Overfill Prevention of Reducing Emissions to Reduce Carbon Footprints

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History of Aboveground Storage Tanks

Aboveground Storage Tanks Facilities have been around for centuries. There are over 1 million aboveground storage tanks in the United States, ranging from 10 gallons to over 1 million barrels capacity. The liquid storage business has self-regulated itself to improve the environmental conditions and the Safety and Health initiatives for their employees and the public. Many of these decisions were made due to minimizing losses. Preserving the environment was a benefit to not losing product through evaporation and employees being place in difficult health situations.

In the Beginning

In the early days, crude oil was stored in many containers ranging from hand-dug ponds to sophisticated, engineered, calibrated, storage containers. Now days, with the advancement of inspection technology and improved construction methods, our storage tanks have become sophisticated calibrated storage containers.

In the mid 1800's, when the development of oil and gas exploration and production became a merchantable business, crude oi was stored in hand-dug ponds. Figure 1 shows a 40' hand-dug pond. Many of these ponds were created where shallow well were perking crude oil from low pressure shallow formations. Most of these resided in the mid-west United States.



Figure: 1

As the oil and gas industry began to develop throughout the country, the need to storage containers became necessary. The industry began building storage tanks out of wood with metal rings. Figure 2 show how the oil and gas industry utilized the wood tanks in areas where oil was being produced.



Figure 2

Advancement in Aboveground Storage Tank Construction

From wooden tanks, we moved into metal tanks. These tanks were built to be bigger and hold more volume as the market for crude oil increased. We have moved from open-source tanks with no floating roofs to open source tanks with floating roofs. Figure 3 is a picture of open-top tanks and open-top tanks with floating roofs, known as external floating roof tanks.



Figure: 3

To further improve our losses and reduce our emission, improving CO2 Emissions Footprint, as an industry, we decided to put dome roofs over these tanks to reduce the amount of contamination of the liquid and to reduce emissions, improving CO2 Footprint.



Figure: 3

To take this a step further, as an industry, we decided to reduce more emissions and improve losses by installing vapor recovery units to capture the vapor space liquids and reduce them down to usable product. Vapor Recovery Units (VRU) have been instrumental in working to reduce emissions from storage tanks, truck loading and unloading operations.



Figure: 4

Overfills and Spills Incidents

Aboveground storage tank overfills, and spills have caused catastrophic damage, often triggering explosions and major environmental incidents. Investigations frequently reveal a pattern of human error, poor maintenance, inadequate safety regulations, and poor implementation practices.

With the advancements of aboveground storage tank, we continued to have spills and overfill incidents. The following is a list of notable incidents.

Notable Aboveground Storage Tank Overfills and Spills

Great Molasses Flood (Boston, MA, 1919)

Though not an overfill of oil, this is one of the most famous AST failures in American history, caused in part by overfilling.

- **Cause:** On January 15, 1919, a 2.3-million-gallon tank owned by the U.S. Industrial Alcohol Company ruptured, sending a wave of molasses through Boston's North End. A later court battle determined that shoddy construction, poor inspections, and overfilling contributed to the disaster.

- **Impact:** A 15-foot-high wave of molasses, traveling at 35 miles per hour, flattened buildings and swept people into the streets. The incident killed 21 people and injured 150 others.

Newark Gasoline Storage Tank Overfill (New Jersey, 1983)

This incident demonstrated the deadly consequences of an overfill at a fuel terminal.

- **Cause:** On January 6, 1983, a gasoline tank overfilled at a marketing terminal in Newark, triggering an explosion and fire.
- **Impact:** The blast killed one person and injured 24 others. The effects of the explosion were devastating, with the force flattening freight cars and destroying other nearby tanks.

Caribbean Petroleum (CAPECO) Explosion (Bayamón, Puerto Rico, 2009)

This disaster highlights how a series of failures, including an overfill, can escalate into a major event.

