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Mind The Gap – Improving Process Safety with an Integrated Approach Using Risk Assessments, Incident Analyses and Audits

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Abstract
Although most organizations have risk critical information available, it is not always integrated. In this paper, a bowtie perspective is proposed that enables an integration of three risk data sources. Issues with these three risk data sources are discussed and ideas for improvement are proposed. The integration of bowtie risk assessments, incident analyses and audit data complements each other and provides an interesting perspective on the status of the process safety management system. The integrated approach can be a useful addition to existing process safety management approaches.

1. Introduction

Process safety incident still occur, amongst others illustrated by the current investigations of the US CSB. In 2005, a major process safety incident occurred in the United Kingdom. A vapor cloud explosion and fires shook the Buncefield oil depot, it was the largest peacetime UK fire (UK HSE, 2011). Although 43 people were injured by the incident, there were no fatalities. The total economic impact of the incident was estimated to be 1 billion pounds (UK HSE, 2008). St Albans Crown Court fined the companies involved with the Buncefield incident millions of pounds (Macalister & Wearden, 2010). Below is a part of the statement which was issued by Gordon MacDonald of the UK Health & Safety Executive in response to the Court decision (ODN, 2010):

"Lessons must be learned from this incident. From the board room down, companies must ask themselves these questions. Do we understand what can go wrong? Do we know what our systems are to prevent this happening? Do we have information to assure us they are working effectively?"

We will have a look at these 3 questions from a process safety management perspective. *"Do we understand what can go wrong?"* Companies generally understand what can go wrong in terms of process safety. For instance by identifying hazards and associated scenarios with HAZID or HAZOP. *"Do we know what our systems are to prevent this happening?"* Again companies know what systems are in place to prevent the identified process safety incidents from developing. For example, through the identification of safety barriers in a risk assessment for high-risk scenarios. *Do we have information to assure us they are working effectively?"* Yet again, companies often have information about whether these systems aimed to prevent unwanted process safety incidents are working effectively. For instance, companies obtain incident and audit data.

The problem is not that companies have insufficient information to answer these questions. Although the information might be available in the organization, it is not always integrated. In this article, it is argued what the issues are when these different forms of information are stored in individual silo's (i.e. incident data in one silo, audit data in another silo etc.) and ideas for improvement are proposed.

Companies involved in high-risk processes can use a variety of methods to analyze and assess risk. These methods usually complement each other well. For example, a semi-quantitative LOPA will provide a different perspective to risk in comparison to a qualitative bowtie risk assessment. The bowtie method is an increasingly popular method to analyze and assess risk (de Ruijter & Guldenmund, 2016). In a bowtie risk assessment, potential incident scenarios and associated barriers are identified (*Figure 1*). Sklet (2006) defines safety barriers as "*Safety barriers are physical and/or non-physical means planned to prevent, control, or mitigate undesired events or accidents"*

In the proposed approach, the bowtie diagram is used as a framework to integrate incident and audit data. Integrating risk assessments, incident- and audit data yields valuable insights on the functioning of safety barriers for high-risk processes.

