

A Lesson for Learning from the Lemoore City Water Tank and Other Hot-Work Related Tank Explosions

An Online Continuing Education Course for Engineers

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A Lesson for Learning from the Lemoore City Water Tank & Other Hot-Work-Related Tank Explosions

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Prologue

On June 21, 2021, a 1.5-million-gallon water tank exploded as a contractor began to weld on the exterior of a raw-well-water storage tank. How could a water storage tank explode, ripping the shell and roof sections away from the floor plate with such force?

Watching the video several times from two different angles, the disaster was mind-numbing to comprehend. Then, instinct and twenty-five years of performing incident investigations kicked in. Not knowing anything but what was shown in the video, two possible causes entered the author's mind. One was contamination of some type of hydrocarbon having been inadvertently introduced into the tank. The second was a breakdown-decay of organic materials in a stagnant untreated tank.

Following the event closely, about a month later, a press release with a preliminary report identified the cause as methane gas build-up from organics in the well-supplied raw water that had been pumped into the tank. Bingo!

This course will review other hot-work-related tank explosions over the last few decades. We all know that if an explosion of a tank during hot-work produces no fatalities, it, in turn, does not produce a lot of media and regulatory interest. So, we will look at the most well-known hot-work tank explosions. There are numerous hot-work-related tank explosions listed in the OSHA, CSB, NFPA, and EPA (See resources in the later section for abbreviated meaning) databases, not including the Lemoore Water Tank explosion. This review focuses primarily on those reported by the CSB and OSHA due to the availability of detailed investigation reports.

We will perform data analysis on key attributes of these incidents to discover commonalities between them (See Appendix A for Data Tables). We will share the incident summaries and any cause and conclusions as a part of this data review. Lastly, we will develop conclusions for both lessons for learning and recommend solutions for you to implement within your company's policies, procedures, administrative controls, engineering design, LoTo, hot-work, and training.

The Lemoore Raw water tank explosion should be a wake-up call for any company that operates and maintains any type of storage tank and contractors who maintain them. Our "sense of vulnerability" is that gut feeling that tells you, "Hey, be careful here." However, this is in constant conflict with "normalization of deviance," the other, darker voice that is constantly telling you that you can accept a lower standard of safety because you have done it before and nothing bad happened. "So, let's keep doing it this way. After all, what is the worst thing that can happen? It's just a water tank. We don't need a permit or to perform a gas check."

Anatomy of the Lemoore Water Tank Explosion

The drawing below is a typical cross-section of an above ground water storage tank. The Lemoore City water tank was not a large enough diameter tank to require intermittent column supports for the roof trestle support beams. Additionally, the overflow drain did not have a weir box installed. Lastly, the Lemoore City water tank had a flatter slope on the bottom of the tank. There are most likely other minor differences, however the form and function and structural-mechanical design were similar to the graphic we are sharing.

