

Case Study 10:

Static Spark Ignites Explosion Inside Flammable Liquid Storage Tank

Fire occurs when there is an ignitable vapor-air mixture and a source of ignition. One of the most difficult sources of ignition to avoid is electrostatic.

At normal handling temperatures, flammable liquid storage tanks might contain vapor-air mixtures that typically cannot be ignited because the vapor-air mixture is too rich (i.e., contains too much fuel and not enough oxygen) to burn. Others will be in the flammable range.

Liquids with low electrical conductivity can accumulate dangerous levels of static electricity that may ignite vapor-air mixtures inside tanks at normal handling temperatures.

This is what happened at Barton Solvents on July 17, 2007, at about 9 a.m. when the tank farm supervisor started the transfer of the final compartment of a tanker-trailer containing VM&P naphta into a 15'000 gallon (57m³) above-ground storage tank. The ignition was due to the charge accumulation of the VM&P naphta and an isolated (not grounded) conductive component.

The explosion sent the VM&P tank rocketing into the air, trailing a cloud of smoke and fire from the burning liquid. Within moments, two more tanks ruptured and released their contents into the rapidly escalating fire that was concentrated inside the earthen spill containment area surrounding the tank farm. As the fire burned, the contents of other tanks over-pressurized or ignited, launching steel tank tops (3- 3.7 meters in diameter), vent valves, pipes and steel parts off-site and in the surroundings. This led to the evacuation of the 6'000 residents living around the tank farm, and eleven residents and one firefighter required medical treatment.

Lessons learned:

It is necessary to:

- Take extra precautions when handling what are known as nonconductive flammable liquids, which tend to accumulate static electricity.
- Implement safety measures concerning bonding and grounding
- Purge the tank head space tanks with inert gas to remove oxygen.
- Add anti-static agent.
- Reduce flow pumping velocity.
- Contact manufacturers for additional safety information that may not be found on MSDSs.



Barton Solvents explosions

Reference:

CSB report “Barton solvents. Static Spark Ignites Explosion Inside Flammable Liquid Storage Tank”.

