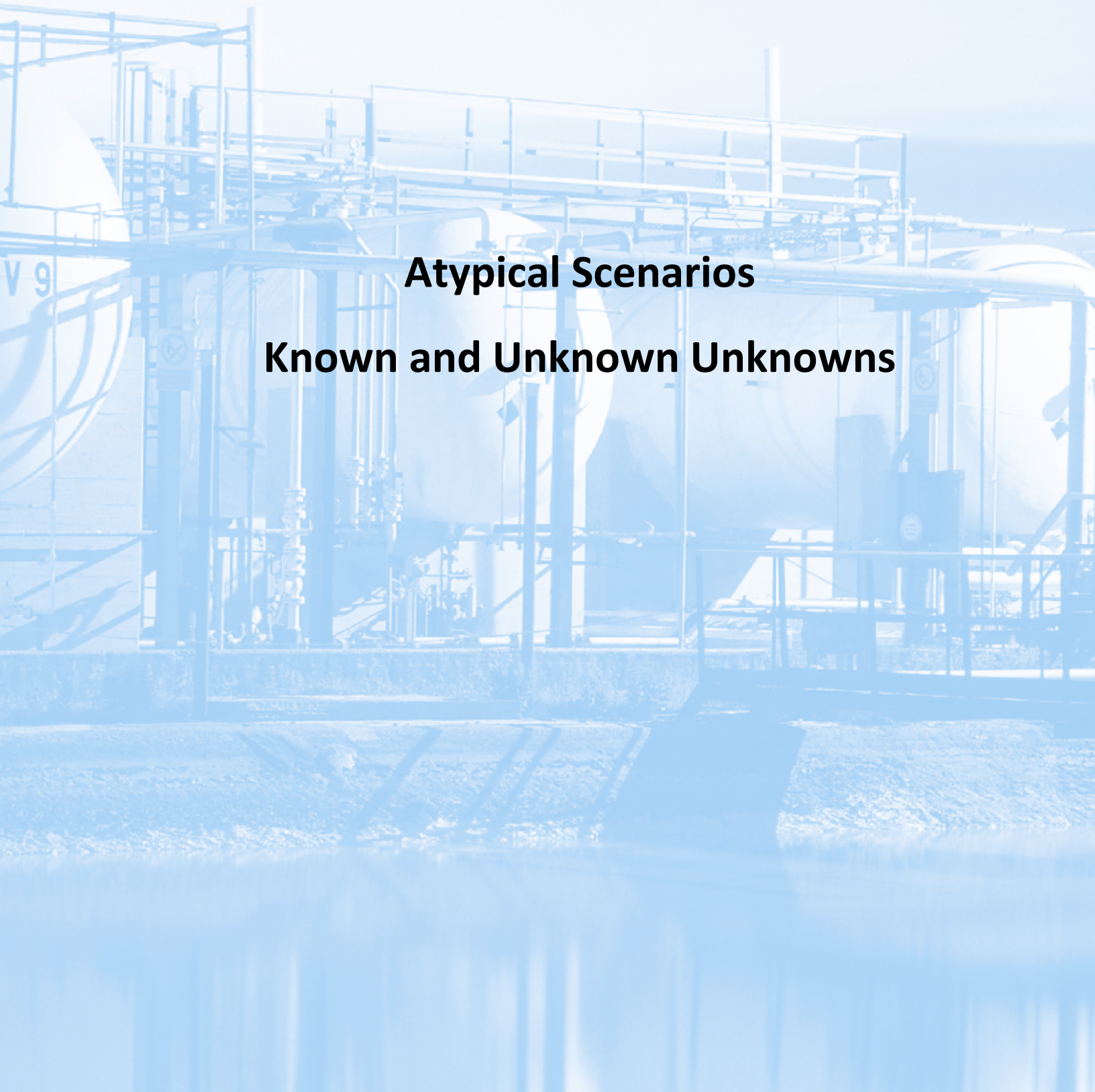

Atypical Scenarios

Known and Unknown Unknowns

EPSC Technical Steering Committee Working Group Report

Atypical Scenarios – Known and Unknown Unknowns

Final Report

Prepared by the European Process Safety Centre

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The European Process Safety Centre

Objectives

1. **Information**
   To provide advice on how to access safety information and whom to consult, what process safety databases exist and what information on current acceptable practices is available.

2. **Research and Development**
   To collect European research and development (R&D) needs and activities in the safety and loss prevention field, to inform members accordingly, to act as a catalyst in stimulating the required R&D and to provide independent advice to funding agencies priorities. "R&D" here includes experimental research and the development and review of models, techniques and software.

