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How Could CSB Investigation Reports Be Improved?

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Each year the CSB provide the process safety community with reports of past accidents in the US process industries. These reports often contain a detailed analysis of the event and its consequences. Often the report finish with recommendations to many stakeholders.
This paper analyze the causes and recommendations in CSB investigative reports from the period 1998 to 2011, by looking at questions such as: How many recommendations does a report contain? Which organizations are they directed at? What systems are most frequently parts of causes or recommendations? And then attempts to look at the question: Are the recommendations directed at the right organizations? - if the goal is to improve process safety. How many recommendations should a report contain to have maximum impact on the learning form the event? What changes have resulted from past recommendations? How can the learning from the investigation reports be improved?

1. Background

The US Chemical Safety Board (CSB) is the result of the Clean Air Act (CAA), which was passed in 1990, and became operative in early 1998. In the mid 90's the US Congress created the Chemical Safety Board as an institution independent of the executive branch, mirrored after the successful model of the National Transportation Safety Board (NTSB). It is charged with investigating accidents to determine the conditions and circumstances which led up to an event and to identify the cause or causes so that similar events might be prevented, as the CSB state the purpose of an investigation is "to determine the root and contributing causes and to issue recommendations to help prevent similar occurrences" (e.g. CSB (2000)). Based this mission statement the CSB must be considered an unqualified success. However, if one compares the CSB with the organization on which it was modeled, that is the NTSB, then one have to ask what impact has the CSB had on the number and severity of process safety events in the US process industry?

2. CSB Investigations since 1998

From its start until the end of 2011 the CSB has published 35 investigation reports involving 14 cases of explosion and fire, 8 cases of explosions, 5 cases of fires and 10 cases of toxic releases. These events have involved on average 2.4 fatalities and 18.5 injuries. An investigation has on average taken 1.6 years to complete.
As an exercise let us compare the numbers for three periods: 1998-2002, 2003-2007 and 2008-2011. In these periods there were respectively 9, 20 and 6 investigation reports published Indicating a spike of activity during the second period. The average number of fatalities involved were respectively 2.4, 2.3 and 4.3 in the three periods, and the number of injuries were respectively 4.8, 30.3 and 13.8, as shown in Figure 2. The spike in injuries during the second period is due to the BP Texas City explosion and fire. However, the severity of the events investigation appear to increase, as indicated by the average number of fatalities in the three periods. The time to complete an investigation has on average been less than 2 years in all three periods.
Such statistical data on fatalities and injuries are rather without value without any information about all the process safety events, that have not been investigated. However, the data do show, that each event investigated affected the lives of more than 20 families or possible the lives of more than 100 persons. In our efforts to find root causes of events to prevent similar happenings in the future the people whose lives are affected by process safety events are largely forgotten.

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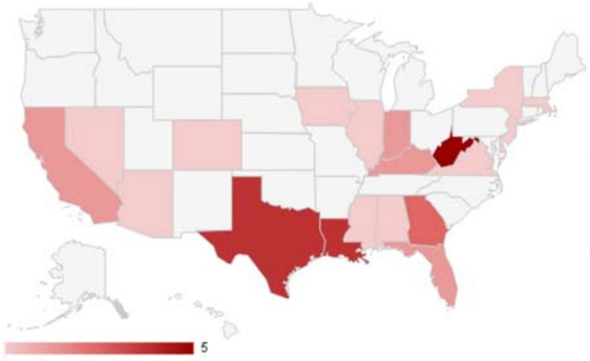

Figure 1 Distribution of CSB investigations across the USA. West Virginia is leading with 5 investigations followed by Texas and Louisiana.