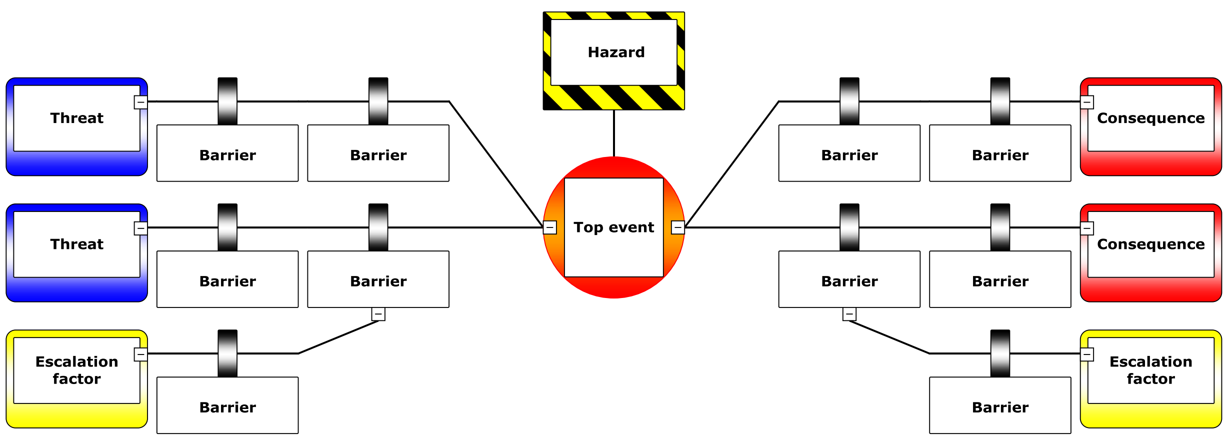

Figure 1 - Basic bowtie diagram

2. Integrating incident data & bowties

First, a perspective is provided on the issue with incident data in high-risk processes and ideas for improvement are proposed. In the next section audit data is discussed.

2.1. Incident data in individual silos

Although process safety incidents for high-risk processes in organizations are analyzed, it is not uncommon that these incidents remain in individual silos (*Figure 2*). An incident is analyzed, but the link or correlations between these incidents remain unclear with the individual silos approach. Recommendations from incidents are applied at a local level and the lessons learned are not utilized in similar and other situations (Drupsteen et al., 2013).

Figure 2 - Incidents in individual silos

2.2. Creating a common denominator between incident and bowties with barriers

A common denominator and framework is needed to create a link between incidents and add context to the data by linking them to bowties. In this paper it is proposed that the barrier concept should play this role as common denominator between risk assessment and incident analysis. The barrier is used in both bowtie analysis and in various barrier-based incident analysis models.

A barrier-based incident analysis method creates the opportunity to integrate incident data and bowties. In this paper, the incident analysis method Barrier Failure Analysis (BFA) will be used. BFA diagrams are comprised of events, barriers and causation paths (*Figure 3*). Bowtie and BFA have barriers in common, this allows us to trend incident data onto bowtie risk assessment diagrams.

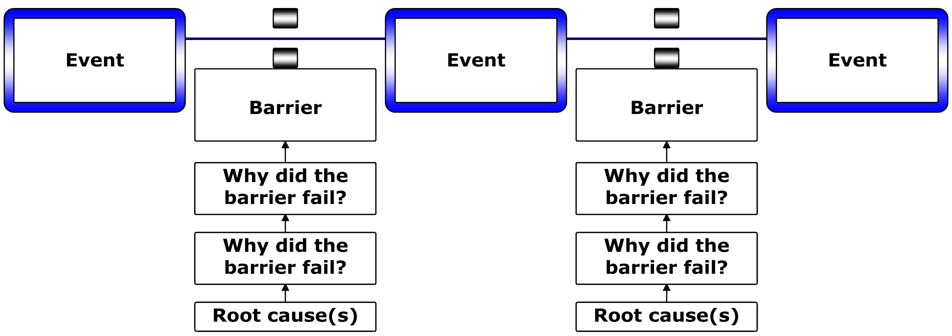

Figure 3 - Barrier Failure Analysis incident analysis method

2.3. Trending incident data onto bowties

Bowties can provide input for incident analysis, since bowties can be perceived as a collection of potential process safety incident scenarios. As shown in *Figure 4*, when an incident occurs, it is often the case that one of the incident pathways in the bowtie has become a reality. This pathway is highlighted in red (corrosion leading to loss of containment, leading to land contamination due to oil spill).

