OSHA in these efforts. Prior to the release of a full report, EPA intends to publish *Alerts* as promptly as possible to increase awareness of possible hazards. *Alerts* may also be issued when EPA becomes aware of a significant hazard. It is important that facilities, SERCs, LEPCs, emergency responders and others review this information and take appropriate steps to minimize risk.

CHEMICAL SAFETY ALERT

p71022-b

PROBLEM

Catastrophic failures of aboveground, atmospheric storage tanks can occur when flammable vapors in the tank explode and break either the shell-to-bottom or side seam. These failures have caused the tanks to rip open and, in some cases, hurled the tanks through the air. A properly designed and maintained storage tank will break along the shell-to-top seam. Then, the fire would more likely be limited to the damaged tank and the contents would not be spilled. This alert describes the types of tanks that may be prone to catastrophic failure and maintenance practices that can help prevent the accidents.

RECENT ACCIDENTS

Several accidents have occurred within the last few years in which storage tanks have failed catastrophically when the flammable vapors inside an atmospheric tank exploded. The tank was either propelled upward from its base (shell-to-bottom seam failed) or split along the side seam. As a result, workers were killed or injured and the contents were released into the environment.

Three specific incidents demonstrate the potential dangers posed to workers, the public, and the environment when these storage tanks fail catastrophically. In these incidents, the shell-to-bottom seam failed after an explosion and the tank was propelled upward. All occurred in older, atmospheric steel storage tanks. Often workers were performing tank maintenance or other activities that introduced an ignition source. The vapors were ignited either inside the tank or outside and then flashed back into the tank.

In a 1995 incident, during a welding operation on the outside of a tank, the combustible vapor inside two large, 30-ft. diameter by 30-ft. high, storage tanks exploded and propelled the tanks upward — one landing more than 50 feet away. The flammable liquid inside was instantly released and ignited, resulting in a massive fire that caused five deaths and serious injuries.

In a 1992 incident, while workers were welding the outside of a tank empty of liquid, the residual vapor in the storage tank exploded and propelled the tank upward and into an adjacent river. Three workers were killed and one was injured.

In a 1994 incident, during a grinding operation on a tank holding petroleum-based sludge, the tank was propelled upward, injuring 17 workers and spilling its contents over a containment berm into a nearby river.

Hazard Awareness

Tank design and inspection/maintenance practices are factors directly related to catastrophic tank failure.

Tank design

Historically, accidents where the shell-to-bottom seam fails are more common among older storage tanks. Steel storage tanks built before 1950 generally do not conform to current industry standards for explosion and fire venting. Atmospheric tanks used for storage of flammable and combustible liquids should be designed to fail along the shell-to-roof seam when an explosion occurs in the tank. This prevents the tank from propelling upward or splitting along the side. Several organizations have developed standards and specifications for storage tank design. Published standards relevant to this design feature include API-650,"Welded Steel Tanks for Oil Storage" issued by the American Petroleum Institute (API). Additional codes and standards, published by API and other organizations, address tank design, construction, venting, and safe welding and are listed at the end of this alert.

Poor inspection, maintenance, and repair practices

Tanks that are poorly maintained, rarely inspected, or repaired without attention to design, risk catastrophic failure in the event of a vapor explosion. Either weakening of the shell-to-bottom seam through corrosion or strengthening the shell-to-roof seam relative to the shell-to-bottom seam will increase the vulnerability of the tank to failure along the shell-to-bottom seam. The practice of placing gravel and spill absorbants around the base of the tank, may increase the likelihood of bottom corrosion. Given years of this practice, the bottom of some tanks, especially older ones, may be below ground level, thereby trapping moisture along the tank bottom. This can weaken the bottom and the shell-to-bottom seam. Alternatively, changes to the roof seam such as modifications to or replacement of the roof, or attachments to the roof, could make the roof-to-shell seam stronger relative to the shell-to-bottom seam.

Other hazards that can contribute to a tank explosion and possible consequences are:

Combustible vapors

Generation of combustible vapors is a hazard not only for the storage of pure flammable liquids but also for the storage of any sludge or mixture where a combustible component is present or can be produced by reaction. Sludge (slop tanks) and mixture (e.g., oil/water) tanks may be particularly vulnerable because they are sometimes open to the air; explosive atmospheres may form inside and outside the tank. Facilities may not always recognize this hazard. In addition, even tanks appearing to be empty may pose a hazard if they still contain combustible vapors.

In the cited cases, the potential for combustible vapors was not clearly recognized and materials were stored in tanks that were not equipped with flame arresters to prevent external fire from reaching the vapor space inside the tank or with vapor control devices to limit vapor emissions from the tank.

Ignition sources

When combustible vapors escape from their containment and mix with air in the presence of an ignition source, combustion may occur. To minimize this hazard, all possible ignition sources must be isolated from potential combustible vapors, e.g., welding equipment or other maintenance equipment that can spark or arc, sources of static electricity, lightning, "hot work" in adjacent areas, and any electrical equipment in the vicinity of tanks that does not conform to National Fire Protection Association (NFPA)-70, "National Electric Code."

