# Institutional support of learning from accidents: some obstacles to getting a useful community-wide database in the EU

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# INSTITUTIONAL SUPPORT OF LEARNING FROM ACCIDENTS: SOME OBSTACLES TO GETTING A USEFUL COMMUNITY-WIDE DATABASE IN THE EU.

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## ABSTRACT

Learning from other people's accidents and misfortune is not a novel accident prevention strategy. The benefits of such learning are obvious. What is not so obvious, however, is how to provide institutional support and how to set up systems that facilitate such learning.

We examine the European Union's Major Accident Reporting System (MARS), which is created in conjunction with the EU regulatory instruments to prevent major industrial accidents, the Seveso-directive. We review some of the general requirements that a successful reporting system must meet and suggest that MARS may not live up to the noble intentions behind its creation.

Our case example is a simple methanol tank storage installation which we believe can be found in most if not all EU member states. We demonstrate that the data in some of the Short Reports in MARS have a number of serious shortcomings. Causes are not identified and lessons learned are left blank. We argue that there are substantial opportunities foregone in the EU system that provides institutional support to learning from past experience.

Over the course of 22 years the EU database has only accumulated about 600 Short Reports for all its member states. We consider it unlikely that this number represents all "major accidents" according to a common sense definition of this concept for such a large territory. We speculate if legal scope limitations may be counter productive and perhaps

even self-defeating for the Seveso legislation's stated objective of accident prevention through information sharing.

We compare MARS with a commercially available accident database. While the two reporting systems suffer from the same fundamental shortcomings the commercial system is marginally superior to MARS. We conclude by emphasising that the value of accident reporting schemes is not only determined by the quality of the data they contain but that institutional support appears to be crucial to sheer survivability.

## INTRODUCTION

### Preface

In this paper we examine man's perhaps oldest accident prevention strategy: learning from past mistakes. In its modern form the key characteristics of this strategy are that past mishaps shall be recorded and analysed to extract lessons learned which in turn shall be disseminated through broad feedback loops in order to prevent future *similar*, and not just identical, accidents.

### Evolutionary learning

Man has learned from his mistakes from ages past. Petroski (1992, 1994, 2006) has identified this type of learning as a type of quasi-Darwinian *evolutionary learning* and has shown this to be of major importance in the history of development of structural engineering. He identifies evolutionary learning in the construction of the Pyramids some 4,000 years ago, in the evolution of steel truss bridges in the late 1800s and suspension bridges in the 1900s. In each case hubris and complacency push successful principles of construction to the limits of failure which in turn spurs the development of improved designs.

A failure therefore provides invaluable insights that cannot be obtained from other means. Indeed, the history of structural engineering is better understood from its spectacular failures than from its spectacular successes. For a failed structure provides a counter example to a hypothesis and shows incontrovertibly *what cannot be done*, while a structure that stands without incident often conceals whatever lesson or caveats it might hold for the next generation. We can learn more from one structure that failed than from a thousand structures that stand. Success may be grand, but disappointment can often teach us more.

There is a parallel here to the philosopher of science, Karl Popper (2002/1959), who argued that falsifiability – and not verifiability – is the hallmark of science. Thus, a theory is scientific only if it is in principle capable of being falsified or refuted; in contrast, a scientific theory can never be shown to be true, Popper argued. Therefore, *refutations* are crucial to scientific progress: a refutation is a single instance (an observation or experiment) that counts against a theory. Similarly, it may be suggested, a design is, in this sense, like a theory: the design "states" that for all intended use conditions it will remain sufficiently robust. A design failure is a refutation: we have observed a situation, which is within the intended use conditions, where the design has failed. Here we refer explicitly to the deliberately vague notion of "intended use conditions". Of course, it is easy to imagine conditions of use that would cause the design to break or fail but which are outside the scope of intended use conditions. Conditions will vary and for a given design perhaps most conditions are clement and do not challenge its robustness. However, the most important lessons come from refutations, demonstrations or real-world episodes that show the weaknesses of a design.

The good news of evolutionary learning is that failures should be valued as unique learning opportunities. The bad news is the cost associated with failure. Evidently, it makes good sense to share the lessons learned from unwanted outcomes in order to minimize the number of times the same lessons have to be learned. This straightforward thinking is reflected in common in common sayings such as Santanyana's : "Those who cannot remember the past are condemned to repeat it".

**Institutional support to reduce the cost of evolutionary learning**

Perhaps because the aim is so self-evidently rational and noble, much effort has been directed towards promoting the exchange of lessons learned.

The ability and willingness to learn from incidents and accidents are not uniformly the same across sectors and cultures. Thus, civil aviation has been a leader in this area ever since non-punitive incident reporting schemes were set up some 30 years ago (Orlady & Orlady, 1999) Moreover, a number of international and national organisations make freely available safety related research, including analyses of accidents and trends. For instance, the Flight Safety Foundation (FSF), which is an "independent, nonprofit, international organization engaged in research, auditing, education, advocacy and publishing to improve aviation safety" (www.flightsafety.org). Among FSF serial publications is the widely known Flight Safety Digest appearing in 10 issues annually. Eurocontrol (the European body for coordinating air traffic control) is another trans-national body which is funding, inter alia, research and studies related to safety.

More recently, serious efforts have been directed at including not only unwanted events, i.e. accidents, but also precursors to unwanted events; precursors which resulted in no harm but under slightly different circumstances could have done so. See for instance NRC (2004).]