3. **Legislation and Regulations**
   To provide technical and scientific background information in connection with European safety legislation and regulations, e.g. to legislative bodies and competent authorities.

4. **Know How Exchange**
   To provide a platform for development of process safety knowledge for its members and to act as a focal point for dissemination of that knowledge to the European process safety community. Involvement in the Centre's groups gives organisations and individuals the opportunity to meet safety professionals from other companies, to discuss areas of common interest and to share knowledge and experience, thus enabling informed comparisons of safety management systems and practice.

Benefits of Membership

- Improved cross-European co-ordination on safety standards
- Identification of areas where manuals and guidelines could be produced
- Improved co-ordination of safety R&D and handling of complex technical research programmes
- Stimulation of R&D in areas where there are gaps in knowledge
- Transfer of knowledge from elsewhere to Europe and between European countries
- Technical input to legislators and standard makers to ensure more realistic legislation
- Sharing and dissemination of information on safety technology and accident prevention
- Access to information from a single source

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Contents

1 Atypical Scenarios – Known and Unknown Unknowns

The Chemical and Process Industries continue to have major accidents. While these might be infrequent, they produce large effects on the facility employees, the community, the environment and the economic viability of chemicals production and use. Furthermore they are a stain on our industry's reputation and perceived value to society.

Our risk management processes aim to identify potential hazardous events, analyse them and eliminate where possible and provide sufficient control and protection for risks which remain. These processes have served us well when the possible scenarios have been identified although 'worst cases' sometimes present special challenges. What remains to be accomplished is the identification of all possible scenarios. Major Accident examples such as Texas City and Buncefield show us that we either did not identify and anticipate the events which actually occurred or we assumed that they were so unlikely as to be of an acceptable likelihood or even, not worth comprehensive study.

How can we improve our ability to find and deal with these 'atypical' (ref a) scenarios? Our hazard identification methods such as Hazard and Operability and 'What if' studies are effective when sufficient creativity is able to identify what we can call 'atypical' scenarios. The other tools such as Fault Tree Analysis, Layer of Protection Analysis 'Risk Graph' and Quantitative Risk Assessment can then address a complete set of scenarios to help us manage risk comprehensively. In the United States, various observers have described these scenarios as 'Black Swan' events, based on the fact that black swans were thought not to exist until the species was found in New Zealand to everyone's surprise.

The European Process Safety Centre (EPSC) has a working group which has sought to find best practices which offer an improvement in scenario development which addresses these missing 'atypical' scenarios. The results of the work are encouraging and offer a way ahead. The work builds on strengthening and enhancing the tools we already use by adding dimensions which appear to have been missed in the past. This report describes practical steps which when properly applied will close some of the gaps in our process risk management systems.

If we categorise events into:

- 'known knowns' - Events which we know about and can plan to prevent or control

- ‘known unknowns’ – Events which we can predict even if they have not occurred yet
- ‘unknown knowns’ - Events which have occurred but we have failed to remember and study (e.g. loss of corporate memory)
- ‘unknown unknowns’ - Events which we have so far failed to predict or have been dismissed as unrealistic

We might see how our Hazard Identification and management processes can be used for each.

The EPSC group is well aware and has concerns that Major Accidents have occurred in the last few decades. The number of reported Process Safety Incidents has declined in most years since 1995 according to the statistics collected by the American Chemistry Council (fig 1). This concern has led to the establishment of an EPSC Work Group studying the subject of Process Safety Incident Metrics and ultimately to the Work Group authoring this report.

The ACC Responsible Care® Process Safety code reporting data is shown:

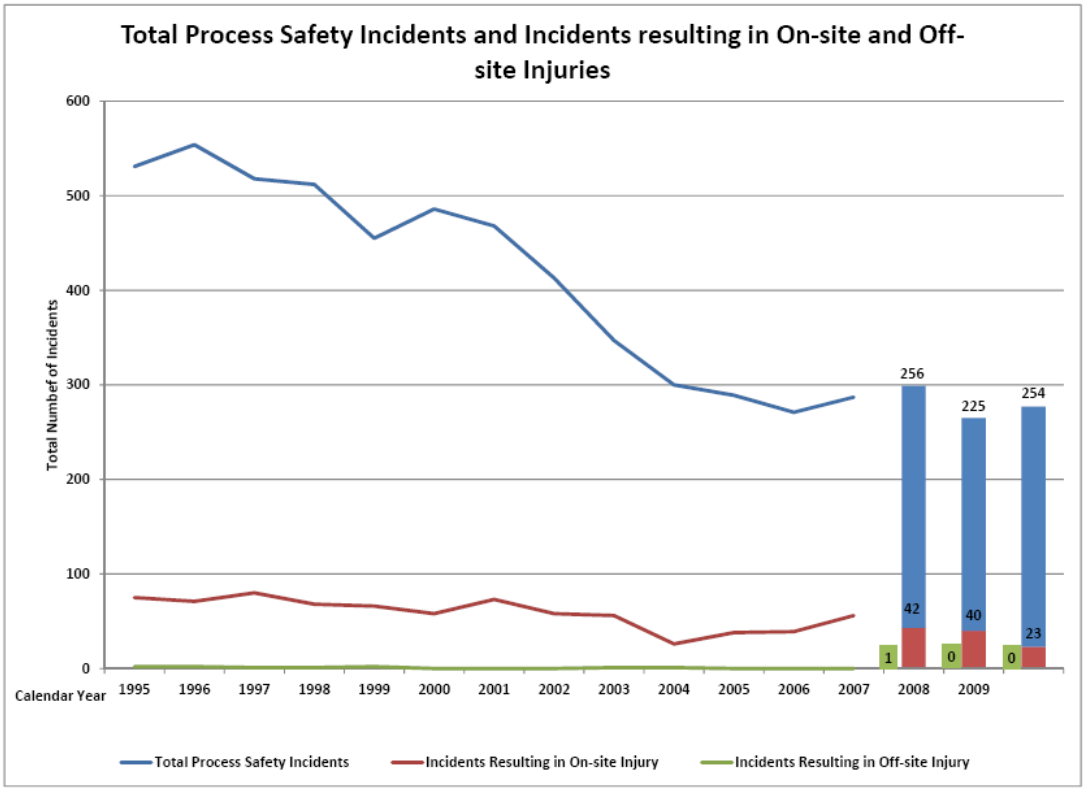

Fig 1

The data reported is of limited value because it does not reflect the true severity of incidents. It is noted that to qualify within the system which operated until 2006, the incident needs to be caused by a process deviation and involve a discharge of 10000lb or more of a flammable material or a reportable quantity of material based on OSHA requirements or an injury or a fire or an explosion.

The companies contributing results to this system also provided information on Occupational Safety performance. Typically, these were Lost Time Incidents and Days Away from Work cases. Again, real severity seems to be difficult to assess from the reporting system.

So the question might be – if we have a decreasing number of incidents, can we be sure that the severity or scale of the events which do occur is also decreasing?

Developments in the Process Safety Metrics field have now moved the system to assign severity to the incidents reported on a scale of 1 (most severe) to 4 (least severe) with appropriate definitions and thresholds.

The expected results of this initiative include an improved means of directing control efforts towards the more severe incidents and the development of Key Performance Indicators (KPIs) whose aim would be to identify the precursors of major accidents. An example of this is Loss of Primary Containment reporting, investigation and reduction programmes. Furthermore, there are opportunities to improve the processes of scenario identification. Of particular interest are the large scale events which are the concern of the question about a reducing total number of incidents being true for major accidents.

The evidence for the frequency rate of major accidents is somewhat ‘sketchy’ because they are quite rare.

Reference to the European Commission’s Major Accident Reporting System (MARS) database shows that the rate is fairly constant. The quality and reliability of the data in this database is not sufficient to draw absolute conclusions but when combined with the ACC data and nationally reported incidents the conclusion can be drawn that reduction of major accidents has not occurred at the same rate as all accidents. The ACC reported seems to indicate a performance rate ‘plateau’ or negative trend from 2005.

Major landmarks in the industry from 1984 onwards include

- Bhopal
- Phillips Petroleum Pasadena
- BP Texas City
- Buncefield

And in a related industry:

- Fukushima 2011

all of which have been extensively investigated and reported. (see references a,b,c) These provide learning experiences which relate to worst case scenarios and human factors. Industry responded by making changes to their Process Safety Management systems and in the case of Phillips Petroleum and Buncefield there have been changes in law and regulator requirements.

These issues are of interest to the EPSC 'Scenarios' group. In each of these cases, the severity of possible accidents and the involvement of human errors were not predicted. In the latter case, it is acknowledged that most accidents are the result of human error.

Can we be sure that our risk assessment and management processes properly identify:

- All worst case scenarios?
- Potential for human error to provoke a worst case scenario?
- Initiators or conditions which can 'defeat' all protection barriers?

and can we be sure that we study these and do not discard them on the basis that they are very unlikely?

(note that for the purpose of this report, Hazard Identification is assumed to be part of the management of risk, but not a complete risk management process)

The work of the group attempts to build on existing successful hazard and risk management techniques such as:

2 HAZARD Identification

2.1 Process Hazard Analysis (PHA)

which is driven by potential accident listing and some severity estimation based on 'credible scenarios' and on identifying worst case scenarios where the consequence severity is often decided by total loss of containment as a result of process containment catastrophic rupture.

