HAZARDALERT

Oil Field Tank Batteries — Flare Flashback Explosion Prevention

A North Dakota-based fossil fuel exploration and production company was performing modifications at a tank battery facility located in the Bakken oil fields. As crews were finishing work, an explosion of the storage tanks occurred. Fortunately, all on-site personnel were working away from where the explosion occurred, and no one was injured. The tank battery was heavily damaged, halting production for several months. Flare flashback was identified as the likely cause of explosion. A flare flashback incident can occur when the flame is drawn backwards into the flare stack due to flow instabilities in the system. Once drawn into the flare stack, the flame front can travel back to the tank battery, igniting flammable vapors in the tanks.

Background

The tank battery design, common to many oil and gas gathering sites, included both an equalization piping system and a low-pressure vent system. The vent system collected vapor from the head space of each tank and directed it to a flare system. The flare system was a typical elevated design, including a flare knockout drum, a flame arrestor, an air-assist fan, and a flare stack (see Figure 1 below).

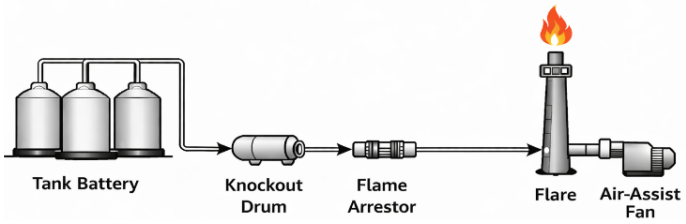

Figure 1: Tank battery flare system.

What Led to the Explosion?

When the explosion occurred, the tanks were all connected via vent system piping, allowing flow of hydrocarbon vapors from all tanks to the flare system. The system was in a transient operating mode, as workers were performing retrofit activities. The following contributing factors were also identified by OSHA:

- Very low levels of hydrocarbon liquids existed in two of the storage tanks, resulting in a reduced amount of vapor flowing through the system.
- The liquid in each of the tanks was stagnant for several days, reducing vapor flow over time.
- The tanks experienced significant temperature fluctuations between nighttime and daytime hours, with the cooler temperatures resulting in a further reduction in vapor flow to the flare.
- The generator powering the air-assist fan to the flare had run out of fuel shortly before the explosion, and air assist flow was lost.
- The flare flame propagated backwards through the flare stack, burned through the flame arrestor, and ignited vapors in the head space of the connected tanks.

Figure 2: Damaged storage tanks from flare flashback event.

Hazardous Conditions

Worker exposures to a flare flashback event, and the resulting fire and explosion, can readily result in severe injuries. Flashback hazards are more likely to exist at oil field tank batteries during certain phases of construction and operation where low flow conditions can occur, such as the following:

- Retrofit
- Shut-In (temporary shutdown)
- Low Production
- Startup

To mitigate the flashback hazard, attention is needed for both flare flame stabilization (flashback prevention), and flare system isolation/purge (flashback protection).

Engineering Controls

Several control options exist that can prevent or control flare flashback explosions. These techniques below should be designed, installed, and operated by individuals with expertise in flare and oil field tank battery systems, and in accordance with industry standards and recommended practices, as applicable.

- **Burner Assembly Design**

  Current flare tip burner technology, such as crimped ribbon designs, provides enhanced flame position stabilization. These burner designs can significantly impact the stability of flame position over a wide range of vent flow rates.

- **Flare Vent Gas Flow Support and Flame Stabilization**

  Flare vent flow support is an effective method of maintaining minimum, positive, flare vent flow and stabilizing flame position. The use of air-assist fans for injecting air directly into a flare plenum is a common method for providing supplementary flare vent flow. Where air-assist fans are used, it is critical that the fan power source is designed for continuous operation. Fan power sources may include the electrical grid or onsite fuel-driven generators, including redundant power sources and automatic transfer to backup power if the primary system fails. To ensure that power is not interrupted, instrumentation that monitors, alarms, and transmits information on existing conditions can be utilized to alert personnel to take necessary actions, such as re-fueling generators before power is lost.

  Alternative methods of providing flare vent gas flow support may also be available, including the use of recirculated, heater-treater vent gas. For these and other methods utilized for vent gas flow support, the system must be designed to function during all applicable phases of construction, operation, and shut-in, as previously noted.

- **Stack Air-Assist Plenum**

  Proper design of the air-assist plenum can also provide means for stabilizing the flare flame. Air-assist plenums designed to not extend the full stack height will significantly reduce the combustible concentration range of the vent gases. In addition, air-assist plenums that terminate near the top of the flare stack will minimize impact on the combustible concentrations of the vent gas, while maintaining the air-assist flow necessary for flare flame stabilization.

- **Detonation Arrestor**

  Tank battery flare system experience suggests that "Deflagration" arrestors, historically used to inhibit reverse flame travel at subsonic speeds and low pressures, are not as effective as "Detonation" arrestors which are designed for supersonic flame speeds and extreme pressures. In addition, experience has shown arrestors need to be installed closer to the flare stack than often occurs. Detonation arrestors should be installed carefully following manufacturer's recommendations for line placement and spacing.