Within major industrial accident prevention several initiatives exist. The Loss Prevention Bulletin published by the UK Institution of Chemical Engineers (IChemE) stands out as a particularly bright beacon with its persistent dedication to the ideals of information sharing. The contributions of Trevor Kletz from the same institution are also difficult not to mention (1988, 1990, 1993). The title of a recent book "*Still going wrong*" (Kletz 2003), however, is indicative that serious barriers to learning from experience exist in practical life. See also Kletz (2004)

In addition, several initiative and databases exist in many countries to support this type of learning (Kirchsteiger 1999a). Probably every large multinational petrochemical or chemical company has a proprietary information system where unwanted events are registered and analysed to prevent recurrence. A few large companies have donated their incident registrations to the IChemE which, after being anonymised, are included in the commercially available “The Accident Database” (TAD). (Smith 2006, personal communication). Besides these commercial initiatives, government funded initiatives exist. Of specific importance to this paper is the EU funded database, MARS.

## The EU MARS accident database

One of the requirements of the European Union’s Council Directive 96/82/EC (“Seveso II”) is that the authorities in the Member States report all major accidents involving dangerous substances and falling under the provisions of the Directive to the European Commission. The objective is to use this information as a basis from which to draw lessons-learned for preventing major accidents and mitigating their consequences. For this purpose, the Commission has set up in 1984 an industrial accident notification scheme, the Major Accident Reporting System (MARS), operated and maintained by the Major Accident Hazards Bureau (MAHB) of the Commission’s Joint Research Centre in Ispra (Italy). In addition to supporting the purposes of reporting under the EU Seveso Directive, the MARS tool is used by OECD members countries and UN/ECE signatories to report industrial accidents under the OECD Chemical Accidents Programme and the UN-ECE Convention on the Transboundary Effects of Industrial Accidents, respectively.

Obviously, the MARS scheme depends entirely on member countries to actually deliver useful input.

MARS is dedicated to collect data in a consistent way, to analyse and statistically process them, and to create subsets of all non-confidential accidents data and analysis results for export to all Member States. In its new version 4.0, MARS represents a modern information exchange and analysis tool. It can serve both as data logging systems and, on different levels of complexity, as data analysis tools. (Kirchsteiger 2001a, 2001b)

The contribution of the MARS system to accident prevention has been recognized in several papers (Rasmussen 1996, Kirchsteiger et al. 1999). The information in the MARS system has been subject to complex data analysis to identify trends, precursor information, and the contribution of human error, amongst others, using descriptive and Bayesian statistical methods. (Kirchsteiger 1997, 1999). There are recommendations also to report near-miss incidents to MARS on a voluntary basis (Jones et al. 1999). As a crude measure of the level of academic interest in MARS we searched Google Scholar for “Major Accident Reporting System” in mid-August 2006. The search returned 110 scientific citations.

In the following we will take up a specific example to illustrate some of the problems in using the MARS database in industrial accident prevention.

## The case example – bulk methanol storage

The case installation is very simple, the bulk storage of methanol in a fixed roof tank. We consider it likely that similar, if not identical installations exist in all EU member states. Consequently we regard it a prime candidate for evolutionary learning supported by information sharing –any lessons learned in one member state are likely to be relevant to other member states.

Our case draws on practical experience of the first author with risk analysis of industrial activities. In 1994 a company ("company A") sought permission to store 2,000 m3 (1,580 ton) of methanol in an existing fixed roof tank in the industrial area in a harbour in Denmark. The tank had earlier stored gasoline. Methanol is classified as "toxic" and the planned inventory exceeded the then Seveso I Directive's column 3 limit of 200 ton for toxic substances, placing the installation in the so-called Seveso upper-tier, which requires a safety report to be submitted to the authorities[1]. The county - which in this case was the coordinating Competent Authority (CA) - was inexperienced with this type of installation and sought advice from a risk analysis consultant to review the information in the safety report. Company A had not identified any particular risks in the safety report and had no reason for concern, as it had no knowledge of any prior accidents with bulk methanol storage. The consultant [the present first author] started the review by requesting a search of the MARS database for accidents involving methanol. The search was carried out by JRC staff, who returned anonymised accident information.

A similar sequence of events took place 11 years later, in 2005. Another company ("company B") sought authority permission to store a similar quantity of methanol in a fixed roof tank in a tank farm in the industrial area of another harbour in Denmark. In this case, the CA, not related to the first CA, assessed the safety report submitted by the company without using consultants. The CA found the consequence analysis lacking and specified some leak and fire scenarios for which safety distances should be computed. Company B hired a consultant for this task. The present first author was not involved in this case.

### The uses of information from incidents and accidents

A number of safety analysts have analysed and described the uses and benefits of information derived from incident and accident reports (e.g., Orlady & Orlady 1998, Schaaf 1991, Johnson 2003). Schaaf et al. suggest that knowledge of prior accidents (a) can improve our model, (b) can be used for monitoring; and (c) can be used for motivation. Modifying this framework to some extent, we suggest that accident and incident information serves four overall goals that we may summarise as: Overview, modelling, motivation and alerts

- *Overview* is provided when reports are aggregated, and patterns and trends are identified via descriptive statistics. Analysts and users have to be careful, however, since incident reporting may possibly be biased (for instance, it may not give a true picture of violations)

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[1] According to the then version of the Seveso I directive in force in 1994. In the Seveso II directive, methanol is now listed as a specific substance with column 2 and 3 values of 500 and 5,000 tons respectively. Today (2006) Company A would therefore be a lower-tier installation not required to submit a safety report. (EU, 2003, Annex 1, part 1)

- *Modelling* is about forming a mental model of how causal mechanisms operate - how things can go wrong. This is based on narrative reports or even a single report of an accident or incident that shows operators and analysts how the interplay of actions and events may lead to danger and perhaps calamity. Model insight involves the user cognitively, revealing *how* things may go wrong.
- *Motivation* is gained when a user realizes that *this could happen to me* (or to our unit). Like insight, motivation is typically derived from narrative account of a single case
- *Alerts*, finally, are concrete instructions or reminders that specific devices require specific maintenance or procedural operations. The utility and meaning of such alerts do not depend on a full narrative report or any specific context at all, but they are nearly always prompted by one or several concrete incidents or accidents.