Proximity to workers and environment

The danger posed by these tanks is often increased when the location of the tank does not conform with current minimum spacing requirements. Sections 2-3.2 to 2-3.3 of NFPA-30 discuss minimum spacing. For mitigating consequences to workers, the environment, and other tanks, proper secondary containment (diking) should be considered for containment.

Hazard Identification

Facilities should evaluate their storage tanks for potential to catastrophically fail and identify factors that could cause storage tank explosion. Some of the factors to look for include, but are not limited to, the following:

- Atmospheric storage tanks that do not meet API-650 or other applicable code(s) and contain flammable liquids or liquids that may produce combustible vapor.
- Tanks with corrosion around the base and/or steel tanks whose base is in direct contact with ground and exposed to moisture.
- Tanks or associated structures (e.g., pipes) with weakened or defective welds.
- Tanks used to store mixtures containing water and flammables where the water phase is at the tank bottom and may contribute to internal bottom corrosion.
- Tanks containing combustible vapor and not equipped with flame arrestors or vapor control devices to limit emissions.
- Possible ignition sources near tanks containing combustible vapor.

Process Safety Areas for Hazard Reduction

Storage tanks should comply with all regulations, industry codes and standards, including inspection and maintenance requirements to keep tanks in proper condition. Facilities with storage tanks that can contain flammable vapors should review their equipment and operations. Areas to review should include, but not be limited to, the following:

1) Design of atmospheric storage tanks

API and other organizations have standards and codes that address recommended practices for tank design and construction. It is imperative to evaluate whether the liquids or certain components of liquid mixtures may generate combustible vapors. Design measures include fire protection, flame arrestors, emergency venting (such as part of the API-650), prevention of flash back (for tanks containing flammable liquids), and proper berming or diking.

2) Inspection and maintenance of storage tanks

API-653 has tank inspection guidelines and procedures for periodic inspections and testing, especially for older tanks. These procedures call for written documentation of inspections by API Certified Tank Inspectors. Measures to review include procedures for pressure testing, welding inspections, and checks for corrosion or metal fatigue. API-650 specifies welding procedures and welding qualifications as well as joint inspection (e.g., radiograph and magnetic particle examination). Programs for tank inspection and maintenance should be developed in accordance with these standards.

3) Hot-work safety

Both the Occupational Safety and Health Administration's (OSHA) regulations concerning hot work and NFPA's standards on welding should be reviewed for compliance. Hazard reduction measures include proper hot-work procedures such as obtaining a hot work permit, having a fire watch and fire extinguishing equipment present, and proper testing of atmosphere for explosivity; covering and sealing all drains, vents, manways, and open flanges; sealing all sewers (to prevent gas or vapor migration); and training workers and providing them with appropriate protective equipment.

4) Ignition source reduction

Both OSHA regulations and NFPA standards should be reviewed for compliance. Hazard reduction measures may include: having all electrical equipment in a hazardous environment conform with the requirements of the National Electric Code (NFPA-70), grounding tanks to dissipate static charge, using only "non-spark producing" tools and equipment in flammable atmospheres, and taking care to not create sufficient heat or sparks to cause ignition of flammable vapors.

Information Resources for Hazard Reduction

The above information is for general guidance only. References with information about the hazards of catastrophic failures and methods of minimizing them are listed below. Regulations potentially applicable to storage tanks and codes and standards that may be relevant are included.

For more information consult the following:

Statutes and Regulations

Section 112(r) of the Clean Air Act focuses on prevention of chemical accidents. It imposes on facilities with regulated substances or other extremely hazardous substances a general duty to prevent and mitigate accidental releases. Accident prevention activities include identifying hazards and operating a safe facility.

EPA's Risk Management Program (RMP) Rule [40 CFR 68] is intended to prevent and mitigate accidental releases of listed toxic and flammable substances. Requirements under the RMP rule include development of a hazard assessment, a prevention program, and an emergency response program.

EPA has tank inspection regulations under the Spill Prevention Countermeasure and Control Plan and Oil Pollution Control Act of 1990 [40 CFR119].

The Occupational Safety and Health Administration (OSHA) has the Process Safety Management Standard [29 CFR 1910.119], which includes regulations on tank inspection, fire prevention, and conduct during hot-work; regulations concerning the storage of flammable and combustible liquids [29 CFR 1910.106]; regulations concerning fire protection and prevention during welding, brazing, and cutting [29 CFR 1910.252] and regulations covering the duties and responsibilities of a fire watch [29 CFR Part 126].

Occupational Safety and Health Administration
Phone: (202) 219-8151 - Public Information
Web site: http://www.osha.gov

Codes and Standards

The American Petroleum Institute (API) has tank standards and guidelines on safe welding.