- **Cause:** In October 2009, an AST overfilled during a gasoline transfer from a marine vessel. Critical overfill prevention equipment was either poorly maintained or non-functional at the time.
- **Impact:** The resulting aerosolized gasoline spray formed a 107-acre vapor cloud that ignited, causing a massive explosion that registered as a magnitude 2.9 seismic event. While no one died, the blast damaged over 300 nearby homes and businesses and released petroleum into the surrounding environment. The event prompted a major Chemical Safety Board investigation.

Adak Petroleum Aboveground Storage Tank Diesel Overfill (Adak Island, Alaska, 2010)

This incident highlights the environmental risk of an AST overfill in a sensitive ecosystem.

- **Cause:** In January 2010, an underground tank was overfilled with diesel fuel during a transfer operation from a tanker. The containment system was overwhelmed, allowing fuel to escape.
- **Impact:** Approximately 142,000 gallons of diesel fuel spilled, with much of it entering a salmon creek and the harbor at the Port of Adak.

Buncefield Explosion Hertfordshire Oil Storage Terminal, (Hertfordshire, England, December 2005)

Even though this facility was fully integrated with a complete control system, a primary tank gauge along with an independent point-level switch assigned as the overfill protection device, documented subsequent testing procedures of the overfill protection device, established communications with pipeline transporter, documented training program, assumptions and complacency, can still cause incidents.

- **Cause:** December 2005, an aboveground tank overfilled unleaded gasoline during a transfer operation from a pipeline transporter. The storage tank began to overfill, for a long period of time, causing hydrocarbon vapors to form in the terminal environment. After all the investigations and studies, it has been undetermined of the actual spark that initiated the explosion. It has been argued that the point-level switch was not replaced with a float, it was replaced with a displacer. It has been argued that the roof should have initiated the shutdown sequence only if the roof made it to the top to do so. Had the device been properly replaced with a float, through a Replacement-In-Kind procedure, it is my expert opinion that the device would have initiated the shutdown sequence.

- **Impact:** HOSL was the 5th largest oil storage facility in the UK, with a storage capacity of 60 million imperial gallons of fuel. The explosion registered 2.4 on the Richter scale. Situated near the M1 motorway, this incident caused major interruptions to transportation. Complete destruction of an industrial complex effecting other businesses. There were no reported loss of life, but did incur over 42 reported injuries. Attempting to extinguish the fires, caused major ground contamination.

Overfills and Spills Prompting Regulatory Changes

Historically, a lack of consistent federal oversight contributed to dangerous practices at AST facilities. Major incidents have often spurred new regulations and industry standards.

- **Ashland Oil Spill (1988):** Although not an overfill, the catastrophic failure of an Ashland Oil storage tank in Pennsylvania, which spilled over 750,000 gallons of oil into the Monongahela River, exposed major regulatory shortcomings. The incident brought the control of ASTs to the forefront of the congressional agenda and highlighted the need for better construction standards and inspections.
- **Oil Pollution Act of 1990:** Following the *Exxon Valdez* disaster and other incidents, Congress passed this law, strengthening the federal government's ability to prevent and respond to oil spills. It increased liability for responsible parties and mandated stricter spill prevention measures for facilities.
- **Post-CAPECO Regulations:** The Chemical Safety Board's 2015 report on the CAPECO explosion led to recommendations for the Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA). These recommendations called for more robust regulations, including mandatory risk assessments and automatic overfill prevention systems.
- **Buncefield Hertfordshire Oil Storage Terminal:** Implementation of the Control Of Major Accident Hazardous regulations 1999 (COMAH). Implementation of SIS Safety Integrity Levels as a systematic assessment for Overfill Prevention systems in accordance with IEC-61511 and the selection of devices in accordance with IEC-61508. The American Petroleum Institute revised API 2350 from a Recommended Practice to an Industry Standard. The revision focused on developing storage tank categories and conducting risk profiles to determine the levels of automation and integration. This methodology was implemented in accordance to IEC-61511 for risk assessments and IEC-61508 to determine the appropriate devices based on risk profiles.