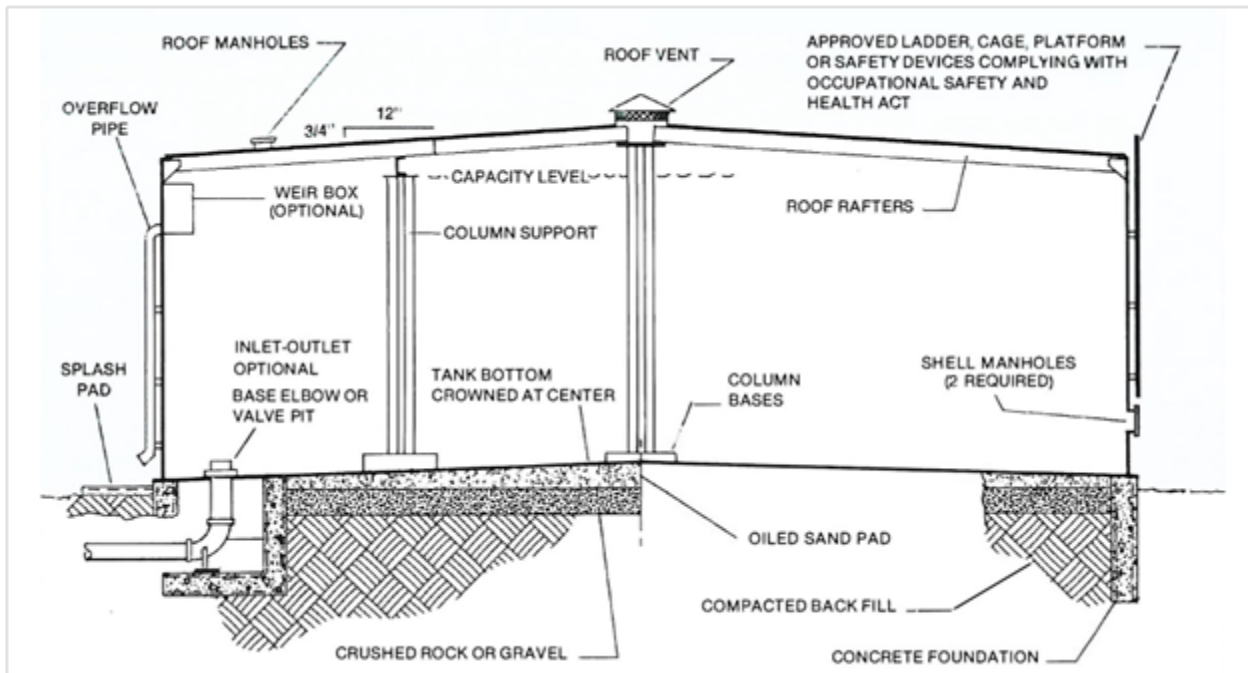


Figure 1: Typical Atmospheric Water Tank Cross Sectional View by creative commons CC BY-SA, modified by J. Caudill

The drawing depicts some key visual information that assists in explaining the venting on this type of closed cone roof tank. Additionally, because the tank is welded steel plate, we know there are two key welds involved with this tank. These welds are *ring-wall to floor-plate* and *roof to side-wall*.

For more visual details, you can view the video here:

<https://www.youtube.com/watch?v=Y0tKDTVmwFQ>. **This is not required** for the course but will provide a visual understanding that may not be as clear from the training module graphics.

Let's cover a couple of basic definitions for hot-work and methane to ensure our alignment on these subject areas.

Hot-work is **any activity or process that generates a source of ignition**—this could be through a **flame**, heat, or a spark. Examples of hot-work include welding, soldering, brazing, cutting, grinding, drilling, and burning or melting metals or other substances, such as glass.

Methane (CH₄) is lighter than air and will rise. It is produced mainly in industry by the anaerobic bacterial decomposition of organics in water, wastewater, chemical processes in refining, and naturally in the environment from the same process. It is also known as natural gas. The public perception of methane is negative and associated with greenhouse gas emissions. When called natural gas, it has a positive public perception as a useful energy source. They are essentially the same, with the exception that most natural gas has much of the sulfur compounds removed prior to use.

There is nothing to suggest that the center vent on the Lemoore City water tank was blocked, either on purpose for maintenance or through other causes. Additionally, venting can occur through the overflow line that is attached near the top fill line of the tank. Tanks vent air and any other gases like methane when filling and vacuum air into the tank when draining.

This particular tank had raw well water stored inside but was down for maintenance, which means that during the days leading up to this incident, it was neither filling nor draining. This allowed the Methane gas to build up. Some of the gas would still have vented out through the center vent, even setting idle. However, the process of organics decaying within the water from biological breakdown processes would not have ceased.

Venting of an idle tank is affected by atmospheric conditions like humidity, temperature, and wind. Lower temperatures, high humidity, and no wind would allow gases to build at a faster rate in the open space above the waterline than if these were reversed. Atmospheric water storage tanks would not be equipped or designed with vents equipped with flame arrestors. The Lemoore tank was just an open center vent with no special venting design.

Water is initially stored in this tank prior to receiving further treatment, prior to distribution to the main supply header. The water comes from three wells located at this particular location. These deep underground wells pump water that contains naturally occurring Methane gas and any residual organics.

We all know that for a fire or explosion to occur, you need heat, oxygen, and fuel. Oxygen is readily available as this is an atmospheric storage tank.

“Atmospheric” implies that the tank operates with very low-pressure changes and maintains a pressure inside the tank very close to the atmospheric pressure outside the tank. This means that they operate within a pressure of ambient to 0.5 psig range. When idle, this pressure is essentially zero and will not assist in pushing out gases built up inside the vapor space.

The contractor welder in this incident supplied the heat from a cutting torch. The fuel came from the naturally occurring methane built up from an idled tank.

We will discuss the actual incident and the details later in this course. However, in this section, we will explain what we see in the explosion and why the floor of the tank remained in the same location.

