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Internal Floating Roof Tank Fires:
The Real World and a New Approach

Kendall C. Crawford, P.E., CSP
Principal Consultant
Crawford Consulting Associates,
Houston, TX

Dwight Williams
CFO/Chairman
Williams Fire & Hazard Control,
Mauriceville, TX

Introduction

This paper discusses a new approach to extinguishing internal floating roof tank fires in context of the "real world" of tank fire suppression. The scope of fuels involved encompasses only "light oils" like gasoline or heating oil. Crude oil behaves differently, is not normally stored in internal floating roof tanks, and is left to discuss another time. We look back at past experience with tank fires, look around to understand why the challenge of internal floating roof tank fires is so difficult, and look forward to a safer suppression approach compatible with current installations. This includes related properties and capabilites of fire suppression agents.

"Distance is Safety"

"Distance is Safety" is a key message Dwight Williams teaches to his fire school students. He learned through years of experience in putting out very large fires that personnel exposure (and thus risk) could be reduced through technology. He states "One of the main goals of new technology should be to give firefighters more distance from the fire." That explains part of the thought process behind this new approach to extinguishing internal floating roof tank fires.

Types of Tanks Which Might Have Fires

There are three general types of aboveground storage tank in use in the petroleum and petrochemical industries. Fixed roof tanks (Exhibit 1), external floating roof tanks (Exhibit 2) and internal floating roof tanks (Exhibit 3). Internal floating roof (IFR) tanks have vents at the top of the walls or on the roof to allow the tank to equalize pressure as the internal roof moves up and down.

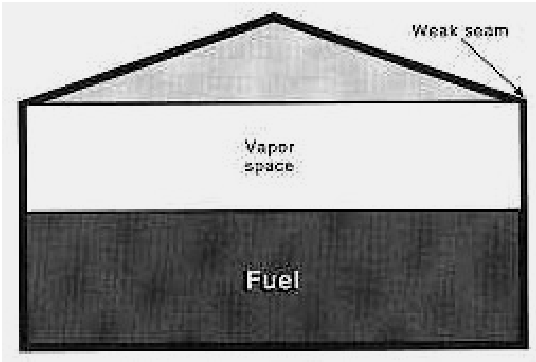

Exhibit 1.
The diagram depicts a fixed roof tank such as the small fixed-roof E&P tanks on the right.


Exhibit 2.
These pictures show external floating roof tanks from the ground and the top.

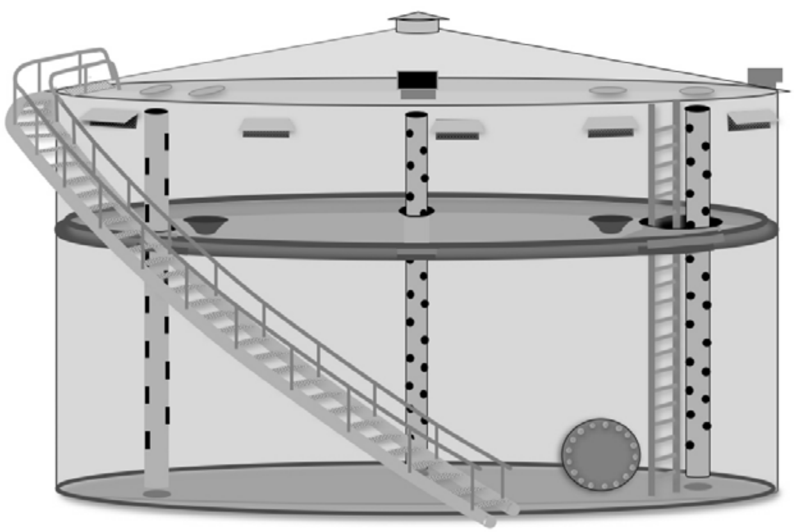

Exhibit 3.
This cutaway drawing shows an internal floating roof tank with vents at the top.

Fire Suppression Basics

Fires can be extinguished by either physical or chemical mechanisms.

Physical suppression includes: 1) cooling the flame to inhibit combustion reactions, 2) smothering or blanketing a fire to separate fuel and air, 3) absorbing the thermal radiation from the flame to reduce fuel vaporization or 4) separating the flame from the fuel with a blowing gas. For hydrocarbon fires the first three mechanisms are combined in the use of foam which is the traditional agent used to suppress tank fires. The last approach works for blowing out candles but not tank fires.

Chemical suppression interferes with the basic combustion process. Chemists sometimes refer to free radical interceptors. Engineers generally say the agent breaks the combustion chain reaction. Dry chemical and halons are examples of chemical fire suppression agents.

How do Fires in Tanks Differ by Roof Type?

Fires in fixed roof tanks typically have all or a portion of the fuel contents opened to the atmosphere by an internal explosion. Fully involved open floating roof fires are similar in approach. For both types fire suppression professionals typically apply foam using ground or elevated monitors. For fixed roof tanks a part of the roof may obstruct the surface providing a challenge in getting foam to the fuel surface.

External floating roof tank fires may have full surface involvement as shown in Exhibit 4 where the roof was sunk by heavy rain during a tropical storm. In the current world of fire suppression large tank fires are extinguished using very large, portable ground monitors as shown in Exhibit 5.

