Incident

Case study — Revisiting the Tacoa Power Plant boilover 40 years on

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Summary

Venezuela's deadliest industrial disaster occurred on 19 December 1982. An explosion in a fuel oil tank at the Tacoa Power Plant, then operated by Electricidad de Caracas, had already claimed the lives of two operators. However, as the resulting fire continued to burn, emergency personnel, onlookers, and media gathered in the vicinity — all unaware of the ominous heat wave creeping to the bottom of the tank. Suddenly, a heel of undrained water was vaporised, ejecting the tank's contents in a violent eruption which gushed burning oil down the steep hillside. Caracas suffered severe blackouts as the grim news emerged. 40,000 people were evacuated. 500 were injured and more than 150 lost their lives.

Keywords: Fuel oil, tank, fire

Prólogo

I can remember when I first learned of this incident. I had been reading *Incidents that Define Process Safety* when I found the double-page dedicated to the Tacoa tragedy. Shocked at the magnitude of destruction from a single tank, my initial curiosity was stalled by the Spanish-English language barrier. For years the incident remained inaccessible, although I have often wondered exactly what happened that day. Last year, as the 40-year anniversary approached, I decided to give things another go. This time I had the help of unlocked archives, a vastly improved google-translate, and several experts who were able to direct me towards reliable source material.

Avid LPB readers will know that as of January 2021, the *Loss Prevention Bulletin* has been fully accessible for all IChemE members, and a search of the records revealed that the Tacoa tragedy was covered in issue 57 of this publication (https://www.icheme.org/media/5781/lpb_issue057p026.pdf). Few might be aware that the (USA) National Fire Protection Association also has a freely searchable archive. After some sleuthing, I discovered that the NFPA had been invited to the scene to provide advice in the wake of the incident. A three-page account of their findings in *Fire Service Today* appears to be the source for much of the information that is currently available in English. However, this stops short of detailing the failings that led to the incident's escalation.

Frustratingly, I have learned that many aspects of the Tacoa tragedy are to this day, still up for debate. Although official investigations were undertaken on behalf of the Venezuelan government, these were never made public. Fortunately, as the years have passed, information has been leaked via court proceedings, articles in the local broadsheet, *El Nacional*, and first-hand accounts of those that were there and survived. In this write-up, I hope to build on earlier publications, and to fill some gaps of not just what occurred, but how and why.

La Planta Termoeléctrica Tacoa

Officially part of the *Ricardo Zuloaga Generator Complex*, the facility was named Tacoa after the seaside village in which it is situated. The original Tacoa thermo-electric power station was built on reclaimed land next to its sister Arrecifes plant in the 1950s, and this was supplemented with the Tacoa expansion plant in the late 1970s. The overall complex supplied 1700 MW of power to the greater Caracas area.

The site is instantly recognisable for its picturesque surroundings and for the three gigantic red and white chimney stacks of the expansion plant. These soar high above the facility, which is sandwiched between the cerulean blue Caribbean Sea and tropical green hills. When the 1970s expansion was made, the only area to install two heavy fuel oil

Figure 1 – The Ricardo Zuloaga Generator Complex. Tanks 8 and 9 were located at the site of the modern-day demineralised water tank (visible behind the tip of the expansion plant's middle stack)

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tanks (no. 8 and 9) was high on the hillside. This topography would play a role in the tragedy to come.

Ignición de un fuel oil pesado

A key mystery in this incident is the behaviour of the process fluid, number 6 fuel oil. Also known as residual fuel oil or bunker C, this is primarily produced from the bottom cut of a refinery's distillation column. Known for being tar-like and sluggish, number 6 fuel oil cannot be pumped without first heating it. Each of the Tacoa expansion plant's fuel oil storage tanks were equipped with six internal steam coils for this purpose. Late on 18 December, night shift operators recorded abnormally high temperatures in the feed line from the storage tanks to the fuel oil burners. Consequently, staff isolated one steam coil, leaving a single coil in operation. Although this was enough to clear the feed line temperature alarm, conditions within tank no. 8 remained far from normal.