## DATA

### Introduction

The case we are going to describe is based on a concrete risk assessment task performed in 1994. The results of the original 1994 MARS search have been lost but we have been able to retrieve the information again in our 2006 search (database records numbers 113 and 233).

### MARS methanol accident search

Two types of reports are available in the MARS system, Short Reports and Full Reports. A Short Report contains available information on the event known at an early time after the occurrence. The so-called Full Report develops in detail the basic information given in the Short Report. Apart from data quality, the basic acceptance criterion for an accident to be included in MARS is that at least the report profile and the Short Report have been completed. (Kirchsteiger 1997). Short Reports are anonymised.

Only Short Reports can be searched on the MARS website. The Short Reports are indexed according to a comprehensive classification scheme which permits Boolean searches. It is not possible to carry out a free text search across all fields and all reports. The search was therefore carried out specifying “methanol” in the fields “AccTypeDescription” OR “SubstDescription”. The search returned 19 results (June 7, 2006). Because a free text search is not possible, there is a slight possibility that the MARS database could contain other records relevant to methanol accidents, but where the term "methanol" is given in other fields than the two we searched although we consider this unlikely. The majority of Short Reports that were produced by the search concern the use of methanol in chemical synthesis, and only two records ( #113 and #233) are relevant to the bulk storage of methanol. Here we give excerpts of key information for each of these records. Quotes from the reports are verbatim, remarks by present authors are inserted in brackets.

**Short Report #113** concerns an explosion of a methanol tank on June 27, 1994. Only the most basic information is provided in the report.

> Accident Type: During a summer thunder-storm in a storage tank, which was filled with 354,000 kg (354 tonnes) of Methanol, an explosion occurred due to the fall of a lightning stroke (external event).
> Substance(s) Directly Involved: Methanol ca. 8000 kg (8 tonnes).
> Immediate Source(s) of Accident. : During a summer thunder-storm in a storage tank, which was filled with 354,000 kg (354 tonnes) of Methanol, an explosion occurred due to a lightning stroke (external event).
> Suspected Cause(s): Lightning, external event
> Immediate Lessons Learned: [none provided]

Discussion: The description simply states that a methanol tank exploded during a thunder storm. There was no injury to people but the tank and its contents were destroyed. The Lessons Learned field is blank and there is no further mention of causes or accident mechanisms.

**Short Report #233** is, in contrast to #113, rich in information and concerns a series of tank explosions and fires on May 15, 1987.

> Accident Type: [M]ost likely the empty tank No 43 exploded first causing the explosions of tanks No 44 and 45. The explosions of tanks No 44 and 45 were followed by the fire of the contained methanol. [...] Probably the explosion was caused by the ignition of a mixture of residual methanol vapours with air formed during the degassing operations of tank No 43 (it was degassed with air in order to recover nonane).
> Immediate Source(s) of Accident: The accident occurred in a coastal petrochemical storage installation. The installation was [located] 20 metres […] from the rail-way [...] and close to a school and other residential buildings. [...] Tank No 43 had previously contained methanol but, when the accident occurred, was practically empty and had to be decontaminated to receive subsequently nonane. Tanks No 44 and 45 were filled with pure methanol.
> Immediate Effects: 4 people were killed and 1 injured [...]. No one outside the installation was injured. The explosion and the following fire caused the destruction of: storage tanks, pipelines, window panes, doors and factory fence. Outside the installation the explosion caused the breakage of the windows and a slight deformation of the doors of the nearby buildings.
> Immediate Lessons Learned: It is believed preventive measures will also be taken for similar installations, which may include: 1- the improvement of the internal safety organization; 2- the installation of sensors [… to] monitor the concentration of dangerous substances in the air, connected with alarm systems; 3- setting up of work-permit procedures; 4- the use of well-trained personnel. Measures to mitigate the effects of the accident: 1- locating plants at a safe distance from other activities.

Discussion: The accident occurred in a petrochemical storage installation located 20 metres away from a railway, close to a school and other residential buildings which were damaged by the explosions. It appears that tank no 43 was being taken out of methanol storage service. This involved a "degassing operation" in which the methanol vapours in the tank are purged with air. The initial explosion occurred during the degassing operation, spread to two other methanol tanks, which then also exploded.  The degassing operation appears to have been carried out without efforts to prevent the formation of ignitable vapours.  The probable, though unsuccessful, accident prevention strategy appears to have been elimination of sources of ignition rather than preventing the formation of ignitable vapours.  There is no mention of the possible sources of ignition.

Summarising the two, the MARS search provides a hint that bulk methanol storage appears to be associated with tank internal explosion hazards.  This is most apparent in MARS report #113 in which a tank explodes when struck by lightning.  The implications of MARS report #233 are less obvious as the case concerns an intrinsically unsafe degassing operation using air.  It appears reasonable to conclude that the first explosion in tank no. 43 was directly attributable to the unsafe degassing operation.  It is less clear if the subsequent explosions in the two other methanol storage tanks were also caused by the degassing operation, or whether they were caused by any intrinsic hazards of methanol.  In essence, the MARS search provides two cases where methanol tanks have exploded.