American Petroleum Institute
1220 L St NW
Washington DC 20005
Phone: (202) 682-8000
Web site: http://www.api.org

Relevant API standards include:
API Standard 620 — <u>Design and Construction of Large, Welded, Low-Pressure Storage Tanks</u>, ninth edition, February 1996 (includes Addendum 1, December 1996).

[API Standard 650 comes from] <u>Welded Steel Tanks for Oil Storage</u>, ninth edition, May 1993 (includes Addendum 1, December 1994; Addendum 2, December 1995; and Addendum 3, December 1996).

API Recommended Practice (RP) 651 — Cathodic Protection of Aboveground Petroleum Storage Tanks, first edition, April 1991.

API RP 652 — Lining of Aboveground Petroleum Storage Tank Bottoms, first edition, April 1991.

API Standard 653 — Tank Inspection, Repair, Alteration, and Reconstruction, second edition, December 1995 (includes Addendum 1, December 1996).

API Standard 2000 — Venting Atmospheric and Low-Pressure Storage Tanks: Nonrefrigerated and Refrigerated, fourth edition, September 1992.

API RP 2003 — Protection Against Ignitions Arising Out of Static, Lightning, and Stray Current, fifth edition, December 1991.

API PUBL 2210 — Flame Arrestors for Vents of Tanks Storing Petroleum Products, second edition, 1982.

API RP 2350 — Overfill Protection for Petroleum Storage Tanks, first edition, March 1987.

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The American National Standards Institute (ANSI) has the B-31.3 Refinery Piping Code and other standards and codes.

American National Standards Institute
655 15th St NW
Washington DC 20005
Phone: (202) 639-4090 or
11 West 42nd St
New York, NY 10036
Phone: (212) 642-4900
Web site: http://www.ansi.org

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The American Society of Mechanical Engineers (ASME) has the Pressure Vessel Code and other codes relevant to tanks and storage vessels.

American Society of Mechanical Engineers
1828 L St NW, Suite 906
Washington DC 20036
Phone: 1 (800) 843-2863 or (202) 785-3756
Publications and membership 1 (800) 843-2763
Codes and standards (212) 705-8500
Accreditation and certification programs (212) 705-8581
Web site: http://www.asme.org

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The American Society of Nondestructive Testing (ASNT) certifies welding and non-destructive examination (NDE) and non-destructive testing (NDT) inspectors.

American Society of Nondestructive Testing
P.O. Box 28518
1711 Arlingate Lane
Columbus, OH 43228
Phone: 1 (800) 222-2768 or (614) 274-6003
Web site: http://www.asnt.org

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The American Welding Society (AWS) certifies welding inspectors with the designation AWS QC-1 (Quality Control) Welding Inspector and has guidelines on safe welding.

American Welding Society
550 NW LeJeune Rd
Miami, FL 33126
Phone: 1 (800) 443-9353 or (305) 443-9353
Web site: http://www.amweld.org

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The National Fire Protection Association (NFPA) has lightning and flammable/combustible liquid codes.

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
Phone: (617) 770-3000
Customer Service: 1 (800) 344-3555
Web site: http://www.nfpa.org

Relevant NFPA codes include:
NFPA 30 — Flammable and Combustible Liquid Code, 1996 edition.
NFPA 51 — Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes, 1992.

NFPA 51B — Fire Prevention in Use of Cutting and Welding Processes, 1994.
NFPA 70 — National Electric Code, 1996.
NFPA 77 — Static Electricity, 1993.
NFPA 780 — Lightning Protection Code, 1995.

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Underwriters Laboratories Inc. (UL) has standards for product safety.

Underwriters Laboratories Inc.
333 Pfingsten Rd
Northbrook, IL 60062
Phone: (847) 272-8800
Web site: http://www.ul.com

Relevant UL standards include:
UL-142 — Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids, 1993.

FOR MORE INFORMATION...

CONTACT THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW HOTLINE

(800) 424-9346 OR (703) 412-9810
TDD (800) 553-7672

MONDAY-FRIDAY, 9 AM TO 6 PM, EASTERN TIME

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http://www.epa.gov/swercepp/

NOTICE

The statements in this document are intended solely as guidance. This document does not substitute for EPA's or other agency regulations, nor is it a regulation itself. Site-specific application of the guidance may vary depending on process activities, and may not apply to a given situation. EPA may revoke, modify, or suspend this guidance in the future, as appropriate.

Appendix E

References:

Lees, Frank P.; *Loss Prevention in the Process Industries*; Second Edition, Butterworth-Heinemann; 1996

Enviro-net MSDS Index; http://www.enviro-net.com.

Pankratz, Mike; *Scheduled Maintenance Protect Your Welding Assets*; Miller Electric Mfg. Co., Appleton, WI; Metalforming Online - Article;
http:// www.pma.org/magazine/97/11/safety/safe.htm