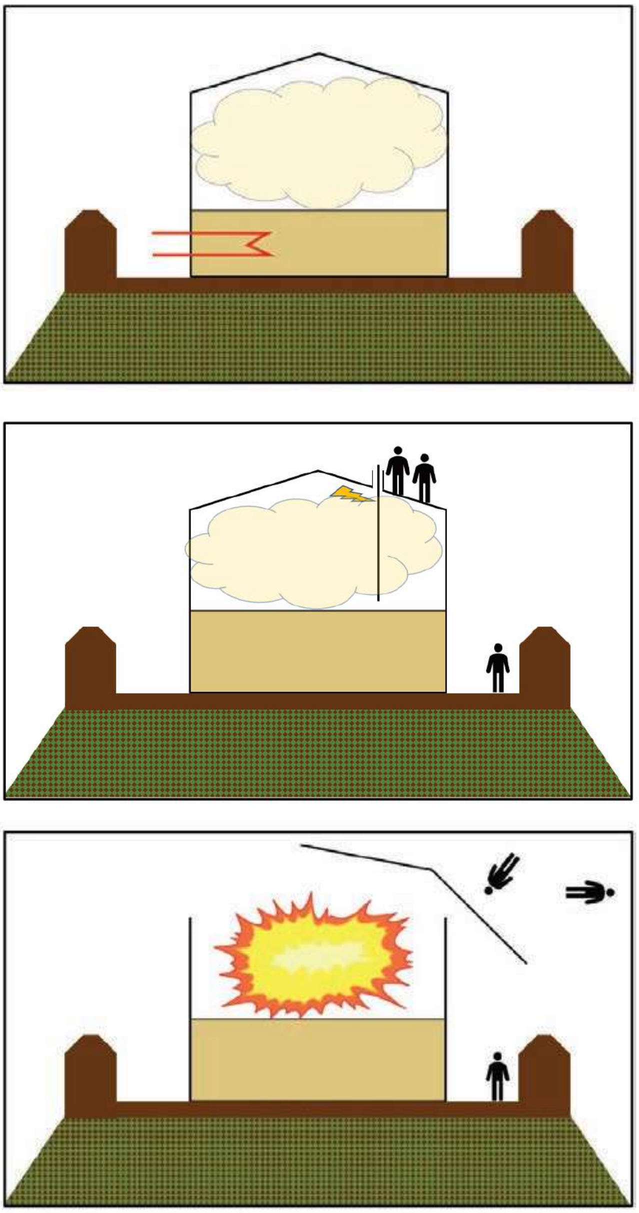

Figure 2 – (Top to bottom)

1. *Fuel oil overheated above its flashpoint.*
2. *Opening of gauging hatch allows air to intersperse with hydrocarbon gas. Ignition source unknown.*
3. *Explosion expels tank roof. Two operators killed.*

One might be curious as to how a heavy fuel oil is able produce a flammable atmosphere. The answer is a combination of blending and inappropriate temperature. Firstly, the specification for number 6 fuel oil allows for lighter ends to be combined with the residual oil to achieve a reduced viscosity, provided that flash point limitations are met. Varying degrees of blending can produce fuel oils with wide-ranging characteristics far removed from the original residual oil. The evidence suggests that the alarms and trips at the Tacoa power plant were configured for a different blend to that which was in the tanks at the time of the incident. Despite the flash point of the fuel oil being 71°C, the high temperature alarms were set at 80°C, with the boiler feed observed as high as 88°C. The lighter components of the blended fuel oil were being boiled-off within the tank.