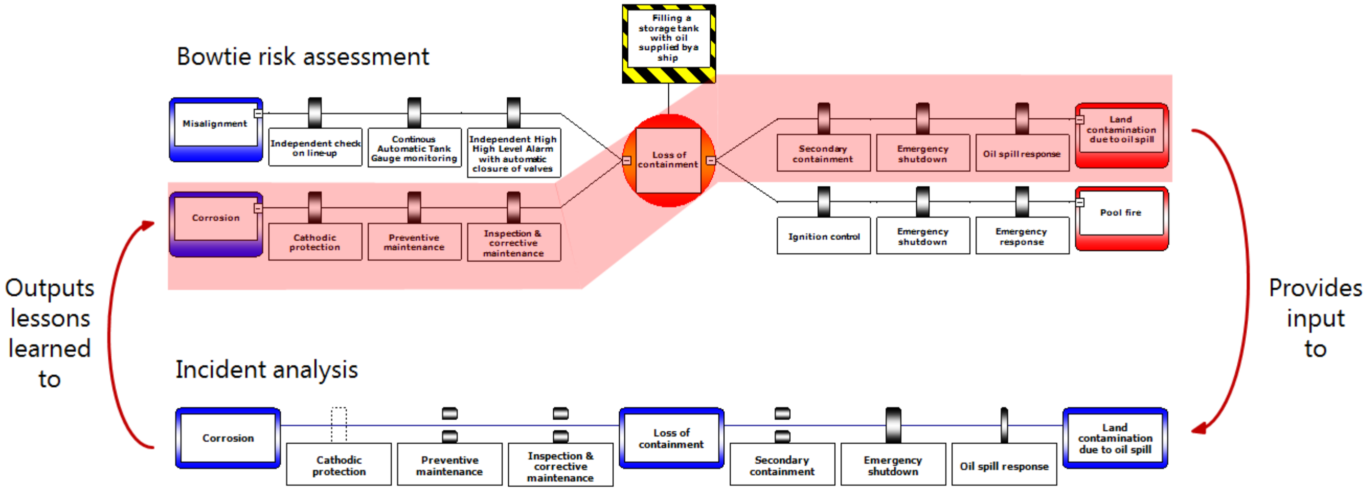

Figure 4 - Feedback loop between incident- and bowtie diagrams

During the BFA incident analysis, the scenario line which was extracted from the bowtie risk assessment is extended with additional information, such as the root causes which resulted in the failure of the barrier (*Figure 5*).

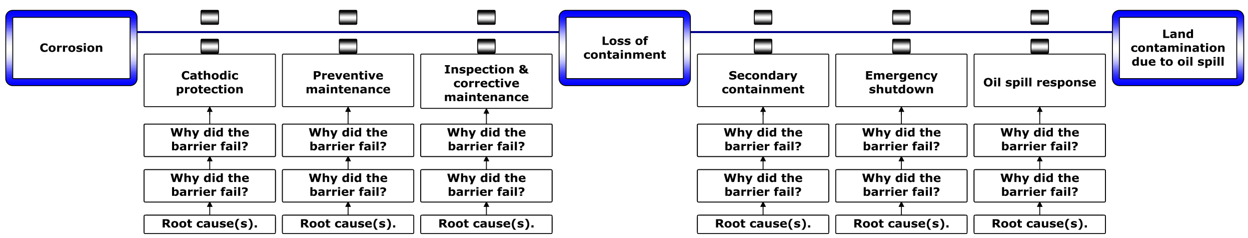

Figure 5 - Templated BFA incident analysis with input from bowtie

Because the scenario was initially extracted from the bowtie diagram, the barrier failure information which was added during the incident analysis can be easily fed back to various elements of the bowtie; top events, threats, consequences and barriers (*Figure 6*). Trending this incident data onto a bowtie diagram provides valuable information over longer periods of time. For example, which process safety incident scenarios occur more frequent and which barriers are (often) implicated in a negative manner. In this way targeted process safety improvement plans can be created by integrating incident data onto the bowtie diagram. Moreover, the link with the incident data, such as root causes and incident recommendations, and bowtie risk assessments remains intact.

Additionally, using the bowtie as input for incident analysis can be a trigger to create and update bowtie risk assessment. For instance, by adding an escalation factor to a barrier in a bowtie after incident analysis.