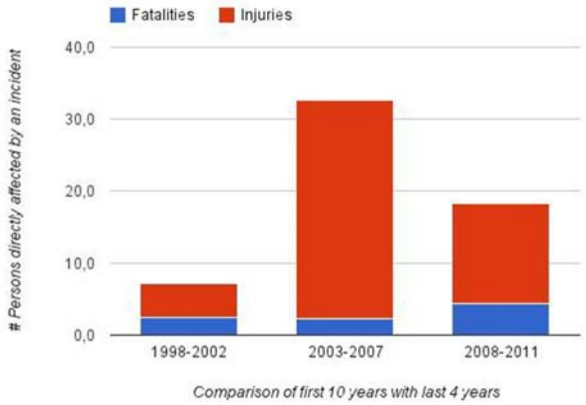

Figure 2 Comparison of #fatalities and #injuries in each investigated incident during periods of approximately 5 years.

Reduced to barely a number in the reports. Industry appear to have little or no focus on how to help those families mostly influenced by process safety events. The lives of these people are at least as damaged as the plant, but the kind of help they need are not what engineers are educated to deliver. Next let us look at the distribution of investigations across the USA. Figure 1 show a map of the USA colored to indicate the number of investigations the CSB have carried out in each state. The maps shows, that there has been no investigations in states close to the border to Canada.

3. Analysis of root causes and recommendations in CSB investigations

The CSB investigations reports clearly state root causes. However, the reader must themselves discover which system or systems failed in a particular cause. Here an attempt will be made to classify the causes according to the systems that failed. Similarly recommendations from the reports will be classified according to the system they influence. To demonstrate the method used details will be shown here for the causes and recommendations in the first investigation report issued by the CSB in 1998 followed by a summary of all reports from the period 1998-2002.

3.1 Analysis of root causes in first investigation report

The first investigation report issued by the CSB concerned an explosive manufacturing incident on January 7-th at the Sierra Chemical Company in Mustang, Nevada. At this process safety event 4 persons died and 6 were injured, thus affecting the lives of at least 10 families – not counting the psychological impact on fellow workers at the site and their families. The report identifies six root causes and one contributing cause for the event. In the report these causes are listed in a table also containing the key findings relating to them, and the causes are reproduced here in Table 1. In Table 1 a column has been added, which states the system or systems which failed for a particular cause.

The tabular layout used in the first report makes it easy to identify the failing system or systems. Other CSB investigation reports don't use this clear layout for stating causes. Unfortunately most causes are stated with the rather weak word “adequate”.

Table 1: Causes stated in CSB's first investigation report (CSB (1998))

Cause	System failing
Process hazard analysis (PHA) conducted by the facility was inadequate	PHA
Training programs for facility personnel were inadequate	Training
Written operating procedures were inadequate or not available to workers	Procedures
The facility was built with insufficient separation distances between different operations and the design and construction of buildings was inadequate	Process design
There was no systematic safety inspection or auditing program	Inspection
The employee participation program was inadequate	Involvement
Oversight by regulatory organizations was inadequate	Regulatory

Table 2: Causes stated in another CSB investigation report (CSB (2000))