**Some problems with extent of information provided**

Among the other 17 reports, two records stand out, namely items #5 and #6, not because they are relevant for the bulk storage of methanol but because they indirectly may point to a weaknesses of the data in the MARS system.  Again, we give verbatim quotes, and phrases in brackets are corrections of misspellings or remarks by the authors of this paper.

**Short Report #5** concerns an explosion on August 13, 2003 in a production line for glyoxylic acid:

> Accident Type:  Explosion in a production line for glyoxylic acid (CAS 298-12-4) with subsequent fire; in the installation various relevant substances were present (methanol, hydrogen, peroxides). 20 workers were injured, 1 of them had to be kept in hospital. The part of the installation which contained the production line was completely destroyed, missile range ca. 150 m
> Substance(s) Directly Involved:  [Glyoxylic] acid has no classification related to Seveso II but so have other substances present in the installation (methanol, hydrogen, peroxides)
> Immediate Source(s) of Accident: The process involves ozone and is known to be extremely exothermic under [c]ertain  conditions - it is assumed that it was a runaway reaction
> Suspected Cause(s):  Unclear
> Immediate Lessons Learned. Unclear, despite intense efforts to find the causes no concrete cause known yet; the inspecting authority has closed the installation until further notice in this respect

Discussion:  First, the consequences of this accident are substantial.  The production line was completely destroyed by an explosion, 20 workers were injured and the “missile range” was approximately 150 m.  This event is beyond doubt a “major accident” according to common sense definition of this concept.  Yet, it is important to observe the statement that “glyoxylic acid has no classification related to Seveso II but so have other substances present at the installation (methanol, hydrogen, peroxides)". We speculate if it could be the involvement or perhaps even the mere presence of these *other substances*, related or unrelated to the causes of the accident, that caused this incident to be reported to the MARS database[2].

Second, the "Immediate Lessons Learned" field is inconclusive. Little is known about causes, although some sort of runaway reaction is suspected. We are informed that the inspecting authority has closed the installation until further notice.

**Short Report #6** concerns an explosion on August 9, 2004 in a production line for glyoxylic acid:

> Accident Type: Explosion in a production line for glyoxylic acid (the same installation was already subject to report a major accident one year before) - causes are not known yet
> Substance(s) Directly Involved: Methanol (CAS 67-56-1), various peroxides
> Immediate Source(s) of Accident: The accident happened in the ozonification unit during start-up; this unit is established in a separate building for cooling purpose
> Suspected Cause(s): Unknown so far
> Immediate Lessons Learned: Still subject to discussion since the installation was reopened recently before the accident after additional [measures] were taken because of the accident in the year before

Discussion: This is the same installation that suffered a similar, if not identical accident, one year before. It is noteworthy that the causes of the explosions are still not known. The new explosion appears to have happened shortly after the installation was reopened after the first explosion.

Summarising the glyoxylic acid case we make two points. First, it is not apparent from the short reports whether the underlying causes of each of the two explosions have been identified or if they merely have not been reported to MARS. The fact that a new explosion occurred in the same plant could suggest that no lessons have been learned. In any case, our key observation is that the publicly available information in Short Reports #5 and #6 has very limited use in practical accident prevention work. Second, we speculate if there may be a possible weakness concerning "scope criteria", i.e., the criteria that define which types of accidents must be reported to the MARS database. Our concern is the obvious *damage potential*, the "complete destruction" of the production line and a "missile range" of 150 meter. The culprit substance has not been identified and could be glyoxylic acid, peroxides, ozone or something else. It is also possible that the culprit is not a specific substance but a special type of reaction chemistry that has an

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[2] This is a reminder that major industrial accidents are not required to be reported to the MARS database unless they meet et least one of a set of specific criteria laid down in Annex VI of the Seveso II directive. One criteria is if the accident involves substances that are classified under the Seveso II directive and the release exceed 5% of the Column 3 quantity. Other criteria are: a death, six persons injured within the establishment and hospitalized for at least 24 hours, one person injured outside the establishment and hospitalized for at least 24 hours, permanent or long-term damage to 1 hectare or more of a lake or pond, damage to property in the establishment exceeding ECU 2 million, amongst others.

inherent runaway potential. What concerns us most though, is the statement that "glyoxylic acid has no classification related to Seveso II but so have other substances present in the installation" We are left with a slight uncertainty whether this incident, which beyond doubt is a "major accident", under some marginally different circumstances would be reportable according to a strict legal interpretation of the scope criteria of MARS and Seveso II regulations.

**TAD methanol accident search**

Because our topic of interest is institutional support to evolutionary learning we wished to compare a privately funded accident database with the government funded MARS initiative. We conducted a small search in the commercially available TAD (The Accident Database) which is operated by and may be obtained from IChemeE in the UK. The search parameter "methanol" in free text returned 129 records. Examination of these records reveals 16 cases which are specifically relevant for the bulk storage of methanol. Of these, 11 cases involve an internal explosion in the tank.

Examples are given below [misspellings corrected in brackets]:

TAD record #1145. March 28, 1976, Addyston, Ohio, USA. "Lightning struck 600,000 gallon storage tank containing methanol. Walls separated from base and tank lifted 80 ft. Bund overflowed and [damage] caused to acrolonitrile tank. Both tanks ignited. Explosion, fire, damage to equipment".

TAD record #3950. July 12, 1995, Tampa, Florida, USA: "Lightning struck a tank of methanol causing fire. One nearby tank filled with solvent reached its boiling point and blew its lid but the blaze was contained. The methanol tank had a 250,000 gallon capacity but was only holding 40,000 gallons when struck."