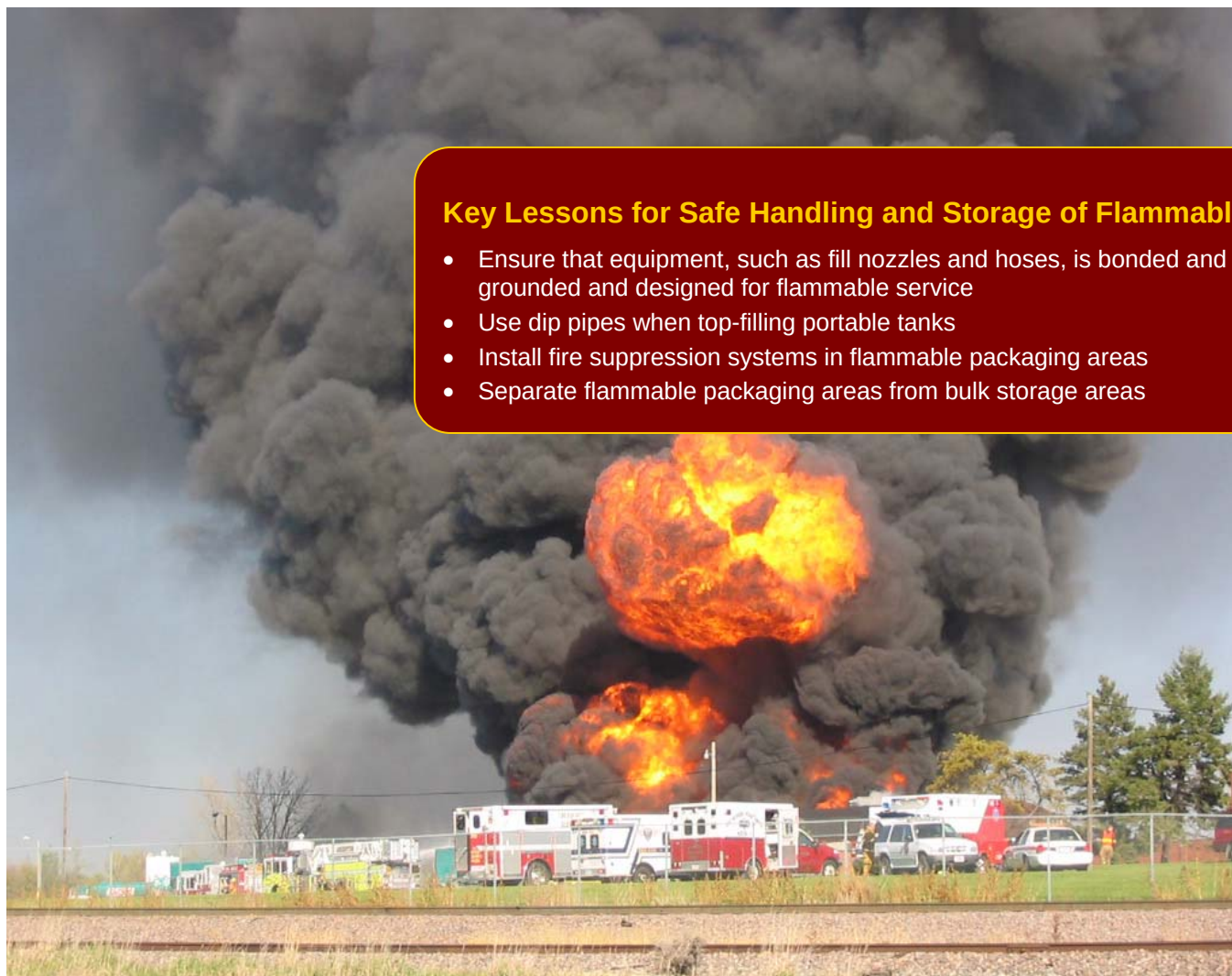


Case Study

U.S. Chemical Safety and Hazard Investigation Board

Static Spark Ignites Flammable Liquid during Portable Tank Filling Operation

No. 2008-02-I-IA (September 2008)



Key Lessons for Safe Handling and Storage of Flammables

- Ensure that equipment, such as fill nozzles and hoses, is bonded and grounded and designed for flammable service
- Use dip pipes when top-filling portable tanks
- Install fire suppression systems in flammable packaging areas
- Separate flammable packaging areas from bulk storage areas

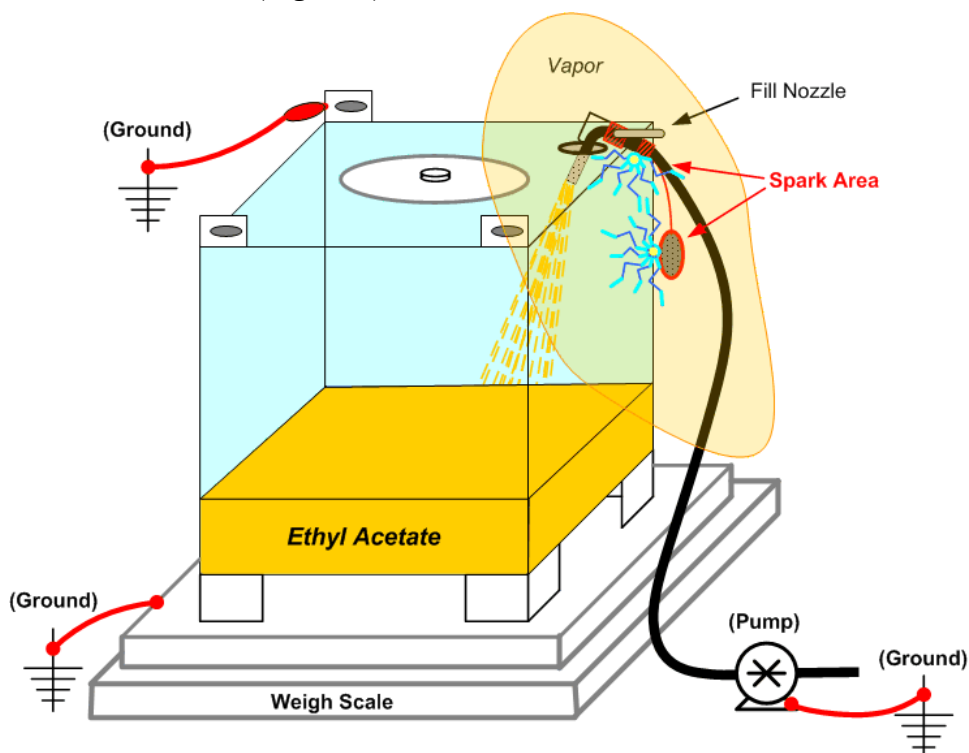
Who's at Risk...