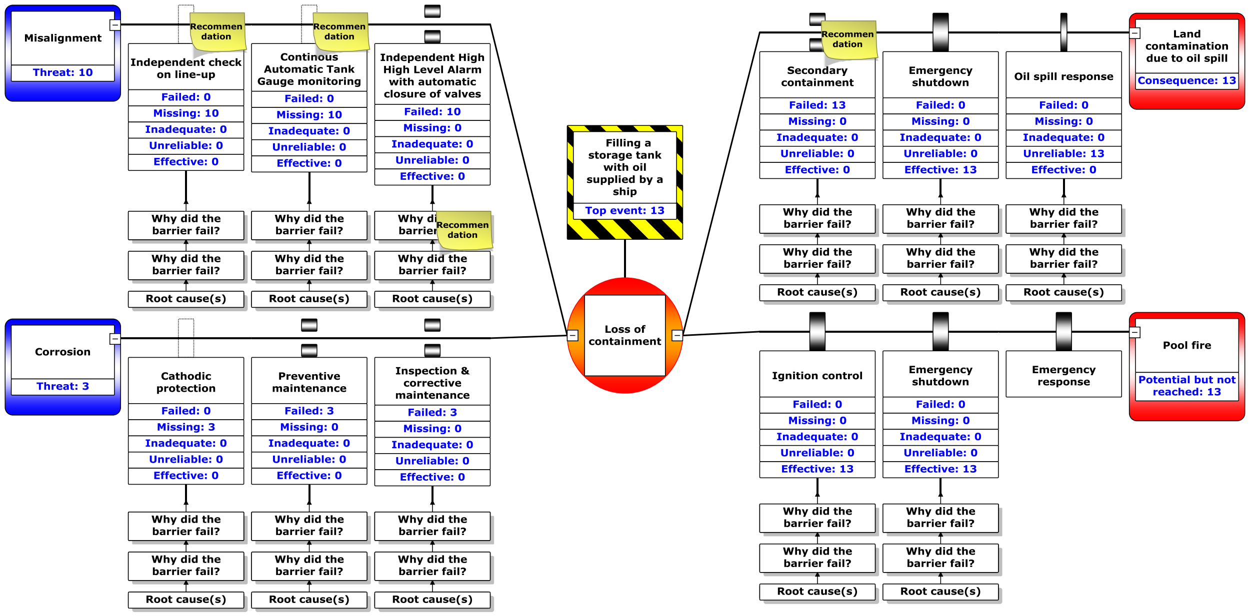

Figure 6 - Trending of incident data on a bowtie diagram

2.4. Incident recommendations

The incident section started by noting that lessons learned from incidents are not used in similar and other situations (Drupsteen et al., 2013). Recommendations focus on root causes after an incident analysis with RCA (Rooney & Vanden Heuvel, 2004). Root causes and associated recommendations can become standalone entities in this way. Root cause recommendations are often long term fixes which are challenging to attain and maintain.

Recommendations in BFA can be made on root cause- and barrier level. Recommendations on a barrier level, depending on the scope and context of the BFA, tend to be more operational. This makes it easier and more realistic to remedy an issue with recommendations on a barrier level in a shorter term. The barrier provides a concrete point to apply lessons learned as well, from either root cause or barrier level, to similar and other occurrences. This is because barrier X might be implicated in bowtie scenario 1, but this barrier could also be present in bowtie scenario 2.

Through the common framework, the correspondence of incident data (e.g. root causes and recommendations) and bowtie risk assessments remains intact. This provides an opportunity to apply lessons learned to similar and other situations.

3. Integrating audit data & bowties

In this section, a perspective is provided at the issue with audit data for high-risk processes and ideas for improvement are proposed.

3.1. Process safety management compliance audits

The process safety management system is depicted in the different silos in order to explain the individual silos issue with compliance audits (*Figure 7*).