Shortly before dawn the next morning, a three-man crew drove up the steep and narrow road to check the level on tank no. 8. This was necessary to facilitate offloading from a docked tanker. Whilst one operator remained in the vehicle, the other two climbed the access stairway to the roof of the 55m diameter 17m tall tank. As the men opened the gauging hatch, hot hydrocarbon vapour interspersed with the air creating an explosive mixture. The source of the subsequent ignition is much contested and will likely never be known. The most widely accepted theory is that there was an attempt to illuminate the dip tube for reading either with a match, lighter or a non-intrinsically safe lamp.

What followed was a massive explosion that ripped off the tank's conical roof. The two operators on the roof were launched into the air and killed. The third crew member was narrowly able to escape as severed oil lines fed a growing fire in the tank's containment dike. By the time he reached the safety of the control room, a gigantic black plume loomed over the facility from menacing flames high on the hillside.

Proteccion contra incendios inadecuada

It soon became clear that Electricidad de Caracas had no contingency plans for a fire in their fuel oil storage tanks. The company lacked a fire-brigade, and their staff had no training or instruction. Three water storage tanks located higher on the hillside held a dedicated firewater reserve, and this was supplemented as required by seawater pumps. Despite this, there does not appear to have been any coordination of the electricity company employees to obtain water from these sources.

The emergency response was delayed by more than 20 minutes as the first fire engines navigated tortuous roads to reach the remote site. Worse still, the track leading to the burning tank was dangerously exposed to a sharp drop on one side. It was too steep and narrow for anything other than an off-road vehicle. Firefighting apparatus arrived from across the region over the next few hours, with engines parked in the streets below, unable to access the elevated fire.

Carrying what equipment they could, responders made their way up to the burning tank on foot. It was then that the neglected condition of the fire response systems became apparent. Of three firewater pumps, only two units were

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operational. As a result, there was insufficient pressure for any hydrant or cooling line to reach the inside of tank no. 8. Further, a dedicated 2,000-gallon foam concentrate tank was found to be completely empty. Under any circumstances, extinguishing an open tank fire of this size would be extremely difficult; the lack of water and foam made this task impossible. The order was given to let the tank burn itself out. However, given the intensity of the fire, action was still required to prevent spread to the neighbouring dikes.

Despite the challenging access, the fire department were eventually able to position a small pumper truck on the hill overlooking tank no. 8 and had also managed to procure several barrels of foam concentrate. However, the necessary plant water to combine with the concentrate could not be sourced; the available connection, a coarse thread NPT (National Pipe Thread), was incompatible with the fine thread NH (National Hose) utilised by the fire department. Desperate for any means to access the water, responders decided on a risky improvision. As the fire raged on close behind them, they set to work fabricating a connection with open flame cutting / welding torches.

Whilst the responders scrambled on the hillside, a crowd had started to gather around them. The press had quickly arrived and were broadcasting live on-scene coverage. Locals and holidaymakers were drawn to the spectacle, some congregating on the beach, and others on the streets below the tank's steep dike walls. Many ascended the hill to get as close as possible to the action. The ensuing fiesta atmosphere betrayed the severity of the situation. Something very unsettling was beginning to take place within the tank...

Ingredientes de la ebullición

What happened next was a situation that no-one was prepared for. In fact, it was unprecedented. Both the NFPA and the American Petroleum Institute (API) had long held the position that no. 6 fuel oil, a refined product, was not subject to boilover. This stance was substantiated by loss history and experimental efforts to induce such an occurrence. Despite this, it is evident that a boilover did occur that day.

With the loss of the tank roof in the initial blast, the resulting open-top tank fire satisfied the last of three requirements for a boilover to occur. The other two ingredients; the presence of water, and an oil with wide ranging boiling characteristics, had been present all along.

There are many means through which water can accumulate in fuel oil storage, for example via leakage of a steam coil, or rain ingress through non watertight components. Although there were some attempts to shift blame on the fire department for applying water to the tank, these accusations were later rebuked. The consensus appears to be that small concentrations of water in the fuel oil supply were expected as part of the marine bunkering. Over time, the water would separate into a layer that would be periodically drained; this operation had not been carried out for an extended period prior to the incident. It is unclear why the water was not drained during the fire. Perhaps the necessary valves were engulfed by the dike fire, or maybe the precaution was not deemed necessary as a boilover could not have been anticipated.