Companies that transfer (pump) flammable liquids.

Incident Description

On October 29, 2007, at about 1 p.m., a fire and series of explosions occurred at the Barton Solvents Des Moines, Iowa, chemical distribution facility. The initial fire started in the packaging area while a 300-gallon portable steel tank, known as a tote, was being filled with ethyl acetate, a flammable solvent (Figure 1).

FIGURE 1.
300-gallon steel tote



An operator placed the fill nozzle in the fill opening on top of the tote and suspended a steel weight on the nozzle to keep it in place.¹ After opening the valve to begin the filling process, the operator walked across the room to do other work. As the tote was filling, he heard a “popping” sound and turned to see the tote engulfed in flames and the fill nozzle laying on the floor discharging ethyl acetate. Before evacuating, employees tried unsuccessfully to extinguish the fire with a handheld fire extinguisher. The

¹ Pressure from the liquid flowing through the nozzle can cause it to dislodge during filling. Hanging the steel weight over the nozzle helped stabilize the nozzle in place.

fire spread rapidly to the wood-framed warehouse, igniting a large volume of flammable and combustible liquids.

One employee received minor injuries and one firefighter was treated for a heat-related illness. A large plume of smoke and rocketing barrels and debris triggered an evacuation of the businesses surrounding the facility. The main warehouse structure was destroyed and Barton's business was significantly interrupted.

The Chemical Safety Board (CSB) is publishing this Case Study to underscore the need for effective bonding and grounding and for fire protection practices that should be observed when handling flammable liquids.²

Flammability of Ethyl Acetate³

The criteria outlined in National Fire Protection Association (NFPA) 30, *Flammable and Combustible Liquid Code*,⁴ state that ethyl acetate is a Class IB flammable liquid. In addition, NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, indicates that ethyl acetate has an elevated flammability hazard rating of "3."⁵

Under the conditions the ethyl acetate was being handled at the time of the incident, the CSB determined that an ignitable vapor-air mixture formed near the tote fill opening. A static discharge (spark) between the tote body and a metal component on the fill nozzle/hose assembly, which included the steel weight, likely ignited the vapor-air mixture.⁶

² On July 17, 2007, about three months before this incident, a large portion of Barton's Wichita, Kansas, facility was destroyed by a fire that the CSB believes was ignited by a static electric spark inside a flammable liquid storage tank. See the CSB Case Study *Barton Solvents: Static Spark Ignites Explosion Inside Flammable Liquid Storage Tank*.

³ Ethyl acetate is generally considered a conductive flammable liquid. However, fire and explosion incidents involving ethyl acetate have been reported that may be attributable to static electric sparks, which are usually associated with non-conductive or low conductivity flammables. In this incident, however, the CSB determined that a spark likely originated from accumulated static on the metal parts of the plastic fill nozzle and rubber hose assembly, which were not properly bonded and grounded. The Information Resources section at the end of this Safety Advisory includes resources about the static electricity hazards associated with transferring non-conductive flammable liquids.