TAD record #5638. April 15, 1992, Wilmington; North Carolina, USA. Tank vapours ignited resulting in fire and explosion in storage tank containing 340 000 litres of methanol. Cause not known. Some methanol spilt into nearby river and there was fear after breaching stepped bank.

Discussion: The direct results of this search are broadly in line with the results of the MARS search, indicating internal explosion hazards of methanol tanks. Several of the TAD reports involve spontaneous explosions in methanol storage tanks, both in fixed installations and marine transportation accidents. Lightening strike is stated as the immediate cause in several cases.

Like MARS, many of the records in TAD give very sparse information on causes. Superficial accident investigation/reporting appears to be a universal phenomenon. However, we consider the TAD search result to be marginally more useful than the MARS search result because there are more observations corroborating our suspicion of methanol tanks being associated with internal explosion hazards. Several of the TAD cases are also described in somewhat more detail than are MARS records.

## DISCUSSION

### General explosion hazards involving bulk storage of flammable liquid

Many years of practical experience have accumulated regarding the prevention of explosion hazards in the bulk storage of flammable liquids. Explosions in cone roof tanks containing *gasoline* are extremely rare. The reason for this is that quality and performance specifications for motor gasoline set a relatively high vapour pressure, useful when we wish to start a cold engine. Volatile fractions in the gasoline will therefore quickly evaporate leading to too high concentrations of gasoline vapour in the vapour space of the tank.

In technical terms, if the concentration exceeds the upper flammable limit (UFL), vapours are no longer ignitable – the vapours are too *rich*. Likewise, if the concentration drops below the lower flammable limit (LFL), vapours are not ignitable – they are too *lean*. Flammable vapours are only ignitable if their concentration falls within the LFL to UEL range. Ignitable vapours are intrinsically unsafe as they only wait for a source of ignition to explode violently. Experience has shown that it is extremely difficult to eliminate all sources of ignition.

Normal tank operations can influence the concentration of vapours in the tank. When a tank is being emptied or filled, the liquid in the tank acts as a piston that sucks in air or expels tank vapours through the tank vent – sometimes referred to as tank breathing. If product is being withdrawn from a gasoline tank rapidly, tank vapours may temporarily become ignitable due to the large inflow of air caused by tank breathing. When a gasoline tank is being filled, tank breathing expels flammable vapours that will be diluted and pass through the UFL-LFL range. If ignited, there will be a flame at the tank vent, but the flame cannot travel back into the tank vapour space because concentrations there are too rich. Except in extreme cases with substantial tank breathing, vapours in gasoline tanks are always too rich. This is also the reason why explosions in car fuel tanks are unheard of.

Nowadays, the preferred storage of gasoline and other high vapour pressure flammable liquids involves floating roof tanks in which the tank vapour space is eliminated. Floating roof tanks greatly reduce the emission of volatile organic chemicals (VOC) and are often installed for environmental reasons. Such tanks have their own hazards however, which fall outside the scope of this paper.

The hazards of gasoline tanks are relevant to the example discussed in this paper because both tanks referred to in the section *The case example* were cone roof tanks that had earlier been in gasoline service. Local experience and knowledge therefore supported an uncomplicated and straightforward fire prevention case – it was simply a change of one flammable liquid for another. The only perceived significant change was that methanol, unlike gasoline, is classified as toxic. Seveso I legislation supported this interpretation. The 1994 methanol storage tank was subject to Seveso legislation, not because of methanol's flammability classification, but because of its toxicity classification.

## Using MARS data in industrial accident prevention efforts

At face value, the two MARS search results are disappointing from an accident prevention point of view. **Short Report #113** states no other causes than lightning strike. But this information is of little practical use in accident prevention, because the construction details and the operating conditions of the tank are not stated. For instance, if the tank was equipped with a standard gooseneck vent, this might explain how ignited vapours could travel back into the tank. Further questions then arise: e.g., was there a flame-arrester in the gooseneck? Information on operating conditions would also have been very useful. For instance, if the tank was being emptied, tank breathing could explain the presence of an ignitable mixture within the tank.

**Short Report 233** conveys little useful generally applicable accident prevention information despite the rich text description. Degassing a tank with air is an extreme and inherently unsafe operation because tank vapours are likely to be in the ignitable range. But this hazard scenario has little general value for other tanks that are not degassed.

## MARS data provides insights into unidentified hazards (improved system modelling)

The lightning strike information in Short Report #113 led the first author to realize (in 1994, when the original risk assessment was made) that methanol had very different properties from gasoline. The vapour pressure is lower and the flammable range is broader as seen in Table 1.

| | Vapour pressure *) | LFL (vol%) | UFL (vol%) |
|---|---|---|---|
| Gasoline | 50-90 kPa (varies according to climate, season and national legislation) | 1.4 vol% | 7.6 vol% |
| Methanol | 30 kPa | 5.5 vol% | 26.5 vol% |

* Data for gasoline is taken as Reid Vapour Pressure (RVP) measured @ 100 °C (38 °C), data for methanol have been computed by the first author for same the temperature for comparison.

Table 1. Properties for gasoline and methanol

With this insight it is a relatively simple matter to compute the two temperatures of liquid methanol that are in equilibrium with methanol vapours corresponding to LFL and UFL. The results are shown in figure 1. The conclusion is that there will be an ignitable atmosphere in a methanol tank if the temperature of the liquid methanol is within the 6-35 °C range.