As shown in this simple drawing (Figure 2), when the explosion occurred (deflagration), equal forces pushed the roof upward and the water inside downward. Due to the design of this particular tank, the roof was not equipped with an explosion hatch nor a breakaway roof designed to come off during an explosion. This meant the downward force of the blast, plus the weight of the water inside, placed the greatest pressure forces at the ring-wall to floor-plate weld. The weld seam broke free from the floor plate. This is confirmed in the video as the intact roof, and side walls are torn from the floor plate, leaving it essentially in-situ. Without the video surveillance, most would assume that the roof would have torn partially open or blown completely off.

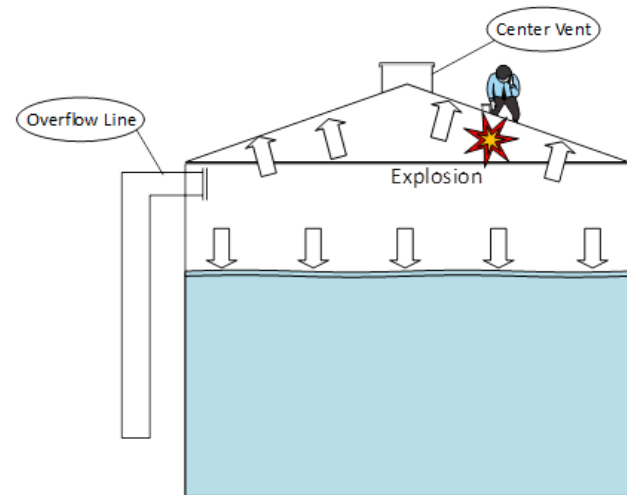


Figure 2: Lemoore Water Tank Explosion Graphic by J. Caudill.

This first section provided the “How did this occur?” We will continue on with “Why this occurred” in the next section.

Why Did This Disaster Occur?

The West experienced the worst modern-day drought in 2021. This drought began several years prior to 2021 and has become more pronounced. Losing this water tank had impacts on this community’s water supply, in addition to a fatality that could have been prevented by following basic safety guidelines.

Like many small towns, a tragedy like this is big news. If the person involved in the accident is from the small town, the impacts are even greater. We know that the City of Lemoore has a population of just over 26,000 based on current U.S. Census Data.

Like many small towns, the city cannot afford a full-time Professional Engineer on staff. This work is contracted through a Consulting Engineering company that we will not identify. This is common practice throughout many small towns in America. The purpose of our indication of this is that most of the work would be monitored by local city workers and not directly by the Consulting Firm unless specifically requested.

This project was a smaller project that was in the last week of completion. Some upgrades to the tank and the distribution station had been in progress for a few weeks. This was considered more of a routine maintenance project.

The work was being monitored by a supervisor from the city. Often, they are not continuously monitored. Therefore, much of the oversight of the work, safety, and other aspects fall on the contractors’ shoulders.

We know from the press release that no gas check was performed to check for gases around the area where the welding was being performed. We can assume, knowing the vent was not bagged or covered, that the center vent was not LoTo'd. Remote work like this is often non-permitted work. Right or not, a city worker will show up, unlock the gate and allow the authorized contract employees to enter.

We know that along with there not being a project engineer onsite, there was also not a safety representative onsite from either the city, consulting engineer, or contractor company.

Lastly, we know that a job hazard analysis (JHA) was not performed. In addition, to a permit that would cover this type of work, applicable procedure, authorized personnel, equipment, PPE (personal protective equipment), hot work precautions, the JHA covers hazards. Other

They were treated
water tank.
None

A JHA was performed that
day, identifying the need to having a
gas check on the
industry.

We may not know because we
cannot access the

The Lemoore City Water Tank
this weld was performed prior to
this occurred to ensure

We now know that the JHA,
and oversight was not site,
you have a permit. s.

Without doing a JHA,
plenty of other

*"Blame not, Tools. This was our
efforts on behalf of*

You likely find out the company he worked for, and the city that hired them. No one wanted the tragedy to unfold at their worksite. Many close to those affected experience survivor's guilt and post-traumatic stress syndrome to varying degrees. The purpose for bringing this out is that the impacts of a catastrophic event affect many, depending on the event circumstances.

In the last two sections, we learned how this event happened and why. In the next section, we will learn about several similar hot-work events involving tank explosion events that are fairly