Contrary to what was believed at the time, it is apparent that the heavy fuel oil fire in tank 8 had a sufficient range of hydrocarbon components, including both light ends and viscous residues, for a *heat wave* to be generated within the tank. In an open tank fire of this nature, it is predominantly the lighter components that are consumed at the surface. The unburned heavier components, heated intensely by the fire, form a layer which is heavier than the surrounding oil. Gradually, this hot dense layer sinks and grows within the tank. At around midday, six hours after the initial outbreak, the heat wave had reached the tank's water heel at a temperature between 150 and 315 degrees Celsius.

Initially, the water would have superheated beyond 100 degrees Celsius due to the hydrostatic head of oil above it.

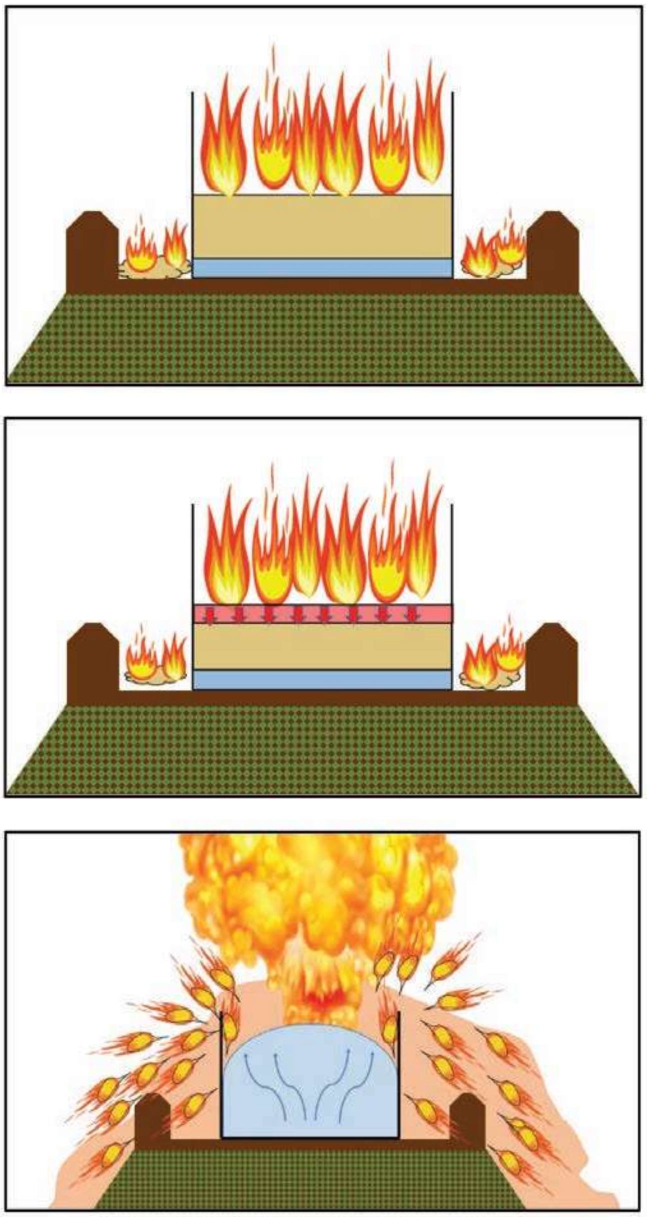

Figure 3 – (Top to bottom)
4. Loss of tank roof results in open-top tank fire.
5. Heat gradient starts to develop within tank as hot residues sink.
6. Heat wave reaches water heel resulting in rapid expansion into steam. A violent boilover occurs expelling the tank contents.