⁴ The NFPA develops widely recognized consensus fire protection codes and standards.

⁵ The NFPA classifies the degree of hazard of a material on a scale of 0-4, with 4 being the most hazardous or "severe." Flammable materials rated "3" on this scale are defined as either liquids or solids that can be ignited under nearly all ambient temperatures. The flashpoint for ethyl acetate is approximately 250F (-40C), and its boiling point is approximately 1720F (780C). See NFPA 30, Section 4.3 "Classification of Liquids" and NFPA 704 (2007 ed.), Chapter 6, for a detailed discussion of NFPA's classification and flammability hazard rating systems.

⁶ A local exhaust ventilation system to remove vapors generated during filling operations was available, but was not turned on at the time of the incident. This system was severely damaged during the incident. As no design plans or specifications were available for review, the CSB was unable to determine if its use could have prevented the initial fire by reducing the concentration of the flammable vapors below the ignitable range.

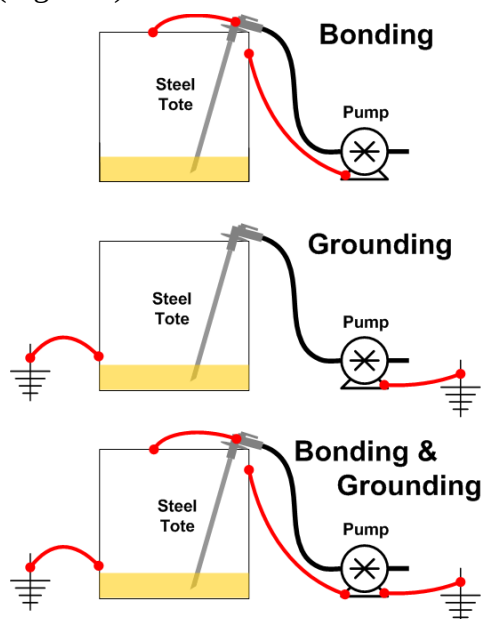
Bonding and Grounding

Static electricity is generated as liquid flows through pipes, valves, and filters during transfer operations. Proper bonding and grounding ensures that static electricity does not accumulate and spark. Static sparks can readily ignite the vapor-air mixtures of many flammable and combustible liquids.

Bonding is the process of electrically connecting, by wiring or direct contact, conductive objects (e.g., fill nozzles to steel tanks) to equalize their individual electrical potentials to prevent sparking.

Grounding is connecting a conductive object (e.g., tanks, totes) to the earth to dissipate electricity from accumulated static, lightning strikes, and equipment faults into the ground, away from employees and equipment (Figure 2).

FIGURE 2.
Bonding and grounding



Fill Nozzle and Hose

Because the steel parts of the fill nozzle and hose assembly (and the steel weight) were not bonded and grounded, the CSB concluded that static electricity likely accumulated on these parts and sparked to the stainless steel tote body, igniting the vapor that accumulated around the fill opening during filling.

The tote was sitting on a grounded weigh scale while being filled, and according to witnesses, the operator attached a grounding clamp to the tote before he started filling it. However, the metal components of the nozzle, the synthetic rubber fill hose, and the pump were not bonded to the tote.⁷

⁷ Bonded hoses contain a conductive wire or fibers that bond the nozzle to the pump and prevent static from accumulating as liquid flows through the hose and nozzle.

The nozzle was made of nonconductive plastic, but it housed a stainless steel ball valve and was fitted with a steel quick-connect fitting. The steel weight (suspended from the ball valve handle with a length of steel wire) was intended to prevent the nozzle from being ejected from the tote during filling.⁸ All these conductive objects were isolated from ground and were susceptible to static accumulation and discharge. The manufacturer's technical documentation for the nozzle and hose revealed that they were not intended for flammable service.

