4. C.A. LA ELECTRICIDAD DE CARACAS, DECEMBER 19, 1982, FIRE (NEAR) CARACAS, VENEZUELA*

by
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4.1 INTRODUCTION

At the recent API fire-safety committee meetings, Martin Henry, Flammable Liquids Engineer with the NFPA, discussed the fire and ensuing tank boil-over which occurred at a privately owned power plant near Caracas, Venezuela on December 19, 1982.

The NFPA was requested by the power company to investigate the loss specifically with regards to two questions: (1) what was the source of ignition, and (2) why a boil-over occurred in No. 6 fuel oil? An official report is being prepared by Bechtel for the Venezuelan government, however, there is no assurance that this will ever be made public. The NFPA report will appear in a future NFPA Fire Journal. The June 1983 issue of "Fire Service Today" will carry a short story of the loss.

The power plant, which was built in 1978, included three 400 MW units plus a 500 MW unit under construction. The plant remained on line throughout the incident drawing oil from smaller tanks located out of the fire area.

There were two 55 m x 17 m (180 ft x 56 ft) (250,000 bbl) cone roof tanks, built by CB & I. Diking/bunding was individual; apparently standard. Spacing appeared to be less than one diameter. The gauge on tank No. 8 indicated that the tank contained 7.5 m (19.5 ft) of fuel oil at the start of the fire. It had been feeding the boilers for six days prior to the fire.

4.2 THE INCIDENT

At 6.15 a.m. while it was still quite dark, three men in a vehicle went to gauge tank No. 8. Two of them went to the tank roof; the third stayed with the vehicle. Approximately 2 minutes later, the roof of tank No. 8 blew off at the same time rupturing lines within the dike. The source of ignition is unknown. It was emphasized, however, that neither man had a flashlight; the inference being that perhaps a match was lit to read the gauge line.

Each tank was protected by a 100 mm (4 in) "drencher" water line extending to the center of the tank roof and designed to cascade water over the roof and shell for exposure protection. Each also had semi-fixed foam protection from five risers spaced equidistant. On tank No. 8, one of these was damaged by the initial explosion.

The power company had no fire brigade and the nearest public fire department was ½-hour away over circuitous roads. It is not known if the drencher or foam systems were operated during the incident. One monitor nozzle was being used for cooling prior to the boil-over of tank No. 8 which occurred about 8 hours after ignition.

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To have "boil-over characteristics", an oil must have a wide range of boiling points, including a substantial proportion of volatile components, along with highly viscous residue, see the Appendix. This combination is present in most crude oils but seldom in other petroleum products. A third requirement is the presence of at least a small amount of water-in-oil emulsion. As crude oil burns, its more volatile constituents are vapourized. The less volatile constituents, however, do not burn but become hot and gradually sink into the bulk of the liquid. This creates a heat wave, with temperatures as high as 315°C (600°F), which travels downward into the bulk of the liquid. In most crude oils, the rate of heat wave travel is in the range of 300 mm to 460 mm (12 in to 18 in) per hour although it can be as high as 900 mm to 1.2 m (3 ft to 4 ft) per hour. Refined products do not create heat waves because they contain hydrocarbons of more uniform volatility. When water comes into contact with a heat wave of sufficient heat and depth, it is converted to steam with an expansion of 1,700 to 1 or greater.

The violent boil-over of tank No. 8 resulted in the death of 40 fire fighters, dozens of civil defence workers, and many spectators. One hundred and fifty-three are known dead and seven are missing. Flowing oil inundated tank No. 9 of similar size and construction. The wave of oil flowed to the sea but was kept from the power plant by a concrete block wall. After several hours of fire exposure, the roof on tank No. 9 lifted allowing venting. Tank No. 9 burned out after 2 or 3 days but the fire smouldered for 20 days.

During the 12 hours leading up to the explosion in tank No. 8, tank No. 9 had been receiving oil from a tanker. First reports that this off-loading somehow was associated with the incident are unfounded.

Sixty vehicles, including all fire apparatus, were destroyed. Inrushing air following the boil-over lifted roof panels of the power plant 300 m (1000 ft) away.

Earlier reports that hydrogen or LPG tanks exploded are unfounded. There were several water spray protected propane bullets at the power plant. The spray systems operated throughout the fire and prevented overpressure even though the tanks were in the path of the boil-over wave.

The main unanswered question regarding this loss is why a boil-over occurred in a tank containing No. 6 fuel oil. The NFPA and API's position has long been that No. 6 fuel oil is not subject to boil-over. This contention has been substantiated by loss history. The power company specifications for No. 6 fuel oil reportedly allowed 5%-20% light fractions, further defined as heavy naphtha with a high vanadium content. We understand that such blending is a common practice in the USA. One source estimates that as high as 92% of all No. 6 fuel oil is synthesized with various types and quantities of light ends.

The oil reportedly had a 71°C (160°F) flashpoint and was to be heated in storage to 65°C (150°F) by six tank heaters; two of which were in use at the time of the incident. However, control room records show that oil at 80°C (176°F) was being returned and cascaded into the tank and that storage temperature was 82°C (180°F). The tank had high temperature alarms which sounded at midnight, 6 hours prior to the incident.