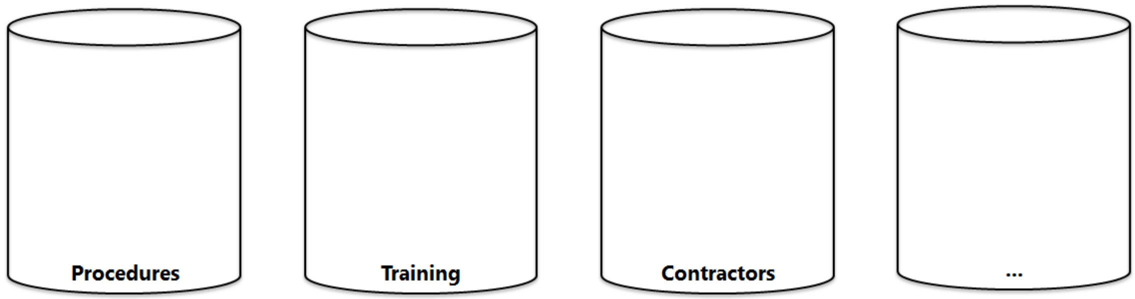

Figure 7 – Depiction of process safety management system standard components in silos

Organizations involved process safety management of hazardous chemicals are required to apply process safety management standards such as the US Occupational Safety & Health Administration (OSHA) 1910.119 standard (1992). One of the components of the US OSHA process safety management standard is compliance audits*: "Employers shall certify that they have evaluated compliance with the provisions of this section at least every three years to verify that the procedures and practices developed under the standard are adequate and are being followed."*

The compliance audit results of a process safety management will show compliance for the different sections of a standard. This gives a good indication of what sections of the standard requires resources. However, the results remain in individual silos, and correspondence between these process safety compliance audit results remains unclear (*Figure 8*).

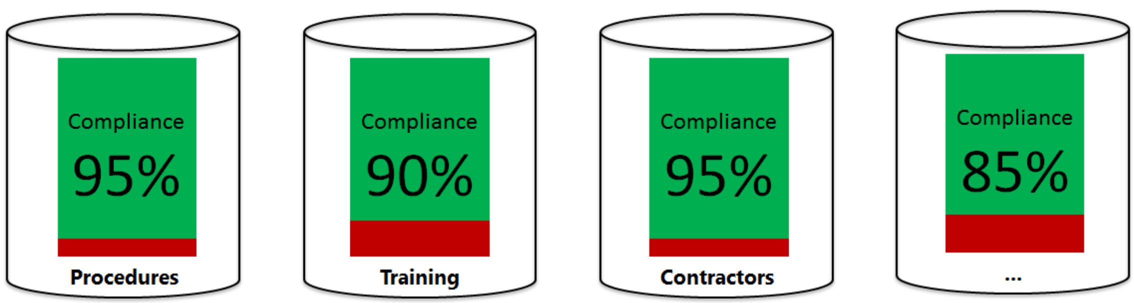

Figure 8 - Process safety management compliance audits

3.2. Risk-based audits

Zemering & Swuste (2005) applied the concept of risk-based auditing to bowties. A risk-based audit takes audit questions on a barrier level regarding the relevant process safety management system. Since barriers are hardly ever comprised of one silo, most questions will related to barriers will require information from multiple (if not all) silo's to be answered adequately (*Figure 9*).

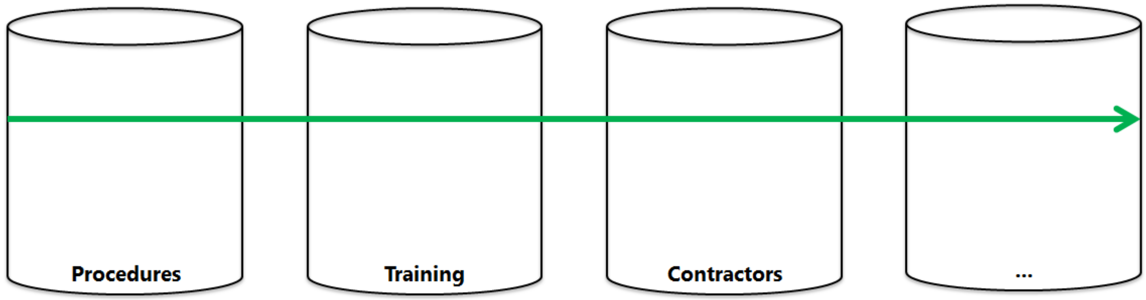

Figure 9 - Taking a slice throughout the process safety management system with a risk-based audit

An example will be used to explain the concept of risk-based audits. The barrier ‘Emergency shutdown’ is taken as an example. Audit questions can be asked to get an indication of the health of the emergency shutdown barrier. These audit questions can be relevant to the different parts of the process safety management system.