Overfill Prevention Programs

Overfill Prevention Programs should provide information to avoid overfill incidents from occurring. Aboveground Storage Tank incidents can lead to catastrophic events. These events could include loss of life, injury to personnel, environmental contamination leading to long-term health effects to humans and animals, equipment damage, and loss of products.

To ensure safe operations and good engineering practices, OSHA provides the Process Safety Management of Highly Hazardous Chemicals standard (29 CFR 1910.119). This standard provides an outline for managing hazards associated with hazardous liquids and chemicals in large facilities with large chemical manufacturing facilities and processes, such as refineries and petrochemical facilities. Since our market is only a subset of a refinery, primarily on the front end storing crude oil and on the back end storing finished products in the form of light distillates for distribution, OSHA produced a recommendations document, OSHA Publication 3903-03 (2017) Process Safety Management for Storage Facilities. This document is not a standard, it is considered to be a recommended practice and advisory in nature and a good engineering practice. It is not uncommon for regulatory agencies to adopt a recommended practice as rule (Shall). This standard will establish a management program that is best fit for your operations, maintenance, and facility management structure.

There are some parts of this standard you will use and some you will not use. It is important to understand the parts of a Process Safety Management program that is relevant to your facility. If will integrate technologies, policies and procedures, and management practices.

A Process Safety Management program will provide the basis of the necessary steps to begin developing an Overfill Prevention program.

Process Safety Management

A Process Safety Management program for storage terminals is different than what you would have for a facility processing hazardous chemicals for manufacturing purposes, as described in *OSHA Process Safety Management of Highly Hazardous Chemicals Standard (29 CFR 1910.119)*. But the PSM program as outline in *OSHA Publication 3903-03 (2017) Process*

Safety Management for Storage Facilities, does not provide enough information or guidance on safely operating a storage tank facility. There are important functions that need to be considered when developing an Overfill Prevention program.

Management Role

Management has everything to lose from an overfill incident. There is nothing to gain from not spending the dollars to implement a proper overfill prevention program. One incident could change the landscape of their business to almost a point of extinction. From the Buncefield incident, the HOSL facility was never rebuilt to its former self.

Management plays an important role in developing an overfill prevention program. Management will make sure that all areas of concerns are addressed and proper procedures and are followed to assure safe operations, lets not forget about loss of product. Management should consult with a subject matter expert to assure that all areas of concerns are addressed within reason and that procedures are not crippling day-to-day operations. There are limits that need to be adhered to so that business can continue without interruptions, but also just doing the bare minimum will never be enough to assure safe operations.

Employee Role

The employee has the most important role in an overfill prevention program. It does not matter how much automation or integration you do; employees are still the single most important part of an overfill prevention program. The Buncefield incident was caused by people making improper decisions on moving forward with operations, knowing that their overfill protection devices were compromised. A contingency plan was not put in place to continue operations with the proper procedures put in place to continue operations with known faulty devices.

The employees have experience in identifying hazardous in the workplace. They also have experience in identifying potential hazards, which is a key component in developing an effective overfill prevention program. Employees must have the initiative to provide feedback and a solution to an issue with programs and procedures.

Process Hazard Analysis (PHA)

The PSM standard allows PHAs to be conducted by many different methodologies, enabling facilities to address their unique process safety challenges in a manner that is most appropriate and cost-effective for them. Typically, storage facilities should be able to use less sophisticated techniques such as Management of Change (MOC) process, What-if, Replacement-In-Kind procedures, Checklists, or a combination of these acceptable methods.

A process hazard analysis is an organized systematic effort to identify and analyze potential hazards associated with storing hazardous chemicals. A PHA team must be comprised of personnel that are knowledgeable in engineering, design, process operations, maintenance personnel, and at least one member of the facility management team. It is recommended to also include a subject matter expert (SME) of the equipment and devices being used in the control methodology being used. The SME would be a completely unbiased party of management, equipment, and devices used to control the transfer and operations of the storage tanks.

