

Exploding the myth

INCIDENT ANALYSIS

The sight of a storage tank full of oil on fire is enough to strike fear into most firefighters' souls. But how often does this really happen, and what causes tank fires? HCB does some digging

The **Bulletin's** monthly *Incident Log* regularly carries reports on storage tank mishaps. Indeed, an analysis of the record from the start of 2001 shows that there have been just over 850 such incidents reported around the world – roughly five or six per month. A little more than half of those – 439 – involved fires or explosion, the sort of accident that can cause injuries and deaths as well as property damage.

The period between 2004 and 2008 appears to have been the high point of storage tank incidents (see Figure 1); perhaps the economic downturn that started in 2008 reduced activity in the energy industry around the world to the point where less product was moving and so there were fewer opportunities for accidents.

However, readers should be cautioned about the data; the *Incident Log* is compiled largely from primary sources – mainly press reports – that appear in the public domain at the time of the accident. As such, its coverage relies on the availability of such reports. In countries where there is a vibrant local press and effective news aggregators, the 'incident count' is likely to be higher. Language also provides a barrier to some

extent. Furthermore, it cannot be ignored that some cultures regard minor property damage and environmental pollution as unremarkable events that are not worth reporting.

That being said, it should come as no surprise to find that the US accounts for the majority of the storage tank incidents reported – 538 out of 852, or some 63 per cent. Not only is the US a large country with a significant onshore oil sector, it also has local press activity across the country and lacks any government interference in the reporting of accidents.

By contrast China, with a comparable land area and a much larger population, reported only 36 storage tank incidents between 2001 and 2013. Unlike the US, China has no local press to speak of and those reports that do make it into the public domain come largely through the official channel of Xinhua. Having said that, it has been noticeable that China has become more open in its reporting of industrial accidents and there is a growing awareness on the part of the government and the public of the importance of reducing environmental pollution.

Figure 1: Storage tank incidents by type, 2001-2013

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Leak	15	16	16	31	43	28	24	37	24	18	19	21	10	302
Rupture	2	2	6	11	8	2	3	5	3	3		6	4	55
Fire/explosion	11	28	26	36	24	44	41	42	44	46	26	32	39	439
Overflow	1	1	5	10	5	3	8	4	3	5	1	1	2	49
Personnel					2	1	2		1				1	7
Total	29	47	53	88	82	78	78	88	75	72	46	60	56	85

Why things go wrong

In order to make any meaningful analysis of the incident record, then, it is better to concentrate on the US, which offers a more representative sample.

A first analysis (see Figure 3) looks at the broad causes of storage tank fires, leaks and ruptures. Based on initial reports, the cause is not always known or not specified at the time; further research would be required to eliminate most of those shown as ‘unknown’. However, excluding those 110 incidents, there are clearly five main causes:

- equipment failure (20 per cent), mainly related to valves and gaskets;
- structural failure (18 per cent), involving the collapse of the tank itself or part of the tank or roof;
- lightning strikes (16 per cent), which impact in particular oilfield tanks in remote locations;
- operational failure (15 per cent), relating to improper actions on the part of site personnel,

Figure 2: Reported storage tank incidents by country, 2001-2013

USA	538
China	36
Canada	30
Australia	25
UK	22
India	17
Russia	14
Japan	13
France	10
Others	147
Total	852

- such as a failure to follow procedures; and
- maintenance-related (14 per cent), usually involving contractor personnel on site, often during welding work.

Each of these areas can be addressed quite simply, either by putting in place better systems for inspections and maintenance work, including the replacement of ageing equipment, or by better training, especially for contract workers. There are also systems available on the

market to reduce the likelihood of a lightning strike causing a fire.

Operators ought to perhaps be more aware of weather conditions, particularly during the second quarter, which is when most of the lightning activity takes place. Other weather-related damage has in recent years been caused by hurricanes, storms and flooding.