It should be emphasized that the above information is not from an official report but are my observations from a brief review of the loss by a NFPA staff member.

4.3 RECOMMENDATIONS FOR THE STORAGE OF HEAVY FUEL OILS

The exact cause of the No. 6 fuel oil tank boil-over has not yet been established. However, some observations and safety precautions can be made regarding the safe storage of heavy fuel oils.

1. The accumulation of water within the tank should be avoided. The accidental injection of water or light hydrocarbons may create a violent evolution of steam or vapour where storage temperatures exceed the boiling point of water or the light hydrocarbons. The resulting pressure may cause failure of the roof-to-shell seam of the tank.

    a) The roof should be watertight and free-draining.

    b) Gauging hatches and roof manheads should be kept closed.

    c) An open rain-proof vent should be considered. Flame arresters or pressure-vacuum vents are not generally used on heavy hot oil tanks since the flame arrester elements may become plugged or the pressure/vacuum valve pallets may stick.

    d) There should be no interconnections to pipelines serving hot tanks through which water or light hydrocarbon liquids could inadvertently enter the tank. If such connections are necessary, they should have double-block valves, sealed in the closed position, with a bleeder between the valves or a roll-out spool piece.

    e) Steam coils for hot-oil tanks should be tested for leakage when the tank is out of service. Preferably, coils should be of the all-welded type to minimize the possibility of leakage. Coolers or exchangers in a line to a hot oil tank should be arranged so that water pressures are lower than oil pressures to prevent water from leaking into the tank.

    f) Tanks equipped with steam coils or heaters hould be observed for steaming or burping. When coils are inactive, an atmospheric bleed should be opened and frequently observed for signs of oil leakage.

    Tank storage temperatures must be carefully controlled. Flammable vapours can be generated if the oil temperature approaches the oil flashpoint.

    Wherever possible, tanks should be operated and maintained either well below the boiling point of water so that water bottoms will not flash to steam, or they should be kept sufficiently hot at all times so that water bottoms cannot accumulate. Tanks should not be operated in a range where temperatures fluctuate above and below the boiling point of water.

    In standing tanks, the main body of the oil may be substantially hotter than the oil near the shell or at the bottom. Hence, the temperature at these points may not be representative.

a) Direct-fired heater tubes, if exposed to the vapour space, will develop hot spots which may exceed the oil autoignition temperatures. It is important that the oil level in the tank be kept above the heater tubes or heating coils.

b) Temperature readings should be recorded routinely to control tank temperature. The temperature measuring device must be reliable and extend into the tank deep enough to obtain representative oil temperatures. Readings should not be taken near the shell or bottom of the tank nor near heating coils or fired tubes.

3. Blending of light fractions with No. 6 fuel oil is a very common practice which can change the physical characteristics of the oil substantially. It is important that samples of shipments of oil received from the supplier be laboratory tested upon receipt to assure that the oil meets specifications.

APPENDIX - BOILOVER

The NFPA Technical Committee on General Storage of Flammable and Combustible Liquids, which is responsible for NFPA 30, the Flammable and Combustible Liquids Code, has developed for the next edition the following definition of the term boilover:

> "Boilover shall mean an event in the burning of certain oils in an open top tank when, after a long period of quiescent burning, there is a sudden increase in fire intensity associated with the expulsion of burning oil from the tank. Boilover occurs when the residues from surface burning become denser than the unburned oil and sink below the surface to form a hot layer which progresses downward much faster than the regression of the liquid surface. When this hot layer, called a 'heat wave', reaches water or a water-in-oil emulsion in the bottom of the tank, the water first is superheated and subsequently boils almost explosively, overflowing the tank. Oils subject to boilover must have components having a wide range of boiling points, including both light ends and viscous residues. These characteristics are present in most crude oils and can be produced in synthetic mixtures."

As this definition indicates, three elements must be present in order for a boilover to occur:

* an open top tank fire
* a water layer in the tank
* development in the tank of a heat wave, which is determined by the nature of the stored product.

When an open top tank containing a product with a wide range of boiling points, such as crude oil, begins to burn, the components with higher boiling points sink below the surface and form a heavy heated layer. This heated layer transmits heat to the cooler oil below, where the components with lower boiling points continue their movement toward the surface. These light end components keep feeding the fire, and the fire continues to radiate heat back toward the tank contents. As it moves toward the bottom, the heat wave grows in both size and density and contains temperatures in the range of 150°C to 315°C (300°F to 600°F). The descending heat wave continues to distil components with lower boiling points from the oil below. When the heat wave reaches a water layer, or water emulsion layer, it first superheats the water, and then causes a steam explosion. The water flashes to steam at temperatures well above 100°C (212°F) and may expand at a ratio of 2000 to 1.

It is estimated that a steam explosion can propel burning oil and vapour to a height ten times the diameter of the tank. In one extraordinary crude oil tank fire in 1926, photographs show a flame mass that is estimated to be 330 m (1100 ft) in diameter at its base and 1800 m (6000 ft) high.