WHITE PAPER

Costs and Benefits of Process Safety

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The traditional approach to the prevention of major accidents has consisted of balancing the potential cost of process accidents with prevention expenditures, as if there were an optimum, an exact proportion that should be committed to the prevention of such events whose probability of occurrence is generally so small that it distorts the proper risk perception within an organization, despite regular media coverage of these large industrial disasters.

As the frequency of such events is expressed in one over tens or even hundreds of years, well in excess of a human life or professional career, it is easy to fall into the cognitive bias which involves adopting a fatalistic view of these accidents in the same way as one regards natural disasters, such as earthquakes and tsunamis.

Cost of Major Accidents

An inaccurate prior evaluation of the consequences of major accidents by companies also contributes to minimization of the real risk and, as a consequence, the need for prevention. Numerous recent examples of varying magnitudes should nevertheless serve to remind us of the extent of such consequences as exemplified on the table below.

The consequences of such major accidents are usually converted into an economic value to be analyzed and managed in any organization, as it is, for instance, for the risk of a defaulting supplier. Some of these costs are quite obvious and simple to evaluate (material damage, loss of production, etc.), some others far more difficult (remediation, impact of media coverage, share value[1], insurance premium, etc.).

The monetarization of human life is obviously always open to debate but it nonetheless underlies any decision relating to prevention within our industrial society. It is in fact prevention of statistical fatalities and its value varies strongly whether one adopts the viewpoint of the legislator, courts or insurer. It is valued for instance ca. €3 M in Europe and $7 M in the USA[2]. These values make it possible to carry out Cost-Benefit Analyses (CBA) and evaluate the commercial viability of risk prevention strategies.

[1] BP lost 55% of its market capitalization in 4 months following the DeepWater Horizon disaster in 2010, amounting to $100 billion.

[2] N. Treich, Cahiers de la Sécurité Industrielle: L'Analyse Coût-Bénéfice, ICSI, March 2008.

Year	Location	Event	Number of Fatalities
2000	Enschede (Netherlands)	Fire and explosion of fireworks	22
2001	Toulouse (France)	Detonation of ammonium nitrate	30
2001	Petrobras (Brazil)	Offshore platform explosion	11
2003	Kinston (USA)	Polyethylene dust explosion	6
2003	Puertollano (Spain)	Explosion in tank due to operational problems in FCC unit	9
2004	Skidda (Algeria)	LNG leakage & explosion	27
2005	Texas City (USA)	Explosion & Leakage from isomerization unit	15
2005	Buncefield (UK)	Explosion and fire at oil depot	0
2007	Torino (Italy)	Aerosol explosion	7
2008	Port Wentworth (USA)	Sugar dust explosion	14
2008	Istanbul (Turkey)	Firework explosion	22
2008	Jacksonville (USA)	Thermal runaway and reactor explosion	4
2010	Middletown (USA)	Gas explosion during a purge	5
2010	Deepwater Horizon (USA)	Explosion and oil spill	11
2010	Ajka (Hungary)	Leakage of toxic sludge	9
2012	Jubidana (Venezuela)	Refinery explosion and fire	50

Litigation costs, such as penalties, fines or other legal expenses, as well as criminal penalties, often tend to be overlooked. Nevertheless, these can prove very significant, as illustrated in the table below.

Obviously, the massive spill that followed the explosion of the Deep Water Horizon oil platform in April 2010 will probably remain for a long time to come in the annals of “multi-billion” disasters with a total cost of over $65 billion, two-thirds of which comprises of civil or criminal penalties.

BP was sentenced again in August 2012 to pay a further $13M following the Texas City accident in 2005 totaling over $50M, an accident for which OSHA identified more than 300 regulatory violations.

The explosion and fire at the Buncefield oil depot in the outskirts of London in 2005 is one of the most significant European events of the last 10 years; the damage cost is reported to exceed one billion euros and the 5 co-operators were sentenced to pay €12M in penalties.