Another area where operators could do much to avoid accidents in storage tanks is in terms of making access harder; there have been a number of fatal incidents caused by people – often teenagers – using the tops of storage tanks as a place to hang out and smoke, and some other significant incidents have been caused by deliberate sabotage, most often by disgruntled former employees.

Indeed, the 538 incidents reported over the period in the US have killed a total of 47 people. Of those, most were the result either of illicit activities or welding work. For instance:

- in April 2003, four teenagers were killed in

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Palestine, Texas when the tank they were sat on top of exploded;

- in May 2007, three teenagers were killed in Mercedes, Texas in a similar fashion;
- in October 2009, two teenagers were killed in Carnes, Mississippi when a tank exploded;
- in June 2007, another accident in Steamboat Springs, Colorado killed two teens;
- in May 2005, two people died after an explosion in a tank battery in Ripley, Oklahoma; it was not clear what they were doing at the site.

Other fatalities relating to welding and other maintenance work include:

- three contract workers killed by an explosion at the TEPPCO terminal in Searcy, Arkansas in May 2009 as they were preparing a tank for the installation of a new gauge;
- two workers killed and another two injured when a tank at the Navajo Refinery in Artesia, New Mexico exploded during welding work;

Figure 3: US storage tank incidents by cause

Equipment failure	84
Structural failure	78
Lightning strike	69
Operational failure	65
Maintenance-related	61
Weather-related	24
Accidents/misadventure	17
Sabotage	17
Overheating/overpressure	11
Static	2
Unknown/unspecified	110

- two workers killed at a water treatment plant in Daytona Beach, Florida in January 2006 when a methanol tank exploded as they were using a cutting torch nearby;
- one contract worker killed and another injured by an explosion in an empty storage tank at the Oiltanking terminal in Channelview, Texas in June 2012 during welding work; and
- one contract worker killed and three injured by an explosion during welding on a waste

oil tank at the Campbell Industrial Park in Honolulu, Hawaii in October 2008.

Where it happens

To some extent, this analysis is replicated when looking at the type of facility involved. The largest number of storage tank accidents (25 per cent) take place in oilfield tank batteries. Such facilities are often unmanned, unfenced and perhaps also overlooked when it comes to maintenance and repair. Any maintenance work may well go unsupervised.

Oil and fuel depots are another common place to find storage tank accidents, including many of those that fall under the headings of ‘operational failure’ and ‘equipment failure’. Lightning strikes can cause problems in oil depots, since they commonly have closely packed tanks and other storage areas, meaning that any initial fire can easily spread to other tanks and stocks of flammable liquids. On the other hand, events at oil depots seldom result



in fatalities; their main consequences are more likely to involve evacuation of nearby residents.

Chemical manufacturing plants account for a significant proportion of storage tank incidents – just under 12 per cent. Not surprisingly, they often involve aggressive products, particularly acids, and regularly result in injuries and fatalities. In addition, the use of fibreglass tanks is more common, and there are numerous incidents caused by damage to such tanks.

Oil refineries contribute regularly to the *Incident Log*; in the US at least incidents involving storage tanks display a wide range of causes and effects and it is also here that some of the largest tanks are involved. For instance, a 286,000-bbl tank at the Paulsboro Refinery in New Jersey lost more than half its contents in February 2012, probably due to a broken pipe; and lightning ignited a rim fire in a tank with around 350,000 bbl of crude oil at the Chevron-Texaco refinery in Pascagoula, Mississippi in August 2003. Neither of these caused any casualties.

Perhaps surprisingly, given that they consist mainly of storage tanks, oil and chemical terminals account for only 8 per cent of all reported tank incidents. Anecdotal evidence suggests that terminal operators and the licensing authorities pay more attention to the quality of tanks at terminals, compared to those at refineries or other plants. Containment systems may also be better maintained, although any major spills do have the potential to cause significant environmental pollution, particularly to waterways. It is interesting to note that some of the worst incidents at storage terminals in the US since 2001 have been weather-related, with Hurricane Katrina and tropical storm Sandy both causing considerable product losses at terminals as they passed through coastal areas.