2.2 Hazard and Operability Study (HAZOP)

which aims to find all hazardous deviations from normal process operations. The outcomes allow the identification of safeguards and recommendations for risk reduction

or further study. HAZOP has been proved over the years as a very good method. However, its effectiveness is not always fully exploited. Examples of this include the focus of studies in the steady state (not including start up and shut down modes) and missing some potential deviations such as corrosion. In this last case, severe corrosion can lead to immediate and catastrophic loss of containment which bypasses all safety barriers.

2.3 Failure Mode and Effect Analysis (FMEA)

which examines each unit operation and equipment unit to define its failure modes (types) and the consequences of its failure.

2.4 Structured 'What if'

A structured brainstorming for unit operations which suggests a more 'creative' approach where some deviations not found by other methods might be discovered.

In most of the methods we describe with possible exception of some PHAs, the practice is to start with a 'deviation' from a well described normal state of operation for a section of the process or an item of equipment. The causes and consequences are then derived by the study team. They arrive at a decision on tolerability of the final consequence which may be determined by company policy or by some form of frequency estimate compared with legal or corporate criteria. As stated earlier, this results in a moderately successful method. The questions remain:

- is this approach optimal for on 'atypical' scenarios?
- would a 'reverse' approach yield different results? (Starting with pre-defined scenarios and working backwards through e.g. the 'bow tie' – see following section)

There is merit in this 'reverse' approach which has effectively been incorporated into some member companies' requirements. This is illustrated that at least one company has specified that for given unit operations such as a distillation column, the worst events which have occurred in the industry must be incorporated in the study, however unlikely their occurrence might be.

3 RISK ANALYSIS (following Hazard Identification)

'Bow Tie' analysis (see fig 2)

In accident research, especially in the high-risk area, fault tree analysis and event analysis are among the methods used to analyse the causes and consequences of accidents. One analytical method that combines these analysis forms is called the 'bowtie' because of its shape (Worm 2008). If this analytical method is used to model the term 'failure', a bow-tie analysis of failure will look like this:

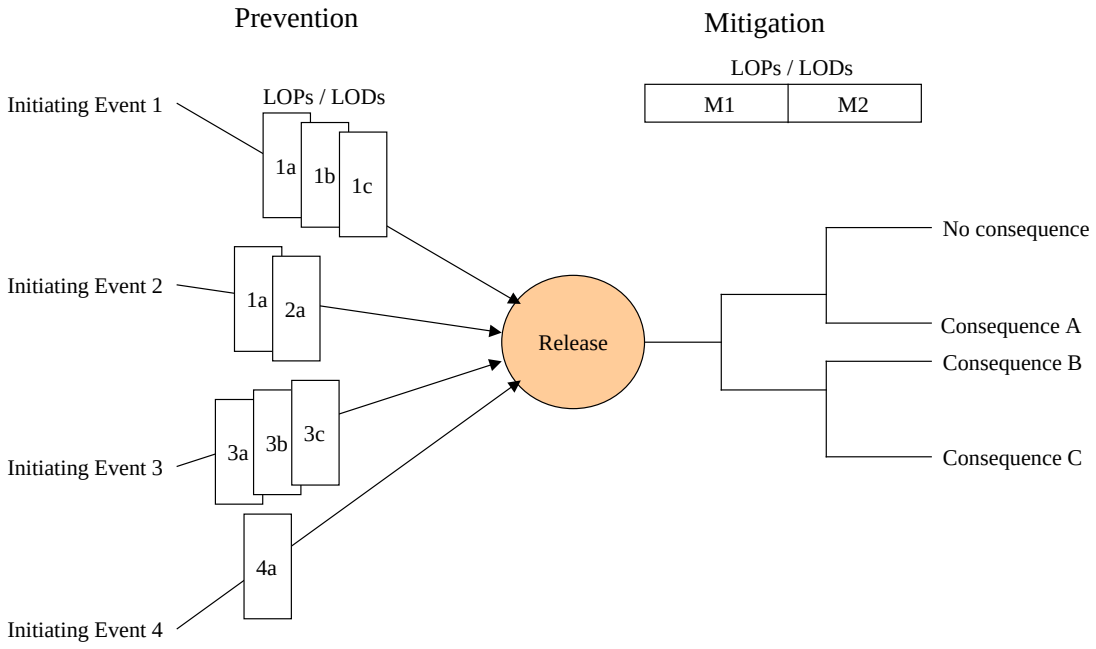

Fig. 2

LOP = Layer of Protection or Safety Barrier
LOD = Layer of Detection

This approach models the various ways which e.g. Release Loss of Containment can occur and the effect of the Protection, Detection and Mitigation measures can be visualised graphically.

