Frank Rizzuto, AMEC Americas Limited, Canada, discusses the importance of making 'beyond zero' safety a benchmark in design, construction and operations.

Caribbean Petroleum fire in Puerto Rico.

GETTING IT RIGHT

During these challenging economic times, companies are driven to maintain performance while at the same time minimising cost, a formula that can lead to shortcutting.

It is tempting to recycle old designs. Worse, there is a tendency to rely on minimal code compliance and project budgets for fire protection based on 'factoring', a formula that may or may not align with commercial reality. This formula can lead to capital loss, human tragedy and environmental disaster.

Minimal code compliance is an arena in which best practice and a higher level of technical safety may be sacrificed in the interest of cost reduction. Although fire codes are periodically updated, these minimal measures necessary to secure approval by

Figure 1. A large vapour cloud ignited at the Caribbean Petroleum tank farm storing gasoline, diesel fuel, jet fuel and heavy fuel oil.

governmental authorities may nonetheless leave a facility potentially unsafe to operate. The International Fire Code, for example, leaves it to the discretion of the local fire official (there may not be one, depending on location) as to whether or not a fire suppression system should be installed on a liquid hydrocarbon storage tank.[1]

Fire codes in general are moving from a prescriptive to a more risk and performance based approach as industry dictates solutions to the authority having jurisdiction, often a person who does not understand the issues involved in historical prescriptive requirements. At the end of the day, the engineering solution that receives approval (usually the lowest cost producer) is the outcome of an exercise in commercial evaluation supported by arguments for consequence versus probability. It is, in practice, the antithesis of inherently safer design (ISD) and 'beyond zero' safety engineering where zero probability is the benchmark.

Superficial risk assessments

During the engineering and construction of downstream petroleum products storage facilities owned by refineries, terminal operators and product end users, the authority with the most to lose but the least say on what is permissible is often the insurance underwriter. Unlike legislated national building and fire codes, industry codes and standards such as API, NFPA and the FM Global system, which on the whole reflect best practice, are not law but merely recommendations. Nonetheless, engineers rely on them as a standard for good practice with which they generally strive to comply.

Insurance underwriters and fire marshals routinely accept less comfortable protection levels offered by the industry they endeavour to safeguard. Pipeline terminal operators, for example, have typically not installed fire detection and fire suppression systems on large diameter storage tanks unless the tanks are over 45 m in diameter, a dimension beyond which some fire codes require it.[2] Facilities owners are inclined to argue that compliance with the minimal separation distances outlined in the fire codes is sufficient, ignoring the nature of tank and containment area fires, which can be multidimensional in character and, in the case of a vapour cloud, do not respect fire breaks and other passive fire protection measures. They 'risk assess' their way out of needing to adequately protect the tank farm, with risk decisions being made on faulty data.

If the tanks are fire code separated and therefore compliant, underwriters have not become excited enough to deny insurance, although they constantly recommend that active fire detection and suppression systems be installed, especially on large diameter tanks. Insurance is a commodity and relies on commodity type pricing, therefore it is rare that a facility is denied insurance based on protection levels. In rebuttal, operators will point out that the contents of one burning tank in a grouping can always be pumped back into a pipeline or a holding tank, thereby removing most of the fuel from the fire area and reducing exposure to adjacent tanks, an example of risk assessing one's way out of needing to provide protection. The fallback is on minimal fire code protection levels.

Examples of getting it wrong

Two recent tank farm fires on opposite ends of the dollar loss spectrum illustrate this trend toward lesser protection resulting in capital loss and environmental damage.

Case study one

A fire at Chevron Texaco's key Escravos oil terminal in Southern Nigeria in July 2002 forced the shut in of approximately 300 000 bpd of oil production when lightning struck one of the terminal's storage tanks, incinerating 100 000 bbls (4.2 million gal.) of crude and distributing fire effluent (volatile organic compounds, carbon monoxide, oxides of nitrogen, sulfur dioxide, hydrogen sulfide, and soot) over the local area. The fire, which burned for several days, caused shutdown of production from offshore lines accounting for approximately 300 000 bpd.