All kinds of material

Over the past couple of years, the **Bulletin** has reported regularly on incidents – often very violent and occasionally involving multiple fatalities – related to the exploitation of shale oil and gas resources. In the storage sector, however, it is hard to identify any added contribution. Crude oil remains the most significant product has far as storage tank accidents are concerned, accounting for 28 per cent of those recorded since 2001, but there is no indication that the

Figure 4: US storage tank incidents by location

Oilwell	137
Oil depot	81
Chemical plant	64
Oil refinery	59
Oil/chemical terminal	44
Factory	35
Asphalt plant	27
Pipeline terminal	14
Water treatment plant	11
Agricultural supply depot	10
Other	56

rate of such incidents has increased of late.

Crude oil incidents are concentrated, as might be expected, among oilfield sites, oil refineries and, to a lesser extent, terminals. By the nature of the volume of product involved, they are often large in nature and can represent a significant environmental risk. Crude oil incidents at oilfield sites are responsible for the greatest number of deaths, as commented above. Those involving oily water, which are almost all at tank batteries, have not contributed to the list of fatalities but a number of workers and contractors have been injured by explosions, usually during maintenance or repair work.

Perhaps surprisingly, given the fact that it is a more volatile product, gasoline has featured in few incidents involving death or injury, and fewer fires and explosions that may have been expected. Perhaps greater attention is paid to safety further down the supply chain, and those that handle it may be more aware of the safety risks. Outside of the US, though, gasoline has been involved in some very bad incidents, most notably the massive fire at the Indian Oil Corp (IOC) depot in Jaipur, Rajasthan in October 2009 that killed 12 people, injured 150 more and necessitated the evacuation of around half a million people. That incident was blamed on the ignition of gasoline leaking from a pipe attached to a tank.

Just how volatile gasoline can be can

Figure 5: US storage tank incidents by product

Crude oil	150
Gasoline	45
Asphalt	31
Diesel	31
Fuel oil	26
Hydrochloric acid	26
Sulphuric acid	22
Kerosene	16
Oily water	18

be gauged from another event, in Danang, Vietnam in March 2007, when four people were killed and five more injured when a 12,500-m³ gasoline tank exploded at the Nuoc Man oil depot. The tank had been filled with water prior to welding work being carried out but it is thought that some pockets of gasoline vapour remained in the tank and were ignited.

And of course it was gasoline that was involved in the Buncefield incident in the UK in December 2005, when product overflowed a tank during a pipeline delivery, causing a vapour cloud that detonated on contact with an ignition source. Although no one was killed in that accident, it was only a matter of good fortune – it happened in the early hours of a Sunday morning. The authorities and industry recognised the risk of a similar incident and have since put in place changes to the terminal design, construction and operational requirements and also highlighted the need for safety leadership in such organisations.

Of the other products involved in a lot of storage tank incidents, it is no surprise to see asphalt feature highly. Storage at elevated temperatures places great strains on tanks and aspects such as overheating, overpressurisation and operational errors make a large contribution to the recorded incidents.

However, aside from the IOC incident in Jaipur, the two other most fatal incidents recorded over the past 13 years have involved other products. In May 2012 a series of explosions at the Bangkok Synthetics plant in Rayong, Thailand killed 12 people and injured 120; it happened while workers were refilling a storage tank with toluene after it had been out of service for routine maintenance. And in October 2008 an explosion during the curing of the coating on a partly built 100,000-m³ crude oil tank at a pipeline terminal in Xinjiang province, China killed 12 contractors working on the site.

It is clear that there are many risks to a storage tank, wherever it is and whatever it has in it – even if it is ‘empty’. However, operators ought to know about those risks and should be taking the appropriate steps to minimise them.

The Bulletin would be interested to hear from anyone with further information or questions on the research summarised here. Email the publisher: peter@hazardouscargo.com.