Cause	System failing
Neither the preliminary hazard assessment conducted by Morton in Paterson during the design phase in 1990 nor the process hazard analysis conducted in 1995 addressed the reactive hazards of the Yellow 96 process. This resulted in the following design, operational and training deficiencies: • The kettle cooling system could not control the exothermic Yellow 96 synthesis reaction • The kettle was not equipped with safety equipment, such as a quench system or a dump system, to stop the process to avoid a runaway reaction • Rupture disks were to small to safely vent high pressure in the kettle in the event of either of the two foreseeable runaway reactions • Morton converted its Yellow 96 production from a staged, incremental addition (semi batch) process to a staged heating (batch) process without assessing the possible hazards of this change, e.g. the increased difficulty of controlling heat output • Operating procedures did not cover the safety consequences of deviations from normal operating limits, such as runaway reactions, or specify steps to be taken to avoid or recover from such deviations • Training did not address the possibility of a runaway reaction and how operators should respond to avoid injury if a runaway reaction could not be controlled	PHA Process design MoC Procedures Training
Process safety information provided to plant operations personnel and the process hazards team did not warn of the potential for a dangerous runaway chemical reaction. • Morton internal memorandum had documented that the desired reaction to form Yellow 96 from o-NCB and 2-EHA was exothermic and that Yellow 96 would begin to decompose rapidly (runaway) at temperatures close to the upper operating temperature • Morton researchers also had identified several situations, such as loss of cooling, which might give rise to temperatures capable of causing violent decomposition • Although information on the reactive hazards was contained in plant files, operators and supervisors were unaware that a dangerous decomposition reaction was possible	Communication
The hazards of previous operational deviations were not evaluated. • Management did not investigate evidence in numerous completed batch sheets and temperature charts of high temperature excursions beyond the normal operating range • Investigation of these incidents likely would have provided an opportunity to uncover the process' reactive hazards and correct design and other problems	Incident investigation
Morton did not follow their Management of Change procedures to review changes made in reaction kettle and batch size. • Morton changed the Yellow 96 processing equipment from 1000-gallon to 2000-gallon kettles and also increased batch size by 9 percent in 1996 • Morton did not follow its Management of Change procedures and did not review the changes for possible safety consequences • A Management of Change review likely would have provided another opportunity for Morton to uncover the process's reactive hazards and correct design problems • The review likely would have also revealed that the changes made resulted in a decrease of 10 percent in the heat transfer area per gallon of reactants. • Half of the batches made after this change exhibited temperature excursions versus 20 percent in the batches before the change	MoC

The only exception is the lag of a safety inspection or auditing program. Unfortunately from the report it is unclear if it the daily rounds by the operator or the monthly rounds by the supervisor which are not performed. In this event most of the systems failing are company systems.

Table 2 gives another example of how causes are stated in investigation report. These causes relate to an explosion and fire at Morton International, which during the investigation was acquired by Dow Chemical. In this case the causes are stated in a form, so they are related to failure of more than one system. This will

make it more difficult for readers to determine if the findings apply to their facility. Especially the first cause is clearly due to failure of PHA, but a consequence of this failure is failure of other systems.
Unfortunately in some of their statements of causes in the Morton International process safety event the CSB starts speculations on what would had happened if Morton International had acted differently. An example of this is the following statement "The review likely would have also revealed that the changes made resulted in a decrease of 10 percent in the heat transfer area per gallon of reactants" in the Contributing Causes section of the executive summary.

3.1 Analysis of recommendations in first CSB investigation report

The recommendations in the first report are divided into three categories: a) those directed at the company, b) those directed at trade associations, and c) those directed at authorities. The recommendations are reproduced in table 3 with an indication of the system they will influence.

Table 3: Recommendations in CSB's first investigation report (CSB (1998))

Recipient	Recommendation	System influenced
Company	Process hazard analysis should include examination of quantity-distance requirements, building design, human factors, incident reports, and lessons learned from explosives manufacturers	PHA
	Written operating procedures are specific to the process being controlled and address all phases of operation	Procedures
	Procedures, chemical hazards, and process safety information are communicated in the language(s) understood by personnel involved in manufacturing or handling of explosives	Procedures
	Explosives training and certification programs for workers and line managers provide and require demonstration of a basic understanding of explosives safety principles and job specific knowledge	Training
	Process changes, such as the construction or modification of buildings, or changes in explosive ingredients, equipment, or procedures are analyzed and PSM elements are updated to address these changes	MoC
	P re-startup safety reviews are performed to verify operational readiness when changes are made	PHA MoC
	All elements of OSHA's Process Safety Management Standard are verified by performing periodic assessments and audits of safety programs	Management
	The employee participation program effectively include workers and resolve their safety issues	Involvement
	Explosives safety programs provide an understanding of the hazards and control of detonation sources including: foreign objects in raw materials, use of substitute raw materials, specific handling requirements for raw materials, impact by tools or equipment, impingement, friction sparking and static discharge	Training
	The following issues should be addressed in plant design and modification: • Operations in explosives manufacturing plants are separated by adequate intra plant distances to reduce the risk of propagation • Unrelated chemical or industrial operations or facilities are separated from explosives facilities using quantity-distance guidelines • Facilities are designed to reduce secondary fragmentation that could result in the propagation of explosions	Process design
Association	Institute of Makers of Explosives (IME) should develop and disseminate process and safety training guidelines for personnel involved in the manufacture of explosives that include methods for the demonstration and maintenance of proficiency	Training
	IME should develop guidelines for the screening of reclaimed explosive materials	Procedures

Table 3: Recommendations in CSB's first investigation report (CSB (1998)) (continued).