A large number of less significant major accidents escape media attention and fall into the €100k to €1M range. The Italian government sentenced the company to a €1M fine and its CEO to 16.5 years jail following the Torino explosion in December 2007,

Year	Major Accident	Estimated Total Cost	Penalties
2000	Enschede (NL)	$300 M	
2001	Toulouse (FR)	>€100 M	
2003	Kingston (USA)	>$150 M	$10 k
2005	Texas City (USA)	$2 Bn	$87 M
2005	Buncefield (GB)	£1 Bn	$12 M
2007	Torino (IT)	N/A	€1 M
2008	Port Wentworth (USA)	$300 M	$6 M
2008	Jacksonville (USA)	N/A	$12 k!
2010	Deep Water Horizon (USA)	$65 Bn	$40 Bn

which claimed 7 victims, identifying not less than 214 regulatory fire safety defects.

These consequences obviously attract significantly less media coverage than the live accident with images of still smoking blown-up plant, by the simple fact they are concluded several years after the event, which has since been replaced by another one.

Cost of Prevention

An analysis of these major accidents unequivocally demonstrates that it is easy, if not obvious, to prevent the majority of them technically. A redundant level trip on the Buncefield tank, a second BlowOut Preventer (BOP) for Deepwater Horizon, a quick repair of the Amuay refinery pump, deliberately left leaking, would have avoided these disasters. It is often regrettable to realize that a sound investment of a few dozen thousand euros in equipment and hours of study, sacrificed at the altar of immediate productivity, would have been sufficient to prevent these disasters.

The costs of prevention of major accidents are within these orders of magnitude. Firstly, they include dedicated human resources to implement and run process safety management systems. However, this also involves hours of studies by specialists: process hazards analyses, laboratory studies, quantitative risk analyses, audits, reliability analyses, etc. These studies are crucial to define the appropriate technical resources (instrumented safety measures, overpressure relief systems, etc.), ultimate barriers to avoid escalation of a simple process deviation into a major accident. The equipment part of process safety expenditure can prove to be the most significant part and depends critically on the quality of the previous phase. As a reference, the investment cost of a simple instrumented safety loop is estimated to be around €5,000 and its over-specification at least €2,000 extra.

A number of technico-economic studies, generally based on Cost-Benefit Analyses (CBA), have attempted to estimate in greater detail the prevention costs of major risks, both in Europe[3] and the USA[4]. One can debate long and hard on the cost of Seveso files, Hazop analyses and other process safety studies. The reality is that they are specific and proportional to the industrial sector and particular risks of the industrial sites. Fine chemistry requires, for example, much greater effort than other sectors by the simple nature of its activity. One cannot spend the same time studying a diesel storage tank, a continuous phosgene synthesis and a multipurpose batch reactor.

To give an order of magnitude, it is sometimes estimated that process safety amounts between 0.5 to 1% of the capital expenditure of a plant construction project and between €50k and €500k annually per major hazards site.

Impact of the Regulations:

The direct consequence of major industrial disasters, like those quoted above, is generally to instigate a review and revision of the regulations governing major hazards industries. The Seveso accident in 1976 obviously gave rise to the eponymous regulations that we are all now so familiar with. More recently, in France, the Bachelot Law was the direct consequence of the Toulouse explosion in 2001. In the US, OSHA implemented a national emphasis program for preventing of combustible dust explosions[5] following the Imperial Sugar disaster at Port Wentworth in 2008. The American offshore Safety and Environmental Management Systems (SEMS) regulations were issued in October 2010, 6 months after the DeepWater Horizon disaster, including a special section on the integrity of BOPs.

Generally speaking, regulations bring progress to the major hazards industry. The European Commission[6] reports and attributes a 10% reduction in major accidents between 2000 and 2008 to the Seveso II regulations, in spite of an overall increase in the number of sites covered. In a way, regulations push industrial companies to displace this optimum of accident prevention/cost expenditure but unfortunately most of the time post-accident.

For several organizations, the efforts in preventing major hazards are limited to what is prescribed through legislation. The primary objective is to obtain, often at the lowest possible cost, an operating permit, a certificate of conformity, a technical report; in short, the paperwork that is strictly necessary.

It is often regrettable to note the low level of expertise of these dossiers which are sometimes not properly understood or even read by the leaders of these industrial companies or the entities which control them. This points to an overall lack of knowledge and expertise. It is also unfortunate that these dossiers are somewhat disregarded by insurers, often too focused on the fire risk that the insurance companies better understand than the process safety risk. The administration knows this all too well, according to T. Trouvé in 2004, then Director of pollution and risk prevention: "As the minister has invited us this morning: the devil is in the paperwork. While the linear meters of paper and probability calculation refinements describing theoretical plants accumulate, plants themselves continue to explode".