Top-Filling

Barton top-filled (splash-filled) its totes and drums in the packaging area. Ungrounded metal parts on the fill equipment likely accumulated a static charge and sparked to the external wall of the steel tote, igniting the vapors around the fill opening. Proper bonding and grounding, or other safeguards, would have reduced the likelihood of static ignition.⁹

A metal fill nozzle or dip pipe that is bonded to a grounded metal tote will not accumulate a static charge. NFPA 77, *Recommended Practice on Static Electricity*, states that portable metal tanks and IBCs (Intermediate Bulk Containers) should be bottom-filled if possible, using a slow velocity of 1 meter per second (3.3 feet per second) or less until the dip pipe is submerged to about 150 millimeters (6 inches).¹⁰ Figure 3 illustrates a dip pipe arrangement using a metal (conductive) fill nozzle and fill hose designed for flammable liquid service.¹¹

⁸ The length of wire used to suspend the steel gear from the fill nozzle handle allowed the gear to swing freely. According to witnesses, the gear would intermittently contact the tote as it swung.

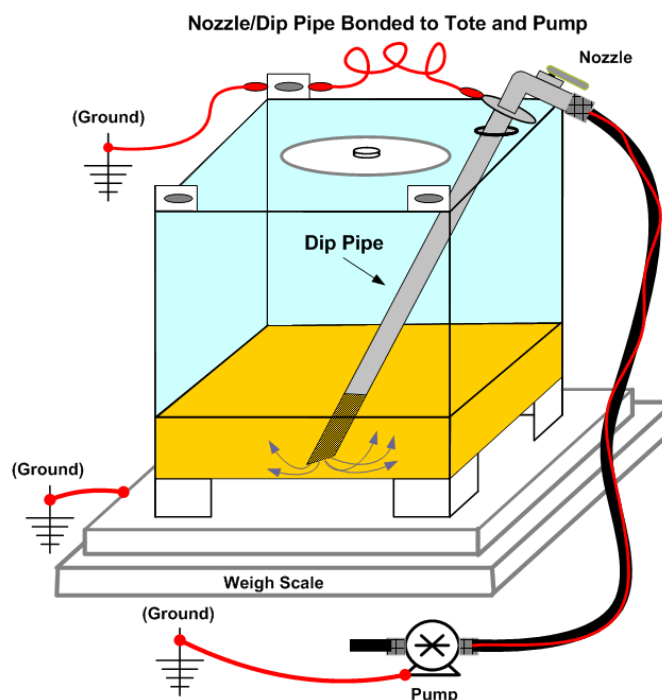
⁹ Other safeguards include reducing the fill (pumping) velocity to minimize static electricity generation, and adding an inert gas to the tote/drum headspace, which displaces the oxygen, thereby reducing the chance of ignition.

¹⁰ NFPA 77, Section 8.13.1.5.

¹¹ When purchasing equipment for flammable service, companies should verify that it is designed for use with flammable liquids and capable of being bonded and grounded.

FIGURE 3.

Dip pipe



Fire Separation and Suppression

The packaging area was adjoined to the flammable storage warehouse. A wall separating the two areas was not fire-rated, and large non-fire-rated doors between the warehouse and packaging area were kept open and were not equipped with self-closing mechanisms. The CSB believes that this lack of effective separation aided the fire to spread rapidly into the warehouse area.

The warehouse had an automatic sprinkler system, which did not extend into the packaging area where flammable liquids were routinely stored.¹² Barton's property insurance company had recently recommended that Barton install an automatic fire suppression system in the packaging area.

The fire started in the packaging area and quickly spread to the warehouse. The warehouse sprinkler system activated after the fire had gained momentum in the packaging area, but was incapable of extinguishing the blaze.