For example, a question regarding emergency planning and response could be: “Is an emergency action plan implemented?” A question regarding training could be: “Is personnel trained in emergency shutdown?” And a question regarding operating procedures could be: “Are the operating procedures for emergency shutdown well communicated to personnel?”

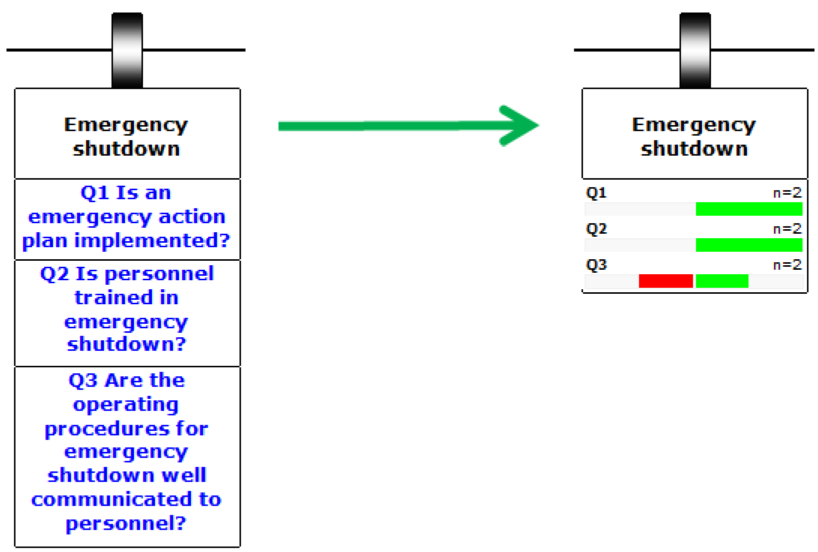

Figure 10 - Risk-based process safety management system audit questions (left) and the visualized audit results (right)

The previous example mentioned 1 barrier and gave 3 example audit questions on different process safety management system components. Applying this risk-based auditing on a larger scale can provide a useful perspective on the audit data into the context of a bowtie risk assessment (*Figure 11*).