And then, suddenly, the water would have flashed into steam, expanding by as much as 2000 times, ejecting the contents of the tank in a vicious eruption.

Volcán hecho por el hombre

Those on the ground observed a gigantic fireball rise out of the tank and into the sky. The intense radiant heat was accompanied by a storm of searing rain. Burning oil spilled over the dike, pouring over settlements and through the streets underneath the steep dike wall. Molten asphalt from the roads mingled with the oil creating a noxious mixture which continued to flow downhill, destroying everything in its path; cars, fire trucks, helicopters. A small beach, some 300m from the tank 8 was consumed in flames as those that could jumped into the sea.

There are many harrowing accounts of the boilover; stories of heroism, trauma, and great personal loss. The exact death toll is unknown; however, estimates are in the region of 150. Of these were 40 uniformed firefighters, dozens of civil defence workers, 17 plant employees, 10 media workers, and scores of civilians. The tragic events at Tacoa accounted for one of the highest single incident losses of firefighters until this unfortunate record was settled by the collapse of the World Trade Centre towers on 11 September 2001.

Whilst secondary to the human cost, the damage to property was enormous at an estimated $50M USD ($150M in 2023 terms). This included the destruction of 60 vehicles and most of the fire apparatus on scene, as well as fire damage to 70 occupied dwellings. Miraculously, the power plants remained relatively unscathed due to their concrete perimeter walls.

The fire in tank 8 was extinguished by the sudden inrush of air during the boilover. However, as the burning oil flowed over into the downhill containment dike, this resulted in a sustained fire around tank 9, another heavy fuel oil tank of

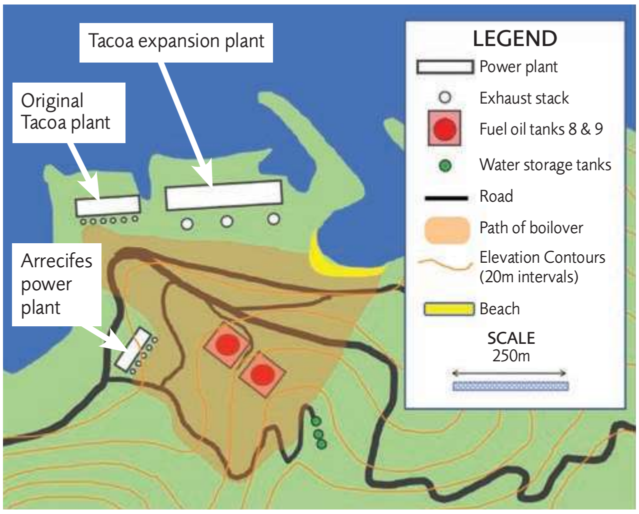

Figure 4 – Map of the Tacoa Power Plant and surrounds recreated by author from google-earth, photos, and videos. Indicative only.

similar size and construction. After several hours of exposure, the roof of tank 9 lifted, but did not fully detach. Much of the extraordinary helicopter footage available online of the Tacoa tragedy shows tank 9 on fire, whilst tank 8 lies blackened and crumpled on the hillside above. As a precaution against another boilover occurring in tank 9, the army evacuated 40,000 people from the area. The second boilover never came and the fire in tank 9 burnt out two to three days later.

Mejoras en seguridad

The events of 19 December 1982 left a permanent scar in the psyche of thousands of Venezuelans. The public demanded

Figure 5 – Image extracted from "Incidents that Define Process Safety" shows the aftermath. Both tank 8 (foreground) and tank 9 (background) appear blackened and crumpled. Notice the steep drop-off of the dike walls and settlements underneath.

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answers, however, these were not forthcoming. The official report of the investigative commission was known to consist of six volumes, however only a superficial 12-page summary was released due to ongoing litigation around the incident.

