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Accidents in “normal” operation – Can you see them coming?

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ABSTRACT

Despite the increased understanding of how accidents occur in the chemical process industry, today's safety measures and indicators do not prevent these accidents from occurring. Finding a way to better, proactively, identifying precursors to imminent safety risks, could help organizations to focus their limited resources. The protocol proposed and demonstrated in this paper shows a way to do this. Basis is to examine usually low consequence, high likelihood reoccurring disruptions or deviations in the process (e.g. defects, disturbances, anomalies) for their relevance to process safety and define those possibly leading to accidents as ‘precursors’. As a next step ineffective supervising and managerial control processes and their underlying latent conditions, causing the persistence of these precursors, are identified and it was shown how these cause safety barriers to become ineffective and to open the way to accidents. In conclusion, this paper demonstrates that the proposed 7-stage protocol developed to this end can explicitly and proactively indicate safety risks, and find the controlling latent conditions causing the trouble. It will help organizations to direct their resources to improve safety, which will include their control structure and their normal way of working and will yield higher efficiency as a side benefit.

1. Introduction

In hindsight it seems that accidents could always have been prevented easily. However, to proactively identify and prevent a possible accident from occurring is more difficult, certainly as such type of accident never happened before (Sonnemans & Körvers, 2006). Past research has resulted in a large number of safety or risk indicators, data and tools aiming to indicate the level and possible degradation of safety, or in other words to warn for risks (Marono, Correa, & Sola, 1998; Øien, 2001; Steen van, 1996; Tixier, Dusserre, Salvi, & Gaston, 2002). Despite numerous measures, accidents keep occurring (Körvers & Sonnemans, 2008). Research continues searching for better safety indicators, since safety depends on numerous factors, similar to equipment reliability and equipment use (see for example, Balasubramanian, Kevrekedis, Sonnemans, & Newby, 2008, Geudens, Sonnemans, Brombacher, & Petkova 2005, Sonnemans, Balasubramanian, Kevrekedis, & Newby, 2008). Following the vapour cloud explosion accident at the BP refinery in Texas City in March 2005 the Center for Process Safety of AIChE in New York has put much effort to develop a set of process safety metrics (CCPS, 2009). This consists of a system of lagging and leading indicators: lagging metrics are retrospective indicators, while leading metrics are forward looking. Example of the former is the number of loss of containment incidents and of the latter action items not carried out. However as in reliability engineering trying to achieve completeness by taking all of them into account is not very realistic (Houben, Sonnemans, & Newby, 2009). Also, monitoring and registration is one step but finding causes of possible (acute) disruptions or (slowly evolving) deviations in a process that can become ‘precursors’ to accident, is another. Safety measures and safety indicators were looked upon initially mainly from a technical oriented focus, but the trend has been towards a more socio-technical oriented one, including technical, human, and organizational aspects (Hale, Baram, & Hovden, 1998). Recent innovations in the field of safety research include even the development of so-called cultural indicators. Although these cultural indicators are accepted in practice and accepted by researchers as very relevant, hard evidence of any immediate correlation with safety was for a long time not proven (Sorensen, 2002). In recent years Shell with its ‘Hearts and Minds’ program developed by Hudson, Parker, & van der Graaf, 2002 has made good progress. Vice versa Hollnagel, Woods, and Leveson (2006) showed in recent years under the term ‘Resilience engineering’ how pressure in an organization to achieve efficiency improvement and cost cutting may over time lead to erosion of safety level.

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Körvers (2004) examined many safety indicators in use. Taking currently most used proactive safety indicators into account and identifying from which events these are derived, he found that most of these events have consequences perceived as ‘high’, hence serious, while the likelihood of the event is disregarded. Subsequently, in hindsight he identified events preceding recent accidents. Contrary to the type of events safety indicators are constructed from, the events preceding accidents mainly had safety related consequences perceived as ‘low’, but they had a high likelihood. He concluded that a discrepancy between current safety indicators and events leading to accidents exists, because the ‘high’ perceived likelihood and ‘low’ safety related consequence events are not taken into account. These events, which we will define in more detail as “precursors” in Section 4.2, were identified as reoccurring disruptions or deviations present in normal operation of a process. He did not conclude though that a lack of reoccurring disruptive or deviating events designated as precursors, guarantees no accident will occur. From the 70 accidents analysed globally, there were 5 of which no preceding reoccurring events could be identified. Conversely, experiencing huge numbers of reoccurring disruptions does not always mean the likely occurrence of accidents. However, the presence of reoccurring disruptions/deviations inside an organization with a safety relation perceived as ‘low’, drew his attention. He also put forward the thought that these reoccurring precursors for a large part are due to failing supervising and managerial control processes.

