Anatomy of a Confined Space Fire

A case study and lessons learned

By Martin H. Finkel

ON APRIL 6, 2000, TANK T-1001 at the Williams Petroleum tank farm at the Port of Anchorage, AK, erupted in flames. Photo 1 depicts the aftermath of the fire—its heat having scorched the exterior coating. Although no one was seriously injured or killed, it could have easily been otherwise. This article explores the fire and its causes, as well as lessons that can be learned from this incident.

Fire in Confined Spaces

Fire is one possible hazard associated with confined space work. OSHA was cognizant of this fact when it required testing for flammable atmospheres prior to allowing worker entry into a confined space as part of its Permit Required Confined Space regulation for general industry (29 CFR 1910.146). But the agency gives no guidance on how to maintain a safe operation inside a confined space when work entails burning, grinding, welding or other "hot work" operations, or, as in this case, the control of static discharge. Many structures in a confined space might trap flammable gas, vapor or residues of previous products (Finkel). Therefore, great care must be exercised when using torches or grinders, or when the potential for electrostatic discharge affecting these areas exists.

In the case of tank T-1001, the operation being performed at the time of the incident was not hot work, but tank cleaning by a contractor specializing in this operation. The previous cargo was jet fuel (flash point: 100°F), but except for this last loading, the tank had contained naphtha (flash point: 0°F) since its construction in 1993. The cleaning job included removal of the log seal around the perimeter of the floating roof. A brief descripton of floating roof tanks follows.

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Floating Roof Tanks

To minimize the environmental loss of volatile product, such as gasoline or naphtha, storage tanks have a roof that floats on top of the product, so that minimal vapor space exists above the liquid product at all times. The roof may be constructed of hollow sections of steel or a flat layer of steel plate with attached floats or "pontoons" (Photo 2), or it may simply be a flat plate of steel or aluminum. The roof will float on the product surface as the level is raised or lowered by normal filling or emptying. It typically will have legs installed so that when the tank is completely empty the roof will remain suspended about seven feet above the floor to facilitate inspection or other activities that require entry. In some geographic areas, such as Alaska, the entire tank is covered with a roof that prevents snow loads from endangering the floating roof. In other locations, such as Southern California where snow is not an issue, the top of the tank is often open to the atmosphere, and the floating roof simply rides up the tank's cylindrical walls.

The Log Seal

To prevent vapor from escaping from around the periphery of the floating roof, a seal of some kind typically rides up and down the tank walls along with the roof. It acts very much like the rings in the pistons of an internal combustion engine. In the case of tank T-1001, the seal was a "log seal," common to fuel storage tanks. The seal's foam core lends some rigidity to the seal, and the ring of foam rubber is then covered with an elastomeric material, such as a thin sheet of neoprene rubber, and the whole is attached in some manner to the edge of the roof. Viewed from above, it would appear like a giant O-ring. As the seal rides up/down the tank wall, it wears and abrades; so, it is typically removed during tank cleaning and maintenance operations to prepare the roof for a new seal.

The most-common method of removing the log seal is to use a razor knife to cut the bottom of the neoprene flap, pull out the contaminated foam core, then continue to remove the rubber from the roof. Of course, being a hollow rubber tube wrapped around the roof perimeter, this seal will generally have raw product trapped inside (in this case, naphtha or jet fuel or a combination of the two). In a similar tank cleaning project at a different Alaska facility, the author witnessed more than 200 liters of jet fuel spill out of a seal when it was cut open.

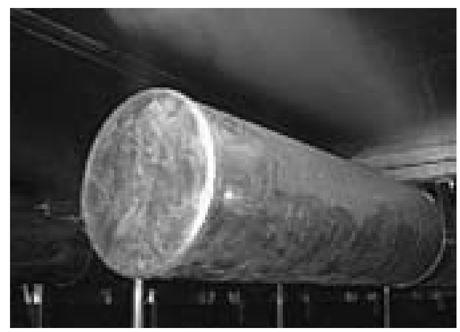
The Incident

The cleaning contractor on tank T-1001 used one worker inside the tank who wore a rubber suit, gloves and boots, and donned a supplied-air respirator to protect him from the product that was anticipated to spill out of the seal. As required by OSHA, an attendant observed the entrant from one of two open manholes at the base of the tank. At the other open manhole, the contractor had placed an air-driven fan to pull fresh air across the tank from the other manhole, so that the attendant would not be exposed to any vapors that developed during this operation. Many contractors in similar situations would attach the fan housing to the tank by bolting it over the manhole; in this case, the fan rested loosely against the tank on a support, which proved fortunate.

Since the operation involved a flammable product, the contractor properly used explosion-proof lights and ventilation. The ventilation fan was bonded to the tank, which was itself grounded, to eliminate static during movement of large amounts of air. But, there is no practical way to electrically bond a razor knife to the tank and the naphtha trapped inside the log seal, and neither the contractor nor anyone else perceived this to be a danger, so no attempt was made to do so.

When a razor knife is pulled through the rubber seal, it generates static that can accumulate in the naphtha trapped within. This static or the subsequent spillage of raw product from the seal down seven feet to the floor of the tank could have caused the fire. During the investigation, the worker cutting the seal reported that he suddenly saw orange light reflected off the tank walls, and when he turned he saw a "waterfall of flames" pouring from the roof seal and igniting the naphtha and jet fuel residues that had accumulated during seal removal. Letting a hydrocarbon fuel "free fall" seven feet is sufficient to generate enough static to cause an incendiary discharge (Luttgens and Wilson). For that reason, vessels such as tank trucks are not loaded by "splash filling" from the top (NFPA). However, in seal removal operations it is common to allow product trapped within the seal to free fall to the tank floor.