With standard European climate conditions, this hazard is present most of the time. For all practical matters, the vapour space in a methanol tank is rarely lean or rich. Most of the time it is ignitable, only waiting for an ignition source to explode violently. This was the major finding in the 1994 case story, and it was a direct consequence of insights gained from the MARS data.

The hazard was unknown to the company A that sought permission to store methanol and it was also unknown to the local authorities (and, we believe, national authorities), who in both cases were familiar with the hazards of gasoline tanks. It has probably also been unknown to the Competent Authorities (CA) that communicated the text of Short Report #113 and #233 and unknown to the MARS staff.

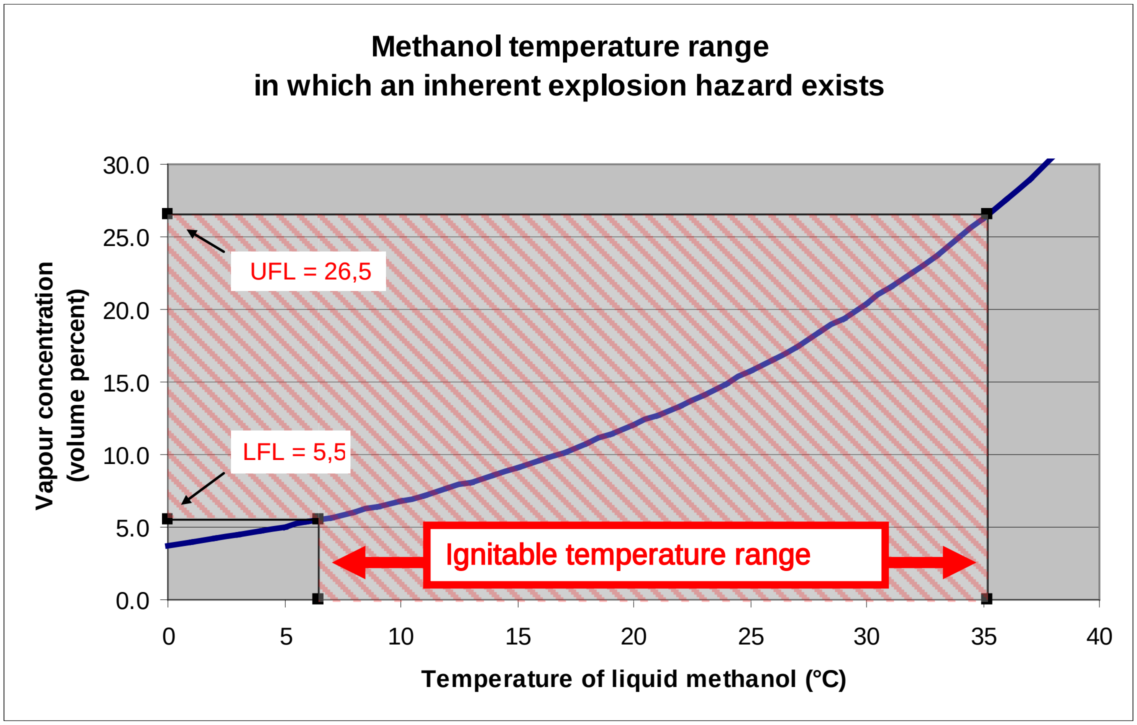


Figure 1. Inherent explosion hazard of methanol storage. Tank vapour space is ignitable if bulk liquid temperature is in the range 6-35 °C assuming ambient pressure of 1 bar.

This case story illustrates what we described above as the second type of benefit (and first highlighted by van der Schaaf 1991) to be derived from accident information, namely modelling insight. When acquiring knowledge about an accident we may gain insight into causal mechanisms which lead to a better modelling of the system. We see how things are interrelated and how they may interact. This knowledge may in turn prompt the development of “deep” knowledge of causal mechanisms or it may remain as shallow (but extremely useful) knowledge of limits and regularities.

It is somewhat ironic that the accident report that contained the most meagre description, #133, and not the richer account of #233, gave rise to this insight.

**MARS data motivates safety efforts**

In 1994, company A had vigorously claimed that it had no knowledge of prior accidents with methanol. It was also quite obvious that the company considered the authority permit procedure to be overly cumbersome and exaggerated – and in general unnecessarily disruptive to their business.

The information on prior accidents with methanol tanks came helpful to the CA field workers as it provided them with empirical evidence of the danger of explosions in methanol tanks. The CA forwarded the case stories to company A and started asking questions why the company had no knowledge of these accidents. Having started in a defensive mode, the CA now felt firm ground under their feet. In this respect, the case story illustrates both "motivation" and "overview" (van der Schaaf et al.'s second and third categories, 1991). Thus, the motivation that stems from the realization that "but for the grace of God here go us" and the overview that comes from identifying commonalities across a range of examples.

**The 2005 case**

The series of events involved in the 2005 case described earlier appear identical in many respects to the 1994 case. (We have no first-hand knowledge of the 2005 case and our account is thus based on information). Company B wished to seize a business opportunity involving the sale of methanol and contracted with a speciality chemicals tank farm located in a harbour area in Denmark for storage and handling. The locations and the CA (competent authorities) in the 1994 and 2005 cases differ. In both cases an existing gasoline tank is selected for the new methanol service. It appears that little effort had been spent on hazard identification techniques when the case was described in the information submitted to the CA. The CA processed the information and found that consequences of accidents were insufficiently addressed. The CA therefore requested that the consequences of some specified leak scenarios should be estimated. The CA did not specify internal explosion as a scenario to be computed. Hence, it appears unlikely that the inherent internal explosion hazard of methanol tanks has been identified. So, whatever lessons the CA of one county learned in 1994 appears to be lost to the CA in another county in 2005.