Electricidad de Caracas made widespread changes to the plant following the tragedy. Aided by the completion of a supply pipeline to the generator complex, the company shifted its dual-fuel turbines to run predominantly on natural gas. Tanks 8 and 9 were removed, and in their place was installed a huge, demineralised water reservoir to feed the boilers. The fire protection systems on all other fuel oil storage tanks were upgraded to include a dedicated ring main and anti-spark systems. As further measures to eliminate potential ignition sources, a hot work permit system was enforced, and smoking was prohibited throughout the plant.

The electricity provider also made improvements to the operation of its fuel oil import and storage facilities. Procedures were introduced to put more scrutiny on incoming marine tankers; each cargo would be tested prior to offloading and if the flash point was found to exceed a minimum limit, the load would be rejected. Similarly, systems were put in place to limit the temperature generated in the storage tanks; at all times this was limited to at least 3 degrees Celsius below the minimum accepted flashpoint. This ensured that flammable vapours could no longer be generated in the tanks.

The company took extensive precautions to prevent the escalation of future incidents. Emergency response plans were written up, regularly reviewed, and updated. Working groups were formed with local fire departments, bringing all parties together for the discussion of safety and training issues. Additionally, a dedicated emergency brigade was established onsite. This was equipped with tankers, rapid intervention trucks, and all other apparatus necessary to guard vigil over the facility.

El capitulo final

So, what has now become of the Tacoa power plant, 40 years on? The vital infrastructure of the *Ricardo Zuloaga Generator Complex* went on to provide reliable electricity to millions of Venezuelans for years after the incident. During this era, the country's generation and power grid was described as *"the envy of Latin America"*.

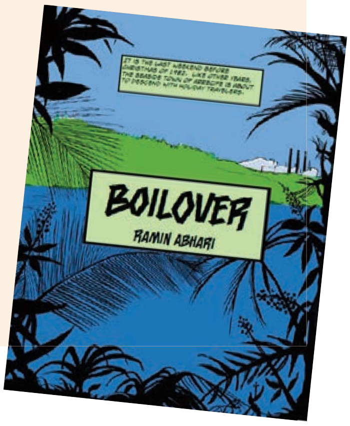
In 2007, Electricidad de Caracas was nationalised, bringing its assets under the control of state-owned, Corpoelec. As part of this shift, the facilities were renamed as the *Josefa Joaquina Sánchez Bastidas Generator Complex*. In the years that followed, Venezuela has suffered from a prolonged socioeconomic crisis, which persists to this day. With a lack of government funds to maintain public infrastructure, it appears that the generator complex has fallen into disrepair and is no longer operational. In recent years, return of power generation capability to Tacoa has become highly politicised against the backdrop of a national generation deficiency and frequent *mega-blackouts*. However, rumours persist that the plants are being permanently dismantled.

The enduring legacy of the Tacoa tragedy is that the NFPA and API updated their guidance to recognise the potential for boilover in fuel oil storage tanks. This change has influenced the safe design, operation, and emergency response of plants around the world. Whilst this is clearly a positive, it is disappointing that many of the other contributing factors from this incident were never disclosed. By not sharing freely our lessons learned, we do an injustice to those affected. Worse than that, we condemn others to a similar fate. Forty years on, it is surely time for the official investigations to be made public, and for Tacoa's full story to be known.

This article would have been much shorter had it not been for the help of Rixio E Medina. I would like to dedicate it to the memory of his dear friend, boss, and mentor, Ibrahim Alfonzo Ferrer. Ibrahim was the Corporate Manager of Industrial Protection at Lagoven (formerly Exxon in Venezuela) and was one of the many that perished in the Tacoa tragedy. I also extend my gratitude to Miro Popić, Maikel Popić, and Eric Omaña for the reference material they have generously provided.

Editor's note

Ramin Abhari's latest graphic novel depicts the events that took place at the Tacoa Power Plant 40 years ago and can be accessed at **https://www.icheme.org/knowledge/loss-prevention-bulletin/free-downloads/cartoons/lpb-cartoons/**



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