Exhibit 4.
This is a full surface fire in a 270’ tank.

Exhibit 5.
Large ground monitors are shown suppressing the tank fire.

External floating roof tanks can have a seal fire involving a much smaller area, such as shown in Exhibit 6. Even in such a severe case as shown, the use of ground monitors would be inappropriate: excessive water could sink the roof resulting in escalation to a full surface fire.

Seal fires typically require much different “up close and personal” techniques. In many past incidents fire personnel have walked on the top of external floating roof tanks or along a wind girder to extinguish rim seal fires using hand-held dry chemical fire extinguishers. More recent technology reducing potential fire exposure is shown in Exhibit 7 where a special portable monitor is carried to the tank platform and mounted on the tank rim.

Exhibit 6.
This Is an External Floating Roof Seal Fire.

Exhibit 7.
Special Monitor Is Extinguishing the Fire,

<u>What's Different about Internal Floating Roof Tank Fires?</u>

First, the roof stays on. If the roof separates at a frangible seam then it no longer is an internal fire and is fought as a full surface tank fire. Second, the fire mostly stays inside the tank while breathing combustion air in through some vents while breathing fire out through others.

By design, internal floating roof tanks have a confined headspace which keeps heat in. Fire heats the metal walls and external roof above the internal floating roof. Internal tank hardware (appurtenances) protruding above the internal roof can protect small fires, being too high to be "foamed" by material applied gently down the side of the tank by foam chambers. Vapor migrating through foam will "ghost" and enrich the headspace. Reigniting is common.

<u>In the Past How Have Internal Floating Roof Tank Fires Been Extinguished?</u>

Firefighting foam has been the historically available "ammunition" in the emergency responders' arsenal. Foam works well on hydrocarbon fires. The water in the foam works physically to cool, and the foam composition forms a blanket to exclude oxygen and seal the hydrocarbon layer to reduce vapor formation (remembering that only vapor burns). But foam only works if it gets to the fuel surface. The primary challenge with internal floating roof tank fires is access to apply foam to <u>all</u> the burning hydrocarbon, including that "hiding" in the appurtenances.

Some tanks have foam chambers while others do not. For those without chambers the vents are an <u>extremely</u> difficult route to introduce foam from ground monitors. And, the foam blanket must be replenished to prevent repeat ignition. Historically, many tanks have been pumped out to remove recoverable product and allowed to burn out.

<u>How are Internal Floating Roof Tank Fires Being Extinguished Today?</u>

Although the tank vents are inconvenient to use for access they have been the "only game in town" for tanks without foam chambers. An aggressive approach to suppression views these vents as a "window of opportunity." Although the portable monitors designed for external seal fires aren't an option, another tool developed for open floaters has been adapted to internal floating roof tanks. These special foam discharge devices, shown being installed on an open floating roof tank in Figure 8, can allow a firefighter to insert foam piping through a vent on an internal floating roof tank as illustrated in the drawing. If successful, this provides a conduit for applying foam conceptually comparable to a permanent foam chamber.

Inserting a Foam Wand gets "up close and personal" for the firefighters because accessible vents may be breathing fire out, increasing potential exposure and risk. While fixed foam chambers on the tank are a desirable means to reduce risk to fire suppression personnel there is no guarantee of success. Neither foam chambers nor portable application devices inserted through a vent guarantee total extinguishment. But sometimes they do the entire job and in other instances they suppress a large portion of a fire. However, the fire isn't out until all of it is out. Additional suppression is needed to secure the tank.

Exhibit 8
This shows a foam wand being installed, in place on an external floating roof tank, with a diagram showing an internal floating roof tank installation through a vent.

The Epiphany

In some "real life" incidents a stubborn fire in an internal floating tank has been "almost out" -- but almost out for a fire is a promise of reigniting when the foam blanket diminishes. In a few unique cases an expert and innovative fire suppression team discharged dry chemical agent from a portable fire extinguisher into the confined vapor space to get the pockets of inaccessible fire. This worked as expected! The foam provided a cooling and sealing blanket over most of the burning fuel and the buoyant cloud of dry chemical particles, acting as free radical interceptors, stopped the burning in the vapor phase and "hidden" appurtenance reservoirs. With periodic replenishment of foam plus water cooling of the tank exterior there was no re-ignition. Although unconventional, this novel dual-agent approach proved the principle that internal floating roof tank fires could not hide from the combined capabilities of foam on the surface and dry chemical agent in the head space.

However, putting personnel in a position to use dry chemical requires increased exposure to fire hazards and increased risk. This led to conceiving a new approach to achieve the same result while applying the principle that "distance is safety."

What Is the New Approach?

Successful experience using phased dual agents for non-confined pressure fire suppression is now well established by specialists in fire suppression. Recognizing the effectiveness a dual agent approach could have as a new approach for the confined spaces of IFR tank fires was consistent. Once conceived, implementing the concept could seem conceptually straightforward. But figuring out 'how to do it" was more difficult. Successful implementation required both proving the premise of dry chemical reaching "hidden fires" and testing the concept on a tank fire.