Risk Graph (see fig. 3):

This is well described in the International Electrotechnical Commission Standard IEC 61511:

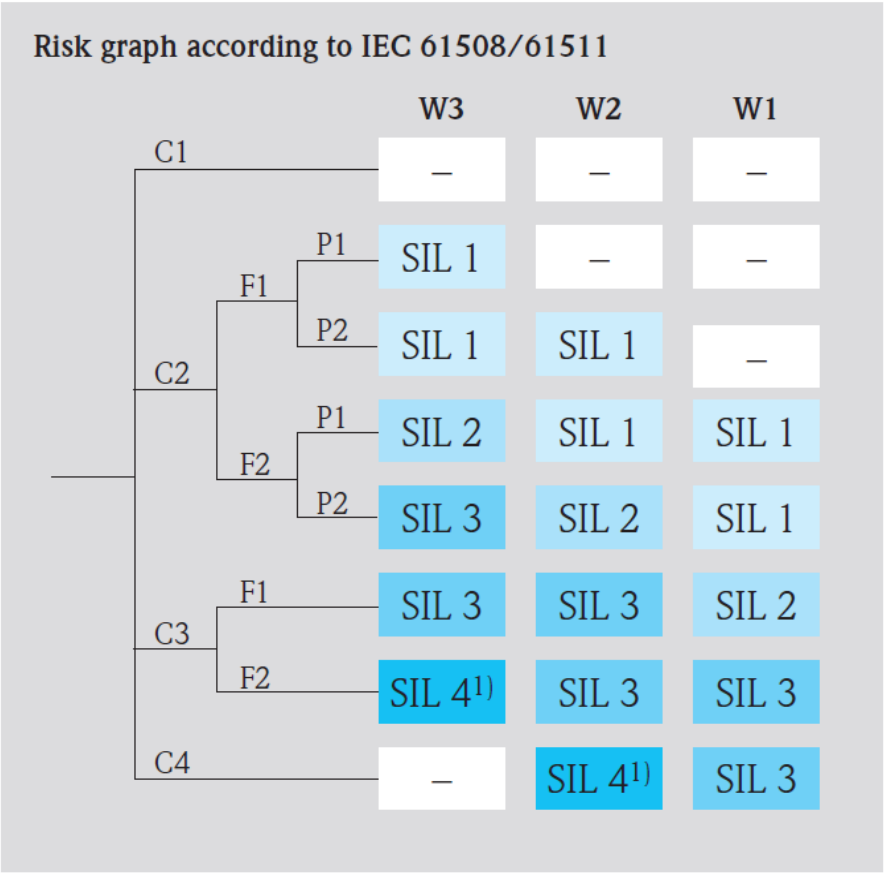

Fig 3

3.1 Fault Tree Analysis

Fault-tree analysis focuses on one particular accident or main system failure (top event), and provides a method for determining causes of that event. The fault tree is a graphical model that displays the various combinations of equipment failures (minimal cut sets), dependent failures and human failures that can result in the top event of interest. Boolean logic rules are used to determine the minimal cut sets. Quantification of the minimal cut sets is possible by various means, e.g. direct estimation of the basic event probability, kinetic theory, Markov processes or Monte Carlo simulation. The construction of a fault tree is carried out by means of standard symbols such as 'and gates', 'or gates' and 'basic events'. A very large and complicated fault-tree can be analysed by a dedicated computer program, which in practice is seldom necessary.

3.2 Layer of Protection Analysis:

This method is based on the identification of potential accident scenarios. A particular scenario will only take place if certain undesired initiating events (e.g. overpressure, operator failure) occur and if layers of protection (independent protection layers (IPL)) fail or are absent. In LOPA, the following types of IPLs are defined:

- process design
- basic process control system (BPCS)
- critical alarms and human interventions
- safety instrumented functions (SIF)
- safety instrumented systems (SIS) or emergency shutdown (ESD)
- physical protection (relief devices)
- post-release physical protection (walls, dikes)
- plant emergency response
- community emergency response
- loss of containment (corrosion)

4 Human Factors/Reliability Analysis

In all these cases there is at least an informal inclusion of human factors as initiating events or deviations. Regulators in Europe have increasingly focused on this, possibly because the most recent major accidents were strongly influenced by human error at various levels in the organisations where the accident occurred.

The UKHSE has identified more than 70 different Human Reliability Analysis methods of which 32 are applicable to Major Hazards. See appendix 2. The choice of method and the development of the necessary skill sets have made progress rather slow.