Because the worker began the cut near the open manhole through which he had entered and was walking away from that manhole, the flames were between the worker and the obvious escape route behind him. So, the worker ran to the other manhole where the fan was located. Remember that the typical method of attaching a ventilation fan—with bolts—would have effectively blocked this escape route. In this case, however, the worker was able to push the fan aside and escape without injury.



The attendant—who observed the tank suddenly burst into flames, obscuring the entrant—left to notify the fire department, since no means were available at the tank location to contact anyone immediately. The attendant was later found uninjured but emotionally shaken by the ordeal. In fact, the intervening time from the arrival of firefighters until the attendant was located was stressful to all, since no one knew his location.

The fire department took a considered approach to the fire and was able to extinguish the burning naphtha inside without endangering response personnel. The heat inside the tank was sufficiently great so that the floating roof was melted and distorted and needed to be replaced. The cost of this incident was considerable, but much less than could have been the case considering the lack of injuries to personnel.

The subsequent investigation by the facility operator eliminated all other possible sources of ignition except for static, which is the presumed source of ignition of this fire.

Lessons Learned

Several lessons can be learned from this tank fire.

Ignition Sources

When engaged in operations within confined spaces where hollow structures can hide trapped products or flammable vapors, workers must be cautious if it is possible to produce heat or a spark (including static sparks) that could be a source of ignition.

Photo 1 (top): The aftermath of the fire in tank T-1001.

Photo 2: One configuration of a floating roof is a flat layer of steel plate with attached floats or "pontoons."

Photo 3: A shoe-type seal is slightly more costly than a log-type seal, but has a much safer design.

Additional safeguards could have reduced the damage caused by this fire, and tank owners would do well to learn this lesson.

Seal Type

The type of seal used in this tank is particularly dangerous. The cost of using a shoe-type seal, where the elastomeric flap is pressed against the side of the tank by a spring-loaded "shoe" (Photo 3), is only slightly higher than that of the log-type seal. The shoe-type seal has a much safer design, as it cannot trap a significant amount of product. Facility owners worldwide are urged to investigate the type of seals used in their storage tanks with floating roofs, and to make appropriate plans to replace those seals with hollow spaces as soon as is practical.

Emergency Personnel & Equipment

When conducting this operation in the future, the facility operator has developed a policy to ensure that the contractor has adequate emergency rescue personnel and equipment on hand. Additional tanks at this facility use log seals. Since it is not possible to eliminate the hazard posed by log seals until all are removed from service, anticipation of a static-initiated fire must include the presence of trained firefighting personnel in the tank's immediate vicinity. In this case, no citations from any authority were issued to either the cleaning contractor nor the facility owner because no existing regulations were violated. Nevertheless, additional safeguards could have reduced the damage caused by this fire, and tank owners would do well to learn this lesson.

During the aftermath of the fire, the author helped develop recommendations on methods to employ in future projects with similar tanks. As part of this process, the details of the fire were posted for public comment on the American Industrial Hygiene Assn. Confined Space Committee's Internet newsgroup, in the hope that similar fires had produced measures which might prevent similar accidents. Surprisingly, no respondents reported knowledge of any similar incident, although this type of operation must be performed thousands of times each year. Apparently, a static-initiated fire during seal removal operations is rare. Several respondents recommended inerting the atmosphere of tanks that undergo this type of seal removal operation to prevent future fires.

Although removing the oxygen from a tank will prevent a fire, in the author's opinion, this is the wrong approach because it requires workers to enter an immediately dangerous to life and health (IDLH) atmosphere. This is too dangerous since each operation would be performed in potentially life-threatening conditions (devoid of atmospheric oxygen), whereas a fire, although a real possibility as tank T-1001 has shown, is a relatively rare occurrence. Anticipating a fire and being prepared for immediate rescue and fire suppression is a much safer strategy. Some respondents recommended placing fire suppression foam on the tank floor prior to cutting into the seal. This would reduce the potential size of any ensuing fire, but it would not prevent vapors from the spilling naphtha from igniting in the first place. In addition, this method creates a slip-and-fall hazard, as the floor would be covered with a slick, opaque foam.

One change to be incorporated into future tank cleaning operations at this site is to immediately clean up any spilling product before it accumulates. In the case of T-1001, the cleaning contractor was allowed to have standing product because it was believed that the high flash point of the jet fuel meant there was little chance of its residues catching fire during this operation. In addition, contractors must now place a bucket under the cut log seal to catch leaking product; a vacuum hose is then used to remove it from the tank before it can fall to the tank floor. The author also recommended that workers start the cut half way between the two manholes and work back toward the opening with the attendant, so that should a fire occur, the worker(s) have access to the opening where someone is available to aid their exit.

Unobstructed Egress

Had the second manhole been obstructed by the fan, this would be an anatomy of a fatality rather than just of the fire. It is not uncommon to see confined spaces with more than one opening but only one actually open. It is recommended that all potential egress points be open during confined space entry, and that any ventilation equipment be set up in such a way that a panicked worker can push it aside and escape.

Fire Rescue Personnel

When the facility operator cleans the remainder of its tanks with log seals, the cleaning contractor will be required to provide a fully equipped fire rescue team. The municipal fire department may agree to stand by during the operation. Since it is not possible to eliminate all hazards during seal removal, being prepared for a fire so that it can be extinguished immediately will minimize damage. Facility owners with similar tank configurations are encouraged to employ a similar proactive strategy.

Conclusion

The incident described could have occurred at any petroleum storage facility in the world—and might again in the future. Everyone can learn from this incident. Employers should train employees to be especially cautious in situations where static generation is possible, particularly when working around hollow structures, such as log seals, associated with confined spaces. ■

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