We have no information whether the CA in 2005 searched the MARS database before defining the accident scenarios. But even if they had done so, we may hypothesise that, in the light of the rudimentary nature of the information in MARS, it seems highly improbable that the information in MARS would have been of any practical use to the CA in this case.

**Some of the weaknesses and strengths of the MARS database**

The MARS data on methanol accidents are rudimentary. There is insufficient mention of designs and other relevant details. However, the most critical shortcoming is the absence of results of systematic accident investigations which might lead to the identification of causes behind the accidents reported - rather than blank "lessons learned" fields.

Why are some descriptions superficial? We have speculated if there could be a policy decision to give priority to the number of accidents reported (quantity) and therefore accept compromises on reporting protocol (quality). The total number of records in MARS appears (June 7, 2006) to be 603. At least, this is the number which is consistently returned when one performs a blank search within various fields such as start-date, substance-involved. Thus the MARS database has accumulated about 600 records during the 22 years it has existed since 1984 - corresponding to a little less than 30 per year for the entire EU, or about two records per country per year[3]. This is not an overwhelming number. So perhaps quantity cannot explain the lack of quality.

Perhaps very strict scoping criteria may limit reporting (i.e., criteria that regulate which accidents fall within the category of mandatory reporting). As became apparent during the review of the glyoxylic acid case, it is conceivable that relevant major accidents may not enter the database because they fall outside the Seveso II legislation scope.

But the most likely cause seems to be poor capture of primary data by member states. As stated before, the MARS scheme is entirely dependent on member states to deliver useful input to the database.

We have searched only the public domain of MARS data (Short Reports). Full Reports are available only to national Competent Authorities as they contain confidential information, e.g. information that may reveal the identity of the country submitting the accident information. It is in principle possible, that the Full Reports available to the authorities contain information that is superior to that contained in the Short Reports. We have, however, interviewed a Danish MARS contact person who indicated that this was unlikely (Gerdes 2006). Still, if it were to turn out that useful additional information is potentially available in the confidential Full Reports, we would argue that this could easily be rectified with the editing of the Short Reports. From an accident prevention view it is obvious that information should be available in a format which is sufficiently detailed to allow for lessons to be learned. Secrecy and accident prevention are not compatible.

We emphasize that our findings do not warrant general conclusions on all records in the MARS database. We have scrutinized only accidents involving methanol and have browsed a number of other reports. Some of the Short Reports are evidently of high quality and are seemingly based on scrupulous application of professional accident investigation techniques. Still, practical use of the MARS database reveals that Short Reports of poor quality are not limited to methanol accidents. A search for “LPG or propane or butane", for instance, produces Short Reports with the same general problems as methanol.

Our main conclusion is therefore, that there are considerable missed opportunities in the EU funded institutional support of learning from past industrial failures

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[3] In 1984 there were 10 member states in the EU. In 1986 the number increased to 12, in 1995 to 15, and 2004 to 25 member states. For the period of interest here, there have been 12-15 member states in the EU.

Although the main tenor of the present paper could appear to be negative, the authors are in fact entirely supportive of the MARS database. We strongly endorse the intentions behind its creation and find the efforts spent in running its operations commendable. But we also think that the considerable literature that refers to the MARS system has been somewhat skewed: We may have overlooked it, but we have not been able to find any mention in the 30 or so articles and reports we have read that describe the MARS system any mention of the poor quality of some reports. The writing of this paper has been prompted by a wish to stimulate a debate about how best to improve the MARS system so that it may genuinely useful to safety analysts and practitioners and – in a wider sense – so that it may contribute to evolutionary learning.

Finally, among the minor quibbles it deserves mention that the MARS search interface is overly complex and not user-friendly. It is a major weakness that a free text search cannot be undertaken across all fields. In the face of the relatively few records, and the nature of the data in at least some of the records, it would appear that a simple search facility might do justice to the information contained in the database of Short Reports.

**General relevance to biofuels (ethanol)**

Our case installation is very simple, the bulk storage of methanol in a fixed roof tank. We consider it likely that this type of installation exists in most EU member states. Therefore, it would have been of great practical value if the EU database had contained rich descriptions of methanol accidents and perhaps even identify the inherent explosion risks of methanol. It would have been a prime candidate for evolutionary learning supported by information sharing. This is clearly an opportunity foregone.

A similar hazard analysis can be made for the bulk storage of ethanol which is subject to almost identical inherent internal explosion hazards. With the groundswell interest in biofuels to reduce CO2 emissions from the transport sector the bulk storage of ethanol is likely to increase greatly in all EU member states.

However, ethanol, unlike methanol, is not classified as a toxic, only as a flammable liquid. Flammable liquids of that type[4] are only subject to Seveso II regulations if the amount exceeds 5,000 tonnes and a safety report is only required if the amount exceeds 50,000 tons (upper-tier). It is quite conceivable that many bulk ethanol storage tanks therefore will not be subjected to Seveso II regulation unless of course they are part of a larger storage complex where other substances (typically gasoline, which have no inherent explosion risks), are stored in quantities that exceed the limits set in the directive. Likewise, ethanol accidents may not be subjected to MARS reporting requirements unless the event is truly spectacular.

We conducted a crude search in MARS for "ethanol". The search returned two records (#379 and #393) concerning spectacular accidents precisely in which an ethanol tank suffered an internal explosion. The reporting criteria in both cases were that damage exceeded 2 million ECU. Both records are rich in text. Neither record identifies the

[4] Classified as "highly flammable" according to annex 1, part 2, category 7b, in Directive 2003/105/EC

inherent internal explosion hazard of ethanol storage. Neither record is informative on how to prevent such internal explosions - an obvious strategy could be to eliminate the formation of ignitable vapours in the first place, for instance using inert gas blanketing or other technical means. But the accident descriptions are silent on this issue.