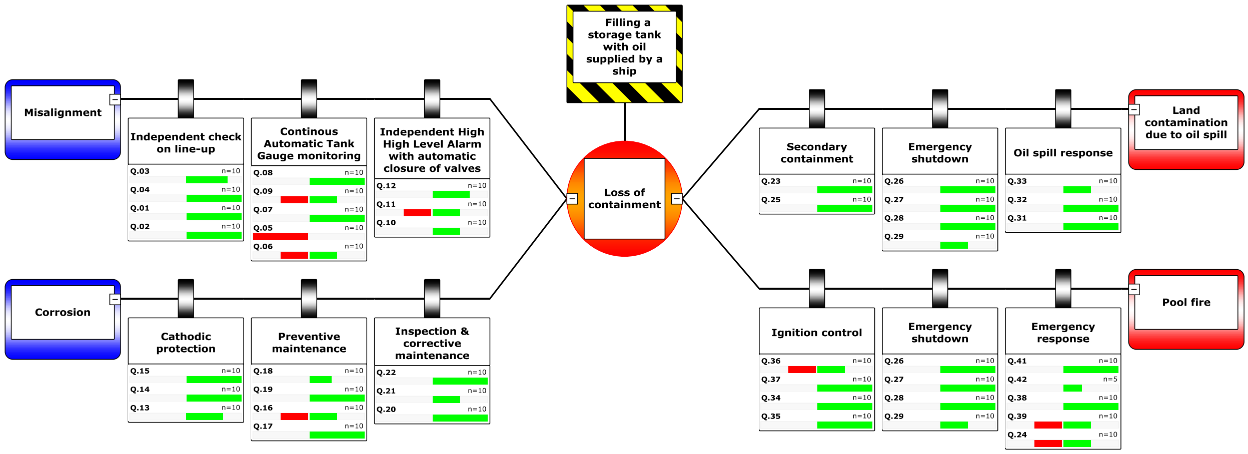

Figure 11 - Risk-based audit on a bowtie

In case of a compliance audit, a small amount negative audit results for a particular process safety management sections might get lost in overall audit results. Whilst these negative audit results on the different process safety management sections might coincidentally affect the same barrier and provide a critical signal of a barrier that is undermined in its effective functioning, an example of this is given in *Figure 12*. Although the overall percentages of compliance may seem relatively high, the bits that were non-conformant may actually affect the same barrier. If this is the case, then this may indicate a significant problem with a barrier and therefore the organization's exposure to risk.

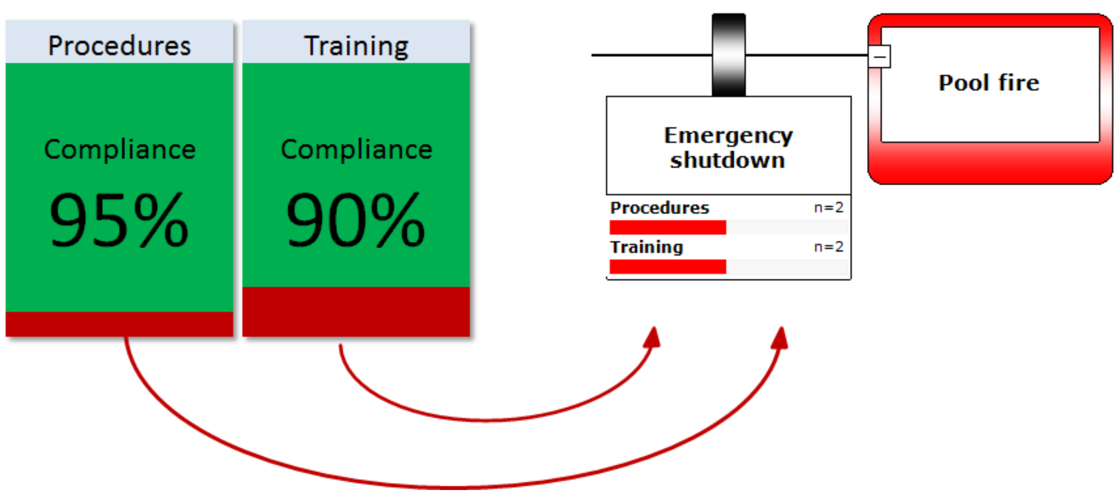

Figure 12 - Depiction of audit result of process safety management system components

4. The interaction between incident & risk-based audits data sources

Integrating incident and audit data have been discussed separately, but they complement each other in an interesting way. An organization does not always have a lot of incident data for a high-risk scenario. This is due to two reasons. The first reason is that for some scenarios there might not be a lot of incident data because the barriers are seldom challenged in incidents. The second reason is that in regards to near misses, the right side of the bowtie can be a blind spot. Although process safety incidents still occur, organizations individually do not face certain high-risk incidents too frequent. Since the right hand side of the bowtie is often dedicated to regaining control over a loss of control situation or mitigating the negative impact of unwanted consequence. An organization can obtain a proactive indication of the health of barriers using audit data if incident data is lacking.

Integrating incident as well as audit data on bowties strengthens the proposed approach. The absence of incident data is not necessarily a sign for solid process safety control. Incidents might not have happened, although the barriers might be in a bad shape. The dynamic component of the Swiss Cheese metaphor (Reason, 1997) provides insight why.

5. Discussion

The approach and proposed ideas have several notes for discussion.