Testing the New Dual Agent Approach with a Tank

The approach chosen for this test phase was relatively straightforward: build a tank with internal hardware simulating an internal floating roof. Install foam chambers and figure out how to implement the dual agent technology. Then test both the concept and the hardware. As shown in Exhibit 9 author Williams had such a tank 20 feet in diameter constructed at Beaumont Emergency Services Training Complex ("BEST"). On this he installed special foam chambers shown in Exhibit 10 adapted with the capability to permit application of dry chemical agent simultaneously or separately. In addition, the internal "floating" roof included appurtenances which could retain fuel and make the fire three dimensional. This represents a key problem experienced in "real world" IFR fires.

Exhibit 9
This is the IFR Test tank at BEST fire field.

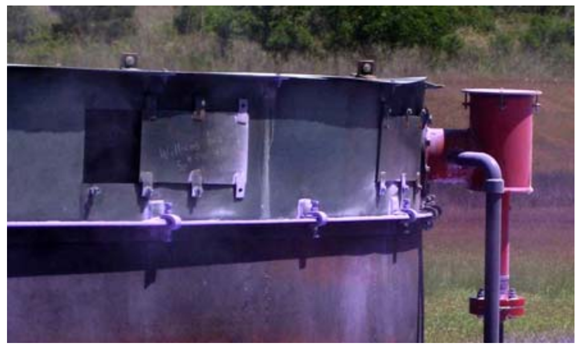

Exhibit 10
This foam chamber has dual agent capability,

A number of tests, represented by May 2008 tests shown in Exhibits 11 through 17, have been run using this tank and equipment to prove the effectiveness of the dual agent concept.

Exhibit 11
Crew is testing tank head space flammability.

Exhibit 12
May 2008 IFR test fire is being lit.

Exhibit 13
Test in IFR tank shows fire visible through both vent windows before being foamed.

Exhibit 14
Tank still smokes after foam application
Note: "Where there's smoke there's fire."

Exhibit 15
Residual appurtenance fire shows through RH vent after foam puts out most of the fire.
Note: where there <u>was</u> smoke there <u>was</u> fire.

Exhibit 16
After foam leaves residual fires the phased application of vivid dry chemical flows from IFR tank vents.

Exhibit 17
Dry chemical application following the foam extinguished residual appurtenance fires.

These tank tests prove the principle, leaving further effective range scope to be better defined.

Testing Dry Chemical for the New Approach with "Hidden Fires"

The "Proof of Concept" tests at BEST fire field in Beaumont Texas demonstrated the ability of the dry chemical portion of the dual agent to extinguish fires not extinguished after foam is delivered through foam chambers. Since that "test tank" was small relative to internal floating roof tanks in commercial use, further tests were done in June 2008. The object was to determine how far a stream of vividly colored commercially available dry chemical agent would travel and put out fires. The challenge was extinguishing fires simulating fires in risers projecting above the internal roof (and foam layer) of an internal floating roof tank.

These tests were conducted at the Emergency Services Training Institute (ESTI) Brayton Fire Training Field in College Station, Texas. ESTI is a member of the Texas A&M University System Texas Engineering Extension Service. This dry chemical test was run in the two-story engine room portion of the "ship" prop. The engine room provides a large enclosure (48 feet long, 23 feet wide and 26 feet high (total volume about 28,700 cubic feet). Three simulated "hidden challenge fires" were located along the path of the dry chemical flow at distances of 27, 34 and 41 feet from the nozzle outlet. These 5-gallon containers contained water with a layer of diesel fuel and about 1 ½ inches of "freeboard" clearance to the open top.

The fuel in the buckets was lit and allowed a pre-burn of about three minutes. The room was closed (except for the three roof vents) and the dry chemical flow initiated. A TEEX staff member (in full bunker gear with SCBA) remained in the room on a mezzanine level to observe flow and fire suppression. All three containers were extinguished in *ca.* 5 to 10 seconds (as well as the LPG lance located further away used which had been used as a pilot to light the diesel).

This test confirmed the ability of the dry chemical to reach a long distance (estimated at 80+ feet) and extinguish "hidden" fires that a foam blanket would not reach.

Conclusion

Historically fires in the "head space" (between the floating and fixed roof) of internal floating roof tanks are very difficult to extinguish. Foam delivered through chambers attached to the tank wall can put out the bulk of the fire. However, "*the fire isn't out until all of it is out*" and several factors interfere with complete extinguishment using only foam:

- an annular surface area adjacent to the tank wall typically continues to burn for a variety of reasons
- mechanical seals can provide a barrier (and "hiding place") difficult for foam to reach
- vapor released from heated fuel under the internal roof pan can continue to travel past into the seals and through a foam blanket
- "appurtenances" such gauge wells or ladder hatches inside the tank can impede a foam blanket and "hidden" fuel continues to burn.

The new phased dual agent, three-dimensional approach described is based on "real world" experience, research and testing. It addresses all of the concerns above while providing a means of extinguishing all the fire in an internal floating roof tank. It preserves the principle of "distance is safety" by not putting emergency responders at risk trying to apply dry chemical to the head space from outside the tank.