There is no shortage of examples and accident literature is replete with situations where the major accident was not addressed in the dossier submitted and examined by the administration. The Toulouse accident in 2001 is just one significant example amongst others where the scenario of ammonium nitrate detonation was not developed in spite of the Oppau accident which had claimed more than 500 victims in Germany 80 years earlier, ironically exactly to the day.

One of the direct consequences is misallocation of prevention expenditure to the detriment of the prevention of higher risks, somehow under-evaluated. There are also a plethora of examples on the risks of:

> gas and dust explosion, where the ATEX regulations in Europe lead to a fixation and disproportionate focus on equipment compliance, or
> thermal runaway lacking specific, prescriptive legislation. The T2 Laboratories accident in 2008 in Jacksonville which resulted in four fatalities is a perfect example where the simple failure of the cooling system led directly to the explosion of the reactor.
> ammonia refrigeration systems with potential effects, in case of failure, outside the site limits not being subject to strong regulatory requirements such as an emergency plan.

Towards a New Approach to Process Safety

Time has come to approach process safety in terms of gains and not costs, in terms of business excellence in the same vein as occupational safety at work or quality.

Process safety professionals are often responsible, for their inability to value their actions in terms of gains and returns on investment rather than costs; and yet they are numerous[7].

Yet in 1994, the excellent survey by W. Bridges[8] quantified the costs and gains from process safety in 25 American companies. A large number of companies considered that the benefits of process risk analyses, carried out as part of implementing compliance to OSHA PSM regulations, totally offset their costs.

A CCPS study[9] in 2006, made with thirty large chemical companies, showed that prevention efforts were directly quantified in

[3] R. Gowland, Considering Industry Costs & Benefits for Safety Management, EPSC 2011.

[4] W.G. Bridges, Cost & Benefits of Process Safety Management: Industry Survey Results, Process Safety Progress, Jan. 1994

[5] Combustible Dust National Emphasis Program – See:
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=directives&p_id=3830

[6] European Commission, Better Information about Major Incidents Risks, Aug. 2012

productivity gains (+5%), reductions in operating costs (-3%), in maintenance costs (-5%) and also in insurance premium reduction (-20%). The European Process Safety Centre[10] (EPSC) made the same case recently with the publication of a video entitled "Process Safety Pays" aimed at senior executives.

Many organizations have understood this for years, often and generally following the painful experience of major accidents or quasi-disasters. They have then invested smartly in process safety in human capital, laboratory equipment, study hours, training hours, management systems and incorporated process safety as a real value for the company.

They have gone beyond the pure regulatory compliance approach by implementing a process safety management system and have invested significant amounts to make it work effectively by developing the skills, the organization and the culture that is specific to process safety[11], as opposed to safety at work.

That is the key issue in reality-due to their different timescale, process safety performance is not measured using the same indicators as safety at work (rates of serious injury & fatalities,…) but rather early warning signs and leading indicators within organizations. What an irony of history was the ceremony of a safety award on the very same day the Deep Water Horizon platform sank.

Implementation and monitoring of these leading indicators for predicting process safety performance is crucial. These can include for instance numbers of manual start-ups, numbers of bypassed interlocks, records of tests of safety instrumented systems,… Who would dare to drive a car whose brakes are never tested for their efficiency?

Conclusion

Despite progress made in the prevention of major accidents, the pure regulatory compliance approach is no longer sufficient and it is essential to go beyond this to achieve sustainable process safety performance within a company. Process safety must be integrated within the different processes of the organization as part of a global approach integrating skills, systems and culture. It must become a real value for the company.

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[7] S. Gakhar, Justifying the Price of Safety, TCE Today, Feb. 2012

[8] W.G. Bridges, Cost & Benefits of Process Safety Management: Industry Survey Results, Process Safety Progress, Jan. 1994

[9] CCPS 2006 – The Business Case for Process Safety – 2nd edition – www.ccpsonline.org

[10] EPSC – http://www.epsc.org

[11] D. C. Hendershot, "PSM – You can't get it right without a good safety culture", Process Safety Progress, Vol. 31-1, March 2012

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