We conclude that the current version of the Seveso directive does not address the inherent internal explosion risks of ethanol storage and that scope criteria may exclude this hazard from institutional support to evolutionary learning. This is obviously an opportunity foregone.

**Comparing MARS and TAD accident data.**

We have compared the results of the MARS search with the results of a similar search in a well-known privately operated database The Accident Database (TAD).

The TAD is not subjected to the relatively narrow Seveso scope restrictions and it contains far more records, about 13,000 compared to 600 in MARS. The TAD database also contains transportation accident, including marine accidents and accidents on inland waterways, and it includes accidents outside the European Union. Many of the TAD records suffer from the same shortcomings as the MARS records do. However, several TAD records give a clear impression of having been written by persons with first hand knowledge of the incident, being rich in text and detailed. The search procedure also permits free text searches in the entire database. In summary, we consider TAD superior to MARS in practical accident prevention work.

It is therefore extremely relevant to ask if the TAD database is more successful than the MARS database. Intriguingly, this is not so. Despite much targeted advertising in e.g. Loss Prevention Bulletin, the TAD has been unable to prove itself a viable commercial activity. Due to little consumer interest and lack of revenue updating the database with new incidents and even basic software maintenance has been discontinued. (Smith 2006, personal communication). The database is still for sale, but for practical reasons it is no longer a living database, it has become a historical archive.

**Improvement potential**

We have not undertaken a comprehensive analysis of all records in the MARS system and will only address some of the obstacles that have to be cleared to make the learning potential fully operative. Insofar as there are problems with poor quality of primary data capture from member states, MARS could offer a sparring service to improve the accident investigation and reporting efforts.

It could also be suggested to ease secrecy. When member states cannot be identified in the Short Report it is impossible for safety professionals to seek more elaborate information on a specific incident. The possible embarrassment of member states if they are identified with records of poor quality could also have a preventive effect. We repeat that secrecy and accident prevention are seldom compatible.

Finally we propose an active alert service with the broadest possible dissemination of lessons learned. In practice this means distribution of alerts and analyses on the internet, for instance as done by the well-known Confidential Human Factors Incident Reporting Programme (CHIRP)[5] in the UK. Originally, CHIRP covered aviation incidents only but it has been extended to maritime incidents in recent years. A number of other highly respected systems for collecting, analysing and disseminating lessons learned exist (Beaubien & Baker, 2002), and an overhaul of the MARS system should be based on a careful review of the best features from the more successful programmes in safety critical domains.

## CONCLUSION

Our case example with bulk methanol storage has shown that the data in some of the Short Reports in MARS have a number of serious shortcomings. Causes are not identified and lessons learned are left blank. The value of this information in the efforts to prevent future methanol accidents is limited - but not nil.

Our case also demonstrates that even the most rudimentary data on past accidents can be of value in accident prevention. Ironically, it was the Short Report in MARS with the most meagre data that gave inspiration to an accident causation hypothesis which eventually proved useful. Also, the mere knowledge of past accidents undermined the Company's assertion that it had no knowledge of any accidents involving the bulk storage of methanol.

Over the course of 22 years the EU database has only accumulated about 600 Short Reports for all its member states. We consider it unlikely that this number represents all "major accidents" according to a common sense definition of this concept for such a large territory. We hypothesise if scope limitations imposed by strict legal interpretation of the Seveso legislation may be counter productive and perhaps even self-defeating for the Seveso legislation's stated objective of accident prevention through information sharing.

We have identified 110 academic citations that mention the MARS major accident reporting system. The ratio of citations to accident records is 1:6, a very large ratio. We have not reviewed all 600 Short Reports in MARS, but our samples indicate problems of quality in some of the data. We support wholeheartedly the intentions behind the creation and operation of the MARS database and have never found any reason to have other than respect for the personnel and institution involved in its operation. Still, we find it a cause of concern that sample searches do not seem to reveal rich material for potential learning and, perhaps just as important, that these problems of poor information seem to be largely absent from the bulk of scientific papers and reports that describe and refer to the MARS database.

We emphasize that our methanol case example does not warrant general conclusions on the entire MARS database. However, we consider it likely that this type of installation can be found in most, if not all member states and we argue that it would have been of

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[5] http://www.chirp.co.uk/main/default.asp

great practical value if MARS had contained richer accident descriptions, identified underlying causes and pointed to efficient preventive measures. We pursue a similar argument in our ethanol tank case - an issue which we foresee will be of increasing importance to all member states due to the groundswell interest in biofuels.

We conclude that there are substantial opportunities foregone in the EU funded scheme that provides institutional support for evolutionary learning.

We have undertaken a comparative analysis of accident records in MARS and in the commercially available TAD. TAD suffers from many of the same fundamental shortcomings as do MARS. On all parameters, however, the TAD seems to be superior to MARS in practical accident prevention work. It is noteworthy, and intriguing, that despite much targeted advertising there has been very limited consumer interest in TAD. TAD has failed to be commercially viable and is now in a dormant state.

It is beyond the scope of this paper to examine or speculate about the reasons for this. Echoing the title of Kletz' 2003 publication, "*Still going wrong*", we acknowledge that there are many barriers to evolutionary learning. We conclude by emphasising, however, that the value of accident reporting schemes is not only determined by the quality of the data they contain but that institutional support appears to be crucial to sheer survivability.

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