If a fire suppression system had been installed in the packaging area and that area had been separated from the warehouse by fire-rated walls and doors, this fire likely would have been extinguished or contained before engulfing the entire warehouse.

¹² At the time of the fire, several 55-gallon drums and approximately 30 smaller containers (i.e., 1-5 gallons) of flammable liquids were stored in the packaging area.

Key Lessons for Safe Handling and Storage of Flammables

- *Ensure that equipment such as fill nozzles and hoses are bonded and grounded and designed for flammable service.*

The fill nozzle and hose used at Barton were not designed to be bonded and grounded, and were not intended for flammable service.

- *Use bonded and grounded metal dip pipes when top-filling portable tanks.*

Although the lack of a dip pipe for filling the tank was not a cause in this incident, use of grounded metallic dip pipes is recommended by NFPA 77.

- *Install fire suppression systems in flammable packaging areas.*

A fire suppression system in the packaging area likely would have stopped the rapid spread of the fire to the warehouse.

- *Separate flammable packaging from bulk storage areas.*

Proper separation from the warehouse by fire-rated walls and doors would have helped prevent the fire from spreading to the warehouse.

Regulatory and Good Practice Guidance

If Barton had implemented a comprehensive static electricity and flammable liquid safety program in compliance with current regulatory standards and good practice guidance, this incident likely would have been prevented.

The Occupational Safety and Health Administration's (OSHA) *Flammable and Combustible Liquids* standard (29 CFR 1910.106), Section (f), "Bulk Plants," contains requirements for portable tank bonding and grounding, that—if implemented properly—would likely have prevented the static spark between the tote and the nozzle.

NFPA 30 *Flammable and Combustible Liquids Code* (2008 ed.) includes guidance on mechanical ventilation; fire separation of dispensing (packaging) and storage areas; and a hazard analysis to determine the extent of necessary fire prevention and control (suppression).¹³

NFPA 77 *Recommended Practice on Static Electricity* (2007 ed.) contains detailed guidance on safely managing static electricity to prevent fires and explosions. Chapter 8.4.4 addresses the safe use of fill (dip) pipes during filling operations, and Chapter 8.13 provides detailed guidance for bonding and grounding, and information on how to safely fill portable tanks.

¹³ Current Iowa State Fire Marshal Administrative Rules require facilities that handle flammable liquids to comply with NFPA 30, which includes a requirement that facilities conduct a hazard analysis to determine if fire control (suppression) is necessary. This requirement applies only to newly constructed facilities.

Companies should address the hazards associated with static electricity and flammable liquid transfer and handling operations by applying these and other good practice guidelines to determine if their facilities are properly designed and being safely operated.

Information Resources

The following references provide additional information on the safe handling of static-accumulating flammable liquids:

- American Petroleum Institute (API), “API Recommended Practice 2003: Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents,” 7th ed. (2008).
- Britton, L.G., and J.A. Smith, “Static Hazards of Drum Filling,” *Plant/Operations Progress*, Vol. 7, No. 1 (1988) pg. 53-78.
- Britton, L.G., *Avoiding Static Ignition Hazards in Chemical Operations*, AIChE-CCPS Concept Book (1999).
- National Fire Protection Association (NFPA), “NFPA 30: Flammable and Combustible Liquid Code,” 2008 ed.
- National Fire Protection Association (NFPA), “NFPA 77: Recommended Practice on Static Electricity,” 2007 ed. NFPA 77 can be viewed, free of charge, on the NFPA website (www.nfpa.org). Access directions: At the NFPA Homepage, go the “Codes and Standards” pull down tab, then click on “Code development process” and scroll down to “Online access.”
- Occupational Safety and Health Administration (OSHA), “29 CFR 1910.106: Flammable and Combustible Liquids Standard.”

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The Board does not issue citations or fines but does make safety recommendations to companies, industry organizations, labor groups, and regulatory agencies such as OSHA and EPA. Please visit our website, www.csb.gov.

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