Recipient	Recommendation	System influenced
Authority	Nevada Occupational Safety and Health Enforcement Section should increase the frequency of safety inspections of explosives manufacturing facilities due to their potential for catastrophic incidents	Regulatory
	Department of Defense (DoD) should develop a program to ensure that reclaimed, demilitarized explosives sold by the DoD are free from foreign material that can present hazards during subsequent manufacturing of explosives	Process design
	DoD should provide access to explosives incident reports and lessons learned information to managers and workers involved in explosives manufacturing, associations such as IME, government agencies, and safety researchers	Communication

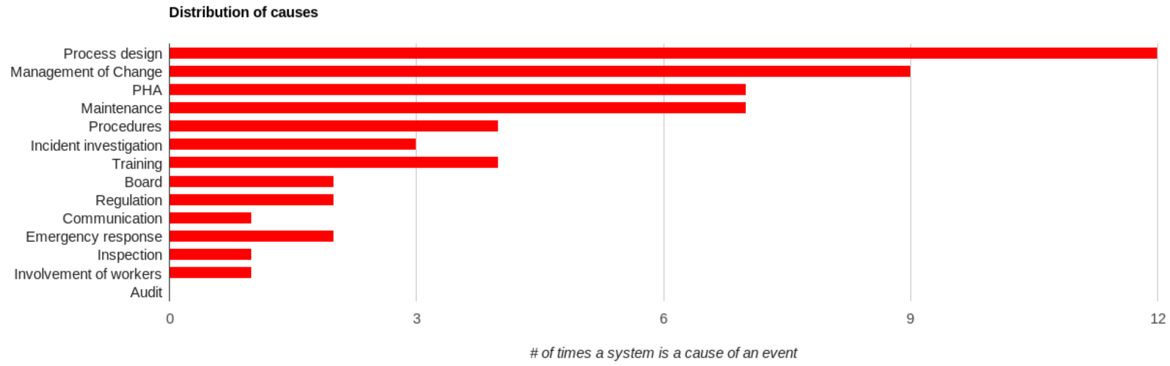

Figure 3 Distribution of identified causes in investigation reports from the period 1998-2002.

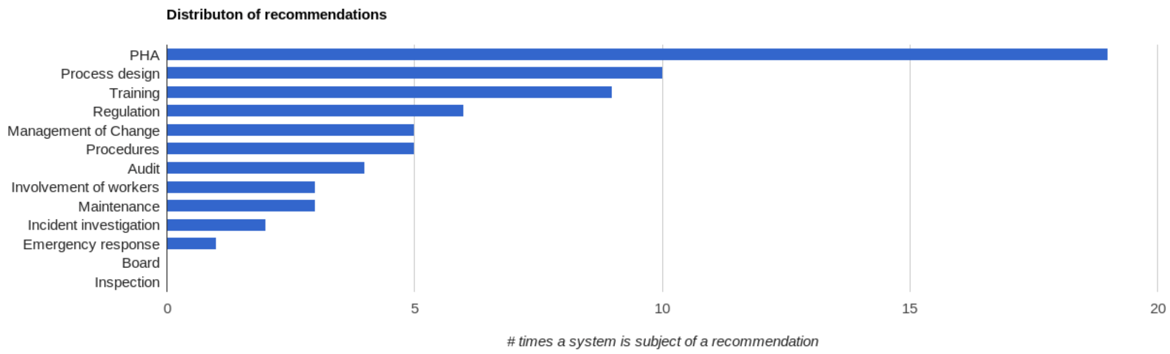

Figure 4 Distribution of recommendations in investigation reports from the period 1998-2002.