Although this approach is presented as an addition to current process safety management techniques such as the compliance audit or RCA, it might cause the organization to introduce a new ways of analyzing and assessing risk. In this case: the bowtie method, BFA and risk-based audits. To use the integrated approach requires that bowties have to be created for particular process safety incident scenarios. This can subsequently become the framework for the integration audit and incident data. Next to bowties, risk-based audits need to be developed for the bowtie risk assessments. The creation and maintenance of bowties, BFA's and risk-based audits will require an investment of resources.

A challenge for this approach is that there is often not a lot of incident data for the organization's process safety incident scenarios. Especially the major accident scenarios are difficult to link back to a bowtie since they (hopefully) don't occur frequent in an organization. Even when a major accident scenario has not occurred, its potential can be expressed in a BFA and providing valuable input if barriers were challenged during the incident.

Process safety incidents might be more complex than a bowtie diagram. This could be a trigger to update the bowtie diagram.

Near misses often neglect the right side of the bowtie. This is dependent though on the scope of the bowtie though, especially the formulation and placement of the top event in terms of point in time. However, the right side of the bowtie is usually aimed at recovering from a loss of control moment or reducing the negative impact of undesired consequence. This bolsters the call of integrating audit data on a bowtie as well, to add context where incident data is lacking.

The goal of this paper is to demonstrate that this could be a useful addition to managing process safety. This can be underlined with an example compliance audit result. In the figure below, training shows 35% compliance. From a compliance audit point of view, it is clear that these are not great audit results for the domain of training. In the bowtie diagram, these negative audit results might be dispersed across the bowtie and not be easily observed. This is illustrated in *Figure 13*. This stresses an important message of this paper. This approach is not aimed to stop organization with process safety compliance audits (or with RCA for that matter). This approach is not a replacement, but can be used complementary to existing process safety management practices.

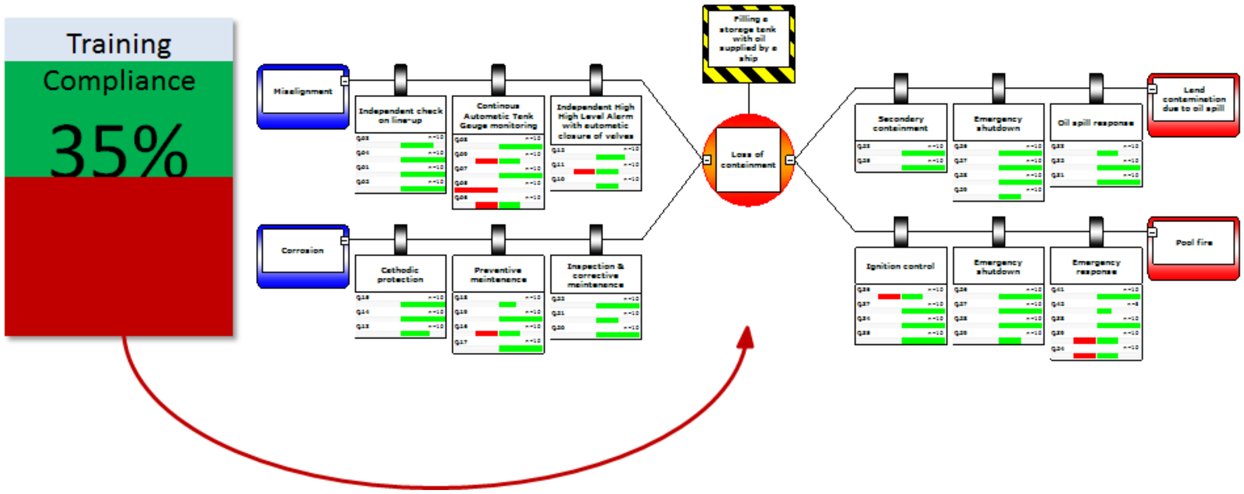

Figure 13 - Different dispersions of negative audit result of a process safety management system component

6. Conclusion

The individual silos issue of risk data (risk assessments, incident- and audit data) in regard to process safety is discussed and ideas for improvement are proposed. These three different data sources complement each other and provide an interesting perspective on the status of the process safety management system. It can be a useful addition to existing process safety management approaches by providing context and different insights into the functioning of the process safety management system.

7. References

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