4.1 Effectiveness of study methods

In every case, the principles of study are clear, but simply saying that a form of study has been adopted does not guarantee quality or comprehensiveness. For example, many studies concentrate on normal operation, steady state and may not cover start up and shutdown stages sufficiently well.

For example: 'We did a HAZOP - that should be enough!'. This statement should be qualified in the sense that it should be able to reveal:

- What was studied? (scope)
- Covered phases of operation from start up through steady state to shutdown
- Loss of utilities (power, cooling etc.)
- Loss of containment (external or internal corrosion, impact by vehicle, ..)
- The roles and competence of the team which did the study?
- What we did with the result
- Were there any unresolved issues which needed to be solved outside the study?
- Sensitivity and Uncertainty issues

    - Sensitivity = significant effect on risk level if a system e.g. a safeguard fails to function on demand,
    - Uncertainty = Where in the study could there be a major effect on risk level if the study input information used is wrong? e.g. assumed failure frequency for a cause or scale of consequence.

These questions really apply to any method used

Additionally, all the methods in current use suffer from the potential to miss scenarios which deserve study. This could be characterised as:

'Our risk management does a good job if we address the scenarios found in the hazard identification stage, but can be powerless to manage those scenarios which we do not.'

This seems to be an important source of uncertainty in risk analysis and management.

In some cases the worst case consequences are not revealed, or if they do appear they are 'consigned' to be dealt with by the Emergency Plan. This means that 'mitigation' of the severity of the event dominates the risk management. This approach works reasonably well with events such as toxic releases and fires where detection, responses such as 'shelter in place' or use of personal protective equipment may be employed. It seems likely that for explosions, mitigation is more difficult since the quantities of hazardous materials released do not need to be great, the range of effect can be very large and the time between the loss of containment and an explosion can be very short, making effective response after release and possibly, detection quite difficult.

If the Texas City tragedy is taken as an example, can we be sure that the HAZOP deviation for high level in the isomerisation tower would be deemed capable of causing a large scale overflow in the next 'node', the atmospheric blow down stack?

and:

If the emission of large quantities of hot flammable liquid and vapour from the atmospheric blow down stack could be predicted, would potential causes and adequacy of protection have been questioned?

It is interesting to note that the Environmental Protection Agency's Risk Management Plan (EPA RMP) requires that the worst case scenarios studied must include Vapour Cloud Explosion effects (even for materials with relatively high flashpoints and boiling points). This fact raises the question about the adequacy of risk study at Texas City and the ability of the regulators to ensure that the rules are enforced properly. It is quite clear that application of the RMP worst case scenario model (RMP comp) predicts overpressures at the Texas City Isomerisation Unit Contractor trailer park far in excess of the ability of the trailers to survive or protect the occupants.

These observations seem to confirm the suggestion that there are opportunities to study worst case scenarios in greater depth. Once such scenarios are seriously considered, the area where greater study could be most helpful is in the categories of causes and protective barrier failures. This corresponds very well with the Left hand side of the 'bow tie' where initiating events such as control system failure or human error start a train of events and protective barriers aim toe prevent the event at the centre of the 'bow tie' from occurring. The same comments can be made about fault tree or event tree analysis.

5 Legislative Requirements

5.1 Europe

The Safety Report requirements of the 'Seveso' Directive require that for establishments meeting the 'upper tier' criteria, worst case scenarios are to be included in the Process Safety Management system. It remains the choice of the individual E.U. member states' Competent Authorities to take this further in defining what this means. It is no surprise that different states have different criteria.

If Worst Case scenarios appear in a Safety Report, their causes include for example – Catastrophic failure of or major releases from Pressure Vessels caused by:

- Residual failures
- Process deviations leading to overpressure or brittle fracture
- Improper vessel isolation
- Loss of containment (external or internal corrosion, impact by vehicle, ..)

Type or phenomena of consequence for the releases are not necessarily specified within the rules although there seems to be a process of 'screening in' possibilities rather than 'screening out' from a comprehensive list. In the latter case it would seem that when a phenomenon was screened out there would need to be a technically sound justification. This approach has merits.

5.2 Other relevant legislative environments

U.S. E.P.A. 40 CFR 68.130:

Facilities covered by this law are required to identify and manage Worst Case and Alternative Scenarios involving the release of hazardous materials which have a quantity greater than specified amounts.

If the United States Environmental Protection Agency Risk Management Plan principles are followed, it seems implicit that:

- Worst Case scenarios must be identified (specific definitions provided e.g. loss of containment of total largest isolated quantity of material in 10 minutes)
  - **Toxic releases**
  - **Flammable releases**
- The Consequences of these scenarios need to be described
- Alternative Scenario – a more likely event of a lower consequence potential

Requires comprehensive study from possible causes and failures to full consequences

In all cases the 'source terms' are defined (e.g. Worst Case - Catastrophic Loss of containment – over a 10 minute period - of the largest isolated quantity of hazardous material)

In the case of toxic releases, the concentration 'Emergency Response Planning Guideline' (ERPG) 2 is used as the 'endpoint'.