Table 3 shows that in most cases a recommendation is directed at a single management system, such as e.g. process design or training. In the following section a summary classification of causes and recommendations from all CSB investigation reports published in the period 1998-2002 will be presented.

3.2 Analysis of investigation reports from the period 1998-2002

Figure 3 shows the distributions of causes stated in executive summaries of investigation reports from the period 1998-2002 an analysis of causes in all these reports similar to the one presented above. And in figure 4 is shown the similar distribution of recommendations in the same series of investigation reports.
The above figures show, that the leading causes of process safety events as identified in these reports are process design, management of change and process hazards analysis. Not surprisingly the most prominent

systems in the distribution of recommendations are also process design and process hazards analysis. In Figure 4 communication have been omitted from the graph, because in most cases these recommendations called for blanket distribution of report findings and recommendations to large groups of members of different associations. The investigation reports published in the period 1998-2002 list on average around 5 causes and about 10 recommendations. The recommendations fall into three groups: those directed at the company or its parent, those directed at associations of companies, specialists or workers, and those directed at authorities in the ratio 7:2:1.
The results presented at the conference will compare the three periods 1998-2002, 2003-2007 and 2008-2011 to see is there are differences between the periods.

4. How could CSB investigation reports be improved

The CSB claim that the purpose of their investigations is to uncover the root causes of the process safety events which they choose to investigate, and to come up with recommendations towards avoiding similar events in the future. CSB is very careful in their formulation of both root causes and recommendations, but the drawback of this is that causes don't explicitly state which management or company system has failed. As an example one of the earlier reports state the following cause: "*Morton converted its Yellow 96 production from a semi-batch to a batch process without assessing the possible hazards of this change, e.g. the increased difficulty of controlling heat output*". Is this due to a failure of the process hazards analysis system or of the management of change system? It could be classified as either one, and since the management of change system could be viewed as a part of the process hazard analysis system, the choice depends on ones point of view. Hence it would help if the CSB investigators performed this classification, and it should naturally be part of the executive summary.
A classification of both causes and recommendations would make it easier for people, whose plant are different from the one involved in the process safety event being investigated, to learn from the event. To further facilitate these learning cross-references from the executive summary to the relevant detailed description of the failure in body of the report. For the recommendations a suitable reference to CCPS guidelines should be provided. In the executive summaries of the reports from the period 1998 – 2002 only one exact reference was found to a particular chapter in a relevant CCPS guideline book. Since CCPS guidelines books are de-facto consensus standards for the process industry learning from the recommendations could benefit from exact references to relevant CCPS guidelines books or a chapter in one of these.
CSB Investigation reports would also benefit from more openness about the process leading to some events being investigated, and others not. A particular example is the of the runaway reaction and explosion at Bayer CropSciences (CSB (2008)), which became a mean to finally eliminate a usage of the extremely hazardous substance methyl isocyanate.

5. Conclusion

The causes and recommendations in 34 CSB investigation reports from the period 1998 to 2011 have been classified according to the systems involved in the failure or influenced by the recommendation. Trends in investigations selected for investigation are compared for three periods using parameters such as number of fatalities involved, number of injuries involved, time from event to publication of report, etc.
Small changes to the reports, which could improve their value in learning from the events to a larger group of people involved in the design and/or operation of process plants are presented.
Everyone involved with the design and/or operation of process plants should learn form the CSB investigation reports. All to often no learning form a process safety events takes place, because one does not see the connection between the facility hit by the process safety event and ones own facility. For example the exposure to hydrogen sulfide experienced by emergency responders to an event in Pennington, Alabama in 2002 parallels a much larger event in the Swedish town of Landskrona more than twenty five years earlier. Apparently the ATSDR was unaware of the large multi-fatality process safety event which lead to an evacuation of the hospital in the Swedish town – not due to hydrogen sulfide, but due to ammonia.

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