The team analyzes potential causes and consequences of fires, explosions, releases of toxic or flammable chemicals, and major spills of hazardous chemicals. The team conducting the PHA must make recommendations for additional safeguards to adequately control identified hazards or to mitigate their effects; and at the same time, do not hinder the day-to-day operations of the facility. Decisions should be made with safe operations in mind as well as having economic impact on the business of the facility.

Safeguards may include inherently safer or passive approaches to hazard control, or suggesting new engineering controls (e.g., improved fire detection and suppression systems at facilities that store heat-sensitive chemicals) or administrative controls (e.g., new operating procedures, inventory control measures, separation of highly hazardous chemicals into different storage areas). Safe upper and lower process limits for such items as temperatures, pressures, flows or compositions, and an evaluation of the consequences of deviation, including those affecting the safety and health of employees, that could occur if operating beyond the established process limits.

Process Safety Information

Storage Terminal companies are required to have written process safety information. This information will help the employer and employees identify the hazards around the hazardous chemicals being stored in their facility. Normally, this is displayed in a Block Diagram or a Process Flow Diagram. Good engineering practices have been exercised to develop Process Instrument Diagrams that illustrate the process flow including the control strategy of the facility. Although storage facilities typically have relatively few procedures, when highly hazardous chemicals are involved, it is still critically important that these procedures are thorough, clear, and communicated effectively to employees annual training audits. Employers must ensure that employees both understand and routinely follow these procedures. This information should be included in all employee training documentation and safety orientation documentation for all employees and visitors. This information should be continuously updated and periodic safety training meetings should be conducted to assure all employees are aware of any new and existing potential hazards.

It is important to continuously update the chemical toxicity, permissible exposure limits, physical data, reactivity data, corrosivity data, thermal and chemical stability data, and hazardous effects associated with inadvertent mixing and exposure of chemicals that may occur. This information changes periodically, therefore, to ensure safe operations and proper extinguishing properties are met in the case of a spill or mixing event due to an overfill.

Safety Training

Employers must provide initial and refresher training to every employee involved in operating a PSM-covered process. Training must also cover the facility's procedures for emergency operations, such as loss of containment scenarios. The level of training may vary for each employee. For example, those who work in the area or operate the equipment will receive more extensive training than visitors or other non-operational personnel, which would require awareness training. Employers must also train contractors or temporary employees on known potential fire, explosion, or toxic release hazards associated with their work and the processes.

Many storage facilities may have minimal process equipment. Nevertheless, facilities must collect information on equipment that is part of the PSM-covered process. Typical equipment may include: storage tanks, piping, pumps, containers, dikes and liners, process alarms, integrated controls, process safeguards, monitoring equipment, electrical classifications, pressure relief system design and design basis, ventilation equipment and system designs, and safety shutdown systems.

Mechanical Integrity Program

It is important to understand the mechanical integrity of the equipment being used to operate a facility. Employers must document that all equipment complies with **R**ecognized **A**nd **G**enerally **A**ccepted **G**ood **E**ngineering **P**ractices (RAGAGEP). In all cases, the RAGAGEP must be both "recognized and generally accepted" and "good engineering practices".

A starting point for creating a mechanical integrity program is listing all equipment, instruments, and components that need to be considered. Manufacturer recommendation on testing procedures and protocols must be considered as part of the mechanical integrity program. If the equipment is considered to be legacy in nature and does not have any mechanical integrity related information, the facility should look for applicable codes/standards or industry best practices.

It is important to implement written procedures that ensure that critical process equipment are properly fabricated, tested, inspected, repaired, and maintained. Mechanical integrity programs must address pressure vessels, storage tanks, piping systems (including piping components such as valves), pumps, relief or vent systems and devices, emergency shutdown systems, and controls (including monitoring devices and sensors, alarms, and interlocks). Storage facilities with PSM-covered processes typically have less equipment to maintain, making compliance less challenging, although no less important.