In a subsequent, more detailed study of 17 accidents in the Dutch chemical industry, Sonnemans, Korvers, Brombacher, Beek van, and Reinders (2003) searched for reoccurring disruptions present in the accident trajectories. They used a simple control model to find out why these reoccurring disruptions were present inside the organization. This study substantiated that a simple model of control elements for observation, judgement/assessment and intervention governed by a steering element would be sufficient for explaining why failing of control enabled the accidents to occur. It was shown that in particular a so-called steering element, supervising the three sub-elements described above, was responsible for more than 60% of all failing control processes, leading to reoccurrence of disruptions allowing accidents to happen.

To establish a link between proactive indicators of safety level and reliability of control processes inside an organization, Körvers (2004) proposed to get hold of the underlying unfolding steps identified by Dekker (2002) causing the control process to fail. These unfolding steps explain why the control process failed and the disruption reoccurred. Subsequently, the influences of these steps which constitute latent conditions affecting the effectiveness of safety barriers present in an organization can be obtained. Safety barriers have the function to prevent a hazard to manifest itself and to protect people, environment or asset from inflicting damage. It will be shown in this paper that the underlying causes of a failing control process can damage these safety barriers by creating ‘holes’ inside the layers. Eventually, when the holes in several of these independent barriers line up, accidents may happen (Reason, 1997).

In this paper we will show that the approach of detecting reoccurring process disruptions/deviations, identifying failing control elements and the influences of these failing control elements via negative latent conditions on the present safety barriers, provides a better understanding why reoccurring disruptions play an important role in measuring safety. Therefore results are derived of applying this approach in three case studies in the Dutch chemical industry. In Section 2 a general overview of the three cases and the criteria for selecting these cases will be shown. In Sections 3 and 4 the applied method of analysis and the results from the three cases will be shown, respectively. In Section 5 additional observations from the analysis will be discussed. Finally, the overall conclusions will be presented in Section 6.

2. Scope of the case studies

In this section the choices of the different cases and the research area inside each different case is discussed.

2.1. Choices for three different case studies

To find a suitable case study, selection criteria and their underlying rationalisations have to be formulated. Bickman and Rog (1998) stated that selection criteria have to be based upon five major aspects; nature of the site, data collection process, degree of authorisation, and of accessibility to information, and other possible support. These five aspects, the selection criteria and their advantages and disadvantages are stated below:

- The site selection is largely determined by the risks present and in this way the importance of safety issues inside a company. Risks are determined by the type, amount and conditions of the materials with hazardous properties stored and the complexity of the process, as discussed by Perrow (1984). Hazardous substance is a *first* selection criterion. The complexity is determined by the type of process, batch or continuous. In a batch process, unlike a continuous process, the number of changes/switches in the chemical and control process is relatively high. These changes often decrease the full understanding of the functioning of the system, which as Perrow mentioned, increases the complexity and herewith the risks. This results into the batch-wise industry becoming the *second* criterion.
- The data collection process is determined by the availability of data and also by the accessibility. Authorisation and other support will be discussed later. The size of a company determines to a large extent the way of working. Large (multinational) companies are more formalised and have more data available. Small companies have an informal way of working and often have less data available, which makes it very difficult to collect and to analyse data. The company size is taken as a *third* criterion.
- Authorisation, accessibility and other support is determined by the relation with and culture of the company. The relation with the company has to be in a way that access to relevant data is sufficiently authorised and fully supported by the company's management. Therefore, the *fourth* criterion is sufficient authorisation to review relevant data. Accessibility and other support are mainly influenced by the culture of researcher and company employees. For example, cultural differences can influence the correct understanding of data or of people. The final selection criterion is therefore whether a company is located in The Netherlands or outside.

The selection criteria narrowed the search for suitable cases down to large Dutch companies in the batch-wise operating industry falling under the Dutch Seveso-II directive (BRZO, 1999). To make it more general, from the around 80 selected companies falling under the previous selection criteria, subsequently companies from different sectors and with different product types were selected.

Eventually, the criterion of authorisation and access to relevant data, led straightforward to the selection of three cases in three (different) chemical companies having batch processes located in The Netherlands. For reasons of confidentiality the names of these companies cannot be revealed, therefore they are named