In the case of flammable material releases, the hazardous phenomena:

- FIRE and
- Vapour Cloud Explosion must be included

In the case of release of flammable material, it is interesting to note that the Vapour cloud Explosion requirement is not dependent on the physical properties of vapour pressure, boiling point. It simply works on the basis of flashpoint.

Dispersion conditions such as weather type and wind speed is specified along with suggested dispersion models.

There follows an example from the RMP Worst Case Scenario consequence evaluation for the release of pentane (similar properties to gasoline) at a rate of 600 MT/hr for 10 minutes (proxy for Buncefield). This results in a 70 mBar overpressure at a distance of 300 metres. It is realised that the actual event in December 2005 was much worse than this because of a number of factors such as quantity of release, the size of the vapour cloud. (The release took place over 40 minutes, producing a vapour cloud of 250,000 M^3, in physical circumstances and weather conditions which promoted vapour formation). Even a VCE with the range predicted in the RMP program for the smaller Alternative Scenario would probably have led to an examination of the degree of overfill protection on the storage tanks for the operations at Buncefield.

6 Buncefield

The concept of 'screening out' the possibility of a Vapour Cloud Explosion at Buncefield would have had to pass through the reality check: "Are there any previous events where gasoline releases have resulted in explosions"? A brief check would reveal that there are cases from history and there have been several since 2005. If the Hazard I.D. described in the DYpasi method (Paltroniemi) was used, the VCE case would be studied. It is reported that there were 7 VCEs following large gasoline tank losses of containment in recent history:

- Houston (Texas) 1962
- Baytown (Texas) 1977
- Newark (New Jersey) 1983
- Naples (Italy) 1985
- St Herblain (France) 1991
- Jacksonville (Florida) 1993
- Laem Chabang (Thailand) 1999
- Puerto Rico, 2009
- Sitapura, Jaipur (India), 2009

So it is difficult to claim that an explosion was an 'unknown unknown'

7 Texas City

The accident at Texas City occurred in a facility that was covered by the E.P.A. statute. The submission of scenarios would have presumably included the release of hot hydrocarbons from the distillation train. Using the simple approach in the E.P.A. statute, the release estimated by the Chemical Safety Board at 59000 lbs would have generated

a 70 mBar overpressure distance of 500 metres and a much higher pressures at shorter ranges. Since most of the persons killed were in trailers which would be destroyed by much smaller overpressures and closer than the 500 metre distance. A smaller quantity of 2000kg would still have caused the >70mBar overpressure at the trailer park.

Considering these 2 examples, it looks as if the E.P.A. statute would require the identification of the consequences of vapour cloud explosions. In the case of Buncefield Vapour Cloud explosion was probably specified if required and in the case of Texas City it should have definitely been considered. Examination of the reporting from the C.S.B. reveals that in addition to the failures of the operators of the facility, the regulatory authorities failed to regulate. This is surprising, considering that there were more than 80 hydrocarbons leaks from this plant in the previous 2 years.

8 Fukushima

To our group it might seem as stretching our remit to examine this, but there are some interesting observations to be made:

Fukushima – was it an unknown unknown?

- The Indian Ocean Tsunami (Dec 26 2004) produced waves up to 15 Metres high
- There are early warning systems
- Japan's methodology for assessing tsunami risks was behind international standards
- Studies in the early 2000s had indicated that the hazards of Tsunamis had been underestimated and recommendations were not followed up by TEPCO
- Fukushima protection was designed for a 1960s tsunami close to the Chilean coast (3.1 metres). Later TEPCO increased the protection for an event of 5.7 metres
- IAEA recommended Best Practice is to take account of and allow for the scale of a possible tsunami event occurring once in 10,000 years
- Historical documents indicated that since 1498 there have been 12 tsunamis with amplitude of more than 10 metres and 6 which were more than 20 metres – this means that there could have been 6 events in 500 years which would have overwhelmed all the control and protection systems at Fukushima
- A simplified cost/benefit analysis for reducing the frequency of catastrophe from 1 per 1000 years to 1 per 100,000 years would indicate that added protection would be very cost effective

So the major accident was not in the category of 'unknown unknown' and is clearly amenable to preventative measures.