Inspections and Testing

Inspections and tests must follow Recognized and Generally Accepted Good Engineering Practices (RAGAGEP), and inspection and test frequency must be consistent with manufacturer's recommendations and good engineering practices, or more frequently if indicated by operating experience. Each inspection and test to verify current equipment integrity must be documented. This documentation serves as proof of compliance, and the records can also be used to assess trends in longer-term equipment degradation which is then used to determine if inspection and testing frequencies should be adjusted. Any

deficiencies identified during inspections and tests must be addressed before further use, or in a safe and timely manner when actions are taken to assure safe operation pending repairs.

When equipment is determined to be deficient, a management of change (MOC) procedure must be established and implemented prior to continuing operation of the deficient equipment outside of established operating limits. The MOC procedure must include a determination of the safety and health impacts of continued operation of the deficient equipment.

Equipment Training

Employers must train each employee involved in the maintenance of the integrity of equipment used in an ongoing process. These employees must be provided an overview of the process, its hazards, and the procedures they must follow in their assigned tasks to ensure they can perform the tasks in a safe manner. This is important because maintenance employees may not be fully versed in process hazards—particularly in cases where storage facilities contract out much of their inspection, testing, maintenance, and repair duties.

The final element of mechanical integrity programs is quality assurance. PSM-covered facilities must ensure that equipment for newly constructed operations is suitable for the intended application and that equipment in existing processes is properly installed and consistent with design specifications. Quality assurance requirements also apply to maintenance materials and spare parts to ensure compatibility with the equipment and the process.

Automated Control Systems and Overfill Protection Devices

A properly engineered and designed overfill protection system is a very important component in an overfill prevention program. This is the final element of control to avoid tank overfills.

The American Petroleum Institute has developed API 2350 Overfill Prevention for Storage Tanks in Petroleum facilities, as an industry standard on how to develop an overfill prevention program. API 2350 uses a risk-based approach to developing an overfill prevention program by incorporating relevant context from IEC-61508 which is an international standard providing framework for developing and maintaining electrical, electronic, and programmable electronic systems to prevent failures that could lead to serious harm or catastrophic events from occurring. In addition, API 2350 also incorporates IEC-61511, an international standard for functional safety providing requirements for the design, operation, maintenance, and reliability of safety systems used to reduce the risk of harmful events occurring, such as tank overfills. Together, both of these documents were used to develop API-2350 standard.

API 2350 is the recommended docoument to develop your overfill protection system architecture. This standard incorporates operational procedures and calculations that are spefic storage tank operations. This standard provides information on developing a risk matrix to categorize your facility and storage tanks based on your location and the sensitivity of where your facility resides. It incorporates safe fill operations and calculations based on your operational characteristics such as incoming and out-going flowrates, mechanical integrity of your storage tank, and operational characteristics such as manned or unmanned which determines your response time to avoid hazardous events from occurring.

This standard also provides guidance on level devices on how to select appropriate devices for use in continuous level measurement and point level devices used in detecting high alarm setpoints that are setup based on the risk assessment that is done for the storage tanks and their filling profiles. Level devices should be selected based on your operational characteristics and your response time to adressing potential hazardous events.

It is important to consider how the facility is controlled by 3rd party pipeline transports. In many cases, there is no hard shutdown devices that will shut down incoming flow from a 3rd party pipeline. There should be a controlled sequence that is initiated by the overfill protection device, to bring the incoming pipeline reciept, to a controlled shutdown. It is very important to understand that storage facilities are equipped with burmed areas with liners that are built to control a tank overfill. It is recommended that if an overfill event had to take place to bring a pipeline down to a safe shut off condition, you would elect to utilize the facilities in a tank farm to accommodate a take overfill event. Emergency reponse procedures and programs are executed to minimize damages to control and prevent a catastrophic event from occurring.

Conclusion

Aboveground storage tanks are very important to our industry. We have developed many standards and procedures to assure we protect the environment and our employees from hazards associated with storage tank operations. All of these points addressed in this document, work together to develop an overfill prevention program.