- **Temperature Detection**

  Investigation of reverse flame travel in flare systems indicates these flames can reside, for up to an hour or more, immediately downstream on the flare side of the arrestor. This is due to both flow dynamics and the existence of liquid hydrocarbons known to collect in small amounts in the bottom of the vent piping at that location. A temperature sensor, installed at the flare side of the arrestor, can provide indication of combustion within the stack and allow the flame to be extinguished before burning through the arrestor and traveling further upstream.

- **Flare Gas Flow Instrumentation**

  Flow-indicating instrumentation in the flare vent header can provide information on current flow conditions as well as trending data for advance warning of impending low flow conditions, allowing

remedial actions to be taken when needed. The appropriate type of flow instrumentation may vary depending on system design and process conditions.

- **Emergency System Isolation**

  Arrestors are designed to pause a reverse-traveling flame front for a short period of time at the flare side of the arrestor. However, arrestor manufacturers have indicated that this combustion can burn through the arrestor and ignite upstream combustibles in less than an hour. Installation of a fast-acting, isolation valve on the upstream side of the arrestor can prevent the flame from reaching the tank battery. This isolation valve can be triggered by either a vent gas flow or arrestor temperature signal.

- **Flame Purge Gas**

  High pressure, inert gas (i.e. CO_2, N_2, etc.) can be piped to an injection port in the vent piping to maintain positive pressure, prevent air ingress, and avoid an explosive air-gas mixture. This purge gas can be triggered by a temperature signal at the flare side of the arrestor. This action can occur simultaneously with closure of the upstream, fast-acting valve described above. The local isolation valve helps ensure that combustion occurring within the vent piping is driven out through the flare stack. Flare system controls should shut down the flare system following a purge gas release, pending manual restart as vent system stability is re-established.

Conclusions

The control recommendations provided above are intended to assist those responsible for design, modification, or operation of tank battery flare systems. These recommendations were noted by various industry experts and equipment vendor representatives, as viable methods of abating tank battery flare system flashback. The risk of severe injury as well as considerable equipment and production losses are strong motivation to carefully consider flashback abatement strategies early in the development of tank battery site design, or to improve existing systems.

Resources

- American Petroleum Institute (API) 521 – Pressure-Relieving and Depressurizing Systems
- American Petroleum Institute (API) 2028 – Flame Arresters in Piping Systems
- American Petroleum Institute (API) 537 – Flare Details for General Refinery and Petrochemical Service
- Center for Chemical Process Safety (CCPS) – Guidelines for Vapor Release Mitigation
- Center for Chemical Process Safety (CCPS) – Guidelines for Pressure Relief and Effluent Handling Systems
- Center for Chemical Process Safety (CCPS) – Guidelines for Engineering Design for Process Safety
- Center for Chemical Process Safety (CCPS) – Plant Guidelines for Technical Management of Chemical Process Safety

How OSHA Can Help

We have compliance assistance specialists throughout the nation who can provide information to employers and workers about OSHA standards, short educational programs on specific hazards or OSHA rights and responsibilities, and information on additional compliance assistance resources. Contact your local OSHA office for more information.

OSHA's On-Site Consultation Program offers no-cost and confidential services to help small and medium-sized businesses find and fix workplace hazards. On-Site consultation services are separate from enforcement and do not result in penalties or citations. Visit the nearest Consultation office, or call 1-800-321-OSHA (6742).

Workers' Rights

Workers have the right to:

- Working conditions that do not pose a risk of serious harm.
- Receive information and training (in a language and vocabulary the worker understands) about workplace hazards, methods to prevent them, and the OSHA standards that apply to their workplace.
- Review records of work-related injuries and illnesses.

- File a complaint asking OSHA to inspect their workplace if they believe there is a serious hazard or that their employer is not following OSHA's rules. OSHA will keep all identities confidential.
- Exercise their rights under the law without retaliation, including reporting an injury or raising health and safety concerns with their employer or OSHA. If a worker has been retaliated against for using their rights, they must file a complaint with OSHA as soon as possible, but no later than 30 days.

For additional information on workers' rights, visit, www.osha.gov/workers.

How to Contact OSHA

OSHA's mission is to assure America's workers have safe and healthful working conditions free from unlawful retaliation. For more information, visit www.osha.gov or call OSHA at 1-800-321-OSHA (6742).

This Hazard Alert is not a standard or regulation, and it creates no new legal obligations. It contains recommendations as well as descriptions of mandatory safety and health standards. The recommendations are advisory in nature, informational in content, and are intended to assist employers in providing a safe and healthful workplace. The Occupational Safety and Health Act requires employers to comply with safety and health standards and regulations promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, the Act's General Duty Clause, Section 5(a)(1), requires employers to provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. The mention of any non-governmental organization or link to its website in this Hazard Alert does not constitute an endorsement by OSHA of that organization or its products, services, or website.

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