Despite the loss of the major portion of the tank's contents and severe damage to equipment, another 80 000 bbls were successfully pumped out of the burning tank into a pipeline. Mobile firefighting equipment was brought into place to try to prevent the flames from spreading to other tanks and additional support was asked from other oil firms. The company announced that there were no casualties. Without extinguishment of the fire by a fixed foam fire suppression system, the inevitable loss of the tank and resulting environmental damage was typical of the 'let it burn' philosophy supported by a consequence versus probability approach that justifies the absence of fixed fire detection and automatic fire suppression systems. It was not revealed whether or not the involved tank was equipped with lightning protection or adequately bonded and grounded.

Case study two

A more recent Caribbean Petroleum fire in Puerto Rico sits at the other end of the loss spectrum. On 23rd October 2009, a large vapour cloud ignited at a tank farm storing gasoline, diesel fuel, jet fuel and heavy fuel oil in approximately 40 aboveground storage tanks. The associated refinery had been shut down in 2000. At the time of the incident, gasoline was being offloaded to a storage tank from a ship docked in San Juan Harbour.

Of course, moving a large quantity of fuel, typically in the order of millions of gallons, from a burning tank to an empty holding tank or back into a pipeline can only be accomplished if the associated pumps are of sufficient capacity and piping is configured to do this before the fire spreads to other tanks. In practice, a fully involved tank fire must be extinguished within the first five minutes of ignition if distortion of the tank shell and loss of the tank itself, as well as its contents, is to be avoided.

Pipeline pumps, such as those of Chevron Nigeria's Escravos facility but unlike those of a typical refinery, are usually sufficiently large to move inventory from a burning tank into a pipeline though not quickly enough to save the tank itself or prevent a fire from communicating with adjacent tanks, particularly after the tank has ruptured and the event has become a containment area fire involving other tanks in a grouping. Unlike the earlier Escravos fire, contents of the burning Caribbean Petroleum tanks could not be moved back into a pipeline. In spite of US$ 6.4 million spent in firefighting, the fires burned themselves out over a period of days with the loss of 20 tanks and thousands of tonnes of fire effluent issuing into the atmosphere. The initial blasts damaged homes and businesses over a mile from the facility, forcing evacuation and resulting in still pending lawsuits.

US Chemical Safety Board (CSB) investigators have determined that a likely scenario leading to the release of fuel and the resulting vapour cloud was an accidental overfilling of the tank. Gasoline spilled from the tank without detection, vaporised, then spread across containment areas and fire breaks (all measures in minimal code compliance) until it reached 2000 ft (610 m) in diameter then found an ignition source in the northwest section of the facility.

The CSB found that on the evening of the incident, the liquid level in the tank could not be determined because the facility's computerised level monitoring system was not fully operational.[3] Operators relied on visual checks of a mechanical gauge on the tank's exterior shell and remained unaware of the spillage and resulting vapour cloud. There may also have been what safety experts speak of as a 'weekend effect' in industry, where weekend maintenance creates an unsafe condition. Given the level of destruction, it is difficult to determine whether or not the mechanical level gauge was functioning during the spill and before fire consumed the tank.

That large volume tank fires generally burn themselves out with loss of both equipment and inventory was demonstrated during the fire in Puerto Rico and, only a month later, by a terminal fire of similar volume and scope but this time with loss of life that occurred in Jaipur, India.

The need to design for safety

Unlike offshore spills, large oil companies, pipeline and terminal operators, end users and their insurance underwriters have not demonstrated great concern for the environmental damage caused by large volume hydrocarbon fires or translated such concerns into a higher level of protection. The uncontrolled incineration of millions of gallons of fuel in a single storage tank, or even 20 storage tanks, has not earned the serious attention of legislators and environmental protection advocates. The threat to public health posed by thousands of tonnes of fire effluent in the earth's atmosphere and ground water or the forced evacuation of thousands of persons from their homes does not affect public sentiment in the way that an offshore oil spill and images of tar coated wildlife might.

Consequently, there is less public pressure to do things better outside actions of the CSB and other investigative agencies who are not empowered to issue citations or levy fines. While technical safety and improved levels of protection continue to receive lip service, anything that does not contribute to the bottom line can, in the end, be tagged as overhead and therefore remains fair game for cost cutters. The fallback on minimal code compliance then dictates design criteria.