9 EPSC member inputs

Some of the identified outcomes of discussions in the group:

- Process Hazard Analysis (PHA) is where identifying scenarios should start (don't rely completely on HAZOP)

- HAZOP remains a preferred best practice
  - Some companies have specified required approaches which promote consistency of outcome and ensure that all required deviations are 'prompted' from a pre-installed list and some consequences are recommended from a simple database

- FMEA is also widely used and has proved to give somewhat different results to HAZOP - a comparison is available from the following link: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.100.2634&rep=rep1&type=pdf

- Composition of and Competence of teams is crucial (PHA and HAZOP)

- HAZOP may be dominated by 'steady state' and start up is not always studied

- This seems to be an issue on continuous processes

- There is a formal requirement for learning from accidents to be included in PHA

- Some companies have certain worst case scenarios MANDATED by corporate decision. These are informed by history in a formal way which is a strong approach since Effectively, these MUST be studied. e.g. Dupont. Approaches

- Repeat reviews are normal. Triggered by
  - Time (in some cases by review and in some cases by a complete rework of study after a specified interval (BASF))
  - Major events in the industry (sometimes prompted by the company itself and sometimes by regulatory bodies)
  - Time
  - Major events

- Worst case (where identified) scenarios are not simply consigned completely to the Emergency Response plan. Several companies mandate worst case scenarios. Included are world events which have or have not happened in the industry sector

- The Bow Tie model offers a real assistance in modeling events

- There is definitely much scope for assisting PHA, HAZOP or LOPA teams by providing
  - Preselected scenarios
  - Software for scenario selection and prioritization based on material properties, quantities, operating conditions etc. This gives good scope for mandating scenarios which must be studied and protection provided. (Dow)

10 Conclusions

The EPSC 'Scenarios' group all have a formal approach to Hazard Identification in their:

- Project Management
- Normal Operations
- Management of Change

The Hazard Identification method of choice is usually built into the Process Hazard Analysis and HAZOP methodologies although member practices are not identical. Where HAZOP is concerned, all members carry out studies in the steady state, but HAZOP is not always conducted for start up and shut down phases. These critical phases are not overlooked but are covered by detailed instructions which include potential hazards and their consequences. The predominant cases in these studies are 'credible' and 'from learning experiences' and rely very much on the discipline and creativity of a properly constituted and competent team.

Whilst efforts are made to study worst cases may occur in HAZOP, events seem to show that we are not always successful. Indeed, even when a worst case scenario is considered, HAZOP may not be the best method to study it. If this is true, the 'bow tie' has potential to become the method of choice.

What comes out of this and a review of company practices could be an approach which says:

We need to gain consistency from our Hazard Identification practices:

- address steady state comprehensively (e.g. HAZOP or FMEA or 'What if')
- ensure that complementary start up and shut down studies are included in Hazard Identification (and study)

And there is much to be gained from:

- critical task analysis and
- human error analysis
- more reliably learning from incidents which have occurred in the past. This is an often quoted 'mantra' but it still seems an area where we industry can do better. The Buncefield case (where VCEs were not accounted for but history tells us that they should have been) is an indicator that there are fewer real 'unknown unknowns' than has been assumed in the past

in predicting atypical events and managing them better.

10.1 When Hazards are identified

We have means of managing risks which fall into the categories:

- ‘known known’ (e.g. by requirements and standards)
- ‘known unknown’ , (e.g. by predictive risk assessment methods)
- ‘unknown knowns’ (by applying knowledge from previous incidents better)

And minimising the residual ‘unknown unknowns’ in terms of numbers of incidents, effect severity and frequency. By the use of a creative approach to imagine the ‘unknown unknowns’ which can be studied with ‘bow tie’ analysis and other methods described in this report.

10.2 Worst Case Scenarios

Where a Worst Case scenario is identified within an established hazard identification system, or by creative imagination, it seems prudent to make sure that such a scenario is studied in depth to see what might cause it. Simply consigning it to an emergency response plan is not enough. Added or more efficient protection against such scenarios is likely to be cheaper than sometimes thought and would be positively indicated by simple cost/benefit analysis.

10.3 Finally

The practices of EPSC member companies show an appreciation of the challenges and a willingness to continually improve performance. Discussions at Technical Steering Committee meetings clearly indicate that even the best performing companies recognise that there is a healthy sense of vulnerability remaining in the area of scenario identification and subsequent risk management.

11 References

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Procedure: Application to LNG
Nicola Paltrinieri*, Alessandro Tugnoli, Sarah Bonvicini, Valerio Cozzani
Università di Bologna, Dipartimento di Ingegneria Chimica, Mineraria e delle Tecnologie Ambientali

b) Accident Epidemiology and the U.S. Chemical Industry
Accident History and Worst Case Data from RPM-info

c) Carnegie Endowment for International Peace just released a paper by James C. Acton and Mark Hibbs titled "Why Fukushima Was Preventable".