Obviously, it is better for fires not to occur in the first place than to have to try and suppress them. Designing for safety, and getting it right, would eliminate many of the causes of spills, explosion and fire. Unfortunately, after the fact fire investigations often make the same mistake in identifying cause, that is, they point to the level instrument that failed or was bypassed and the monitoring system computer that was down at the same time the overflow ignited and caused the fire that destroyed the tank farm. Yet the upstream cause of a fire incident can sometimes be found closer to the drawing board, long before the project itself went into construction.

Insufficient expertise has been brought to projects by some design engineers and their contractors. History has demonstrated that technical safety in general, and fire detection and suppression systems in particular, are not always designed in sufficient detail to ensure that they meet the performance criteria necessary to reliably achieve their intended role. In some cases the parameters are not even clearly defined. The problem is compounded when the system designer or specifier has not had the operational experience or feedback necessary to ensure system practicability.

The CSB has urged refineries, pipeline and terminal operators to improve their commitment to technical safety. By merely identifying the widget that broke or malfunctioned, or shifting blame to the operator most closely associated with the failure (who is often a victim of an operating budget insufficient to keep instrumentation and safety equipment functioning properly) the ensuing responses aimed at preventing similar recurring incidents are seriously compromised. This approach simply returns an improperly designed system or plant to status quo and encourages cookie cutter style engineering of new facilities.

The role and responsibility of the design engineer is to bring the highest level of competence to the job. The engineer must deliver 'beyond zero' safety through all stages of project development, construction, operating and closure phases leading up to the last day the facility is in operation before decommissioning, and owners should be willing to pay for it. To avoid the recurring theme of human and environmental catastrophe, hazards must be reduced by means that are built into the design of the facilities and inseparable from them. In other words, inherent technical safety is built into and stays with the facility for the lifetime of the asset.

Figure 2. Aerial view of the Caribbean Petroleum facility after the explosion.

Procedures to increase technical safety

Here are some prescriptive measures for building improved technical safety:

- Bring the right qualifications, skill sets and experience to the job, from the feasibility study stage through to detail engineering, procurement of equipment and construction of new facilities.
- Do not rely on minimal fire code compliance as a basis for facilities design criteria.
- Understand the inherent limitations in publicly available tank fire data and use this with extreme caution as input to risk assessments regarding fire protection decisions.
- Conduct due diligence and verify available data.
- Know and independently assess the properties of liquid hydrocarbons being stored and handled. Indentify boil over liquids before they get into the wrong type of tank, regardless of precedent.[4]
- Avoid cookie cutter solutions by thinking and designing 'outside the box'.
- Build redundancy into tank safety systems so that instrumentation cannot be easily neutralised or bypassed. If necessary, remotely (offsite) monitor critical safety instruments such as tank level alarms and heater controls.
- Select appropriate fire detection and fire protection technology regardless of cost. The cost of fire detection and suppression systems is typically less than one half a percent (0.005) of the total project value, not a figure that would make or break any project.
- Ensure that the choice of fixed fire suppression system on a large diameter liquid hydrocarbon storage tank is reliable and capable of automatically and rapidly extinguishing the blaze, not merely controlling it, before the discharged water contributes to a boil over. Remember the lesson contained in 'Galileo's Lost Lecture', that is, fire suppression systems are not scale invariant. NFPA 30, Tables 2-1 through 2-4 suggest there is little possibility of automatically extinguishing fire in a tank that exceeds 150 ft (45 m) in diameter using top mounted foam chambers while testing and experience has shown that the maximum tank diameter for which a fire can be successfully extinguished, or even controlled, is actually much less.[5] Only in recent years have fixed fire suppression systems such as instant foam and Foam Fatale been developed that can effectively extinguish fires in these large diameter storage tanks. Put out the fire; reduce the fire effluent; save the tank farm.
- Provide capital budgets that genuinely reflect the commercial cost of protection. Do not tailor the level of protection to a predetermined budget.
- Make 'beyond zero' safety a benchmark in design, construction and operations.

References

1. 2006 International Fire Code, 3404.2.9.1.1.
2. 2005 National Fire Code of Canada, 4.3.2.5(1).
3. CNN, 17 November 2009, Puerto Rico fire linked to faulty gas tank monitoring system.
4. 2006 International Fire Code, 3404.2.9.1.4.
5. Swedish National Testing and Research Institute, Brandforsk Project 513 - 021, Tank Fires, Review of fire incidents 1951 - 2003.

Note

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