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Near Misses from the Seveso Inspections: Use of Knowledge Based Methods for Safety Improvement

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In Italy, the 2016 campaign of Seveso inspections has been the first after the Seveso III (European Directive 2012/18/UE) implementation. That inspection plan involved the audit of about 150 of the over 450 upper tier establishments. During the 2016-2017 campaigns, about a thousand documents of operating experience OE reports have been gathered. The aim of the paper is to describe the methods adopted for exploiting in a more formal way this valuable information treasure. The study adopts cognitive methods, based on different taxonomies and classifications, to extract knowledge useful for different aims. The paper shows some examples to exploit alerts for stakeholders. Results of extracted knowledge are valuable for inspectors to address future inspections, and for regulators to issue new guidelines.

1. Introduction

In recent Seveso inspections in Italy, the focus is on the study of incidents and near-miss events. The approach, based on near miss discussion compared with safety barriers, is considered “risk based”, as it is able to single out the critical issues of the safety system. In Italy, the practice of exploiting the “operating experience” document OE (basically the Incidents and Near Misses recorded at the site) for assessing the global efficiency of a safety management systems SMS, was presented years ago by few pioneers (Agnello et al. 2012) and today it is becoming more and more common. In 2016 and 2017 campaigns of Seveso Inspections, under Seveso III legislation, the new guideline has been applied for the first time by the inspection teams participated by INAIL, Environmental Agencies, and Fire-fighters representatives. The paper discusses the potential of OE’s. Section 2 describes the objectives; section 3 tells of the document archive and a brief overview of the state of the art for this topic. Section 4 describes the methodology proposed and the procedure used for extracting information and, hopefully, knowledge from this archive. Section 5 contains the application outcomes of two case studies.

2. Aim and objectives

The aim of the paper is to understand how to exploit in a more formal way the valuable knowledge contained into the documents archive, for addressing the inspectors’ training, upgrading the inspection activity, disseminating safety information, so that to improve the safety of the chemical industry in Italy. The paper discusses a methodology adopted for near miss analysis, suitable for major hazard industries under Seveso legislation. At the time of writing this paper, the archive have a thousand documents of OE’s gathered during 2016 and 2017 inspections campaigns in the Seveso upper tier establishments. It is definitely out of scope of this paper to discuss the responsibilities of assessors, any erroneous assessments, as well as the duty holders for the inadequate implementation of the safety regulations. The “not blaming” culture is essential to learn from incidents and near misses.

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3. Background

3.1 Inspection documents archive

The archive contains two types of documents: the accident and incident reports (i.e. OE) and critical system CS reports. The documents gathered come from different sites, both process plants and storage depots operating in several chemical sectors. The OE documents are predefined forms, which the operator fills in with the most significant events occurred in the recent past at the plant. The contents deal with information referring to both the recording of the event and its analysis, including the description of the occurrence, the failed (or missing or misapplied) technical or procedural measures adopted for prevention or mitigation scope, the recovery actions undertaken, and, hopefully, the follow-up actions identified and planned as corrective measure for improving the safety system. Although the form is the same for all owners, the compiling mode varies by establishment and by type of event recorded. Their accuracy is not homogeneous and the interpretation of OE concept changes from one establishment to another. At a few establishments, just the releases of hazardous substance without consequences are registered. In other cases, reports include anomalies, unsafe situations, failures, and trivial errors; that is, events not directly related to major accident hazard. The documents are various, but represent truthful pictures of deviations occurred inside the establishment. In addition to these records, the archive also has the documents containing the outcomes of the risk assessment for all the establishments inspected the CS reports. They provide a bow-tie-based representation for each top events assessed, with the technical and organizational safety barriers to prevent the accident, those to monitor the event and its escalation, and those to mitigate the consequences, Bragatto et al (2017).

3.2 Near Miss analysis: state of the art

There is no room in this paper to discuss different methods used in the literature to manage near miss information. In most papers, the subject is argued from the point of view of the management, using internal experience for the continuous improvement of their own SMS. Significant examples are in Andriulo & Gnoni (2014) or in Phimister & al. (2003). Anyway, the problem is similar to the exploitation of accident databases. A significant example is in Jacabson & al. (2009), Sales & al. (2007) and in Kirchsteiger (1999). In Gnoni & Saleh (2017) near misses are discussed in the light of safety principles, independent on the industrial domain. The typical methods of knowledge management, including case based reasoning and text mining, are also used to extract useful information for safety improvements. An example is in Suzuki & al. (2006). The knowledge management techniques are now much more powerful than in past and widely applied in many different fields. Thus, an investigation of their potential for near miss management is challenging indeed.

4. Methodology

Each document archived has a few attributes, e.g. the industrial sector, the inspection's year. All the other information requires search within textual descriptions. Thus, the huge amount of documents inhibits and discourages any human attempt to extract information only by reading the reports. Applying text-mining techniques to reduce the human efforts to select key concepts would be desirable. However, a straightforward application of these techniques is not enough for eliminating some noises, including namesakes, ambiguities, special jargons used in the company or own abbreviations, in addition to implicit and tacit concepts not clearly expressed but useful for understanding the event and its context. The proposed methodology suggests using a semantic search engine to support the experts in the search activities. Therefore, taking advantage of the characteristics of those tools, including dictionary management features, taxonomies, synonyms, "queries" become filters to reduce the set of reports and focus on the most relevant ones. Combining the use of taxonomies together with synonyms is the capability of looking for concepts not simply keywords, thus the search is like to apply a mask to the document to point out only the words pertinent to the query. A few of simple taxonomies corresponding to the topics of the key elements involved, including events, equipment, and working activities, have been defined. The use of semantic search engine is a challenge to improve the methods for extracting the knowledge quickly, without replacing the inspectors' expertise and competence but rather as a facilitator of their work. The system adopted for testing the methodology is IBM OmniFind™; one of its capabilities is to provide brief summaries for each found document, dynamically generated according to the query, with the advantage to understand quickly the relevance of the result. Another key feature is the semantic proximity calculation of the outcomes with respect to the target. The procedure, described in Ansaldi et al. (2018), shows how the semantic distance plays a key role in decisions of improving queries, with new keywords, synonyms, and reducing any ambiguities. Both summaries interpretation and semantic distance offer remarkable advantages to the experts for evaluating quickly the document relevance with respect to the search.

4.1 Proposed procedure

The OE archive includes the most meaningful events occurred in the recent past at the establishments, including anomaly, near miss, incident, and accident. Anomaly is a deviation from the normal procedural or organizational operative conditions, not involving major accidents hazard MAH. In Seveso establishments, near miss, incidents and accidents always deal with a loss of containment, respectively, without consequences, or with minor or major consequences. The diagram shown in figure 1 describes a classification of the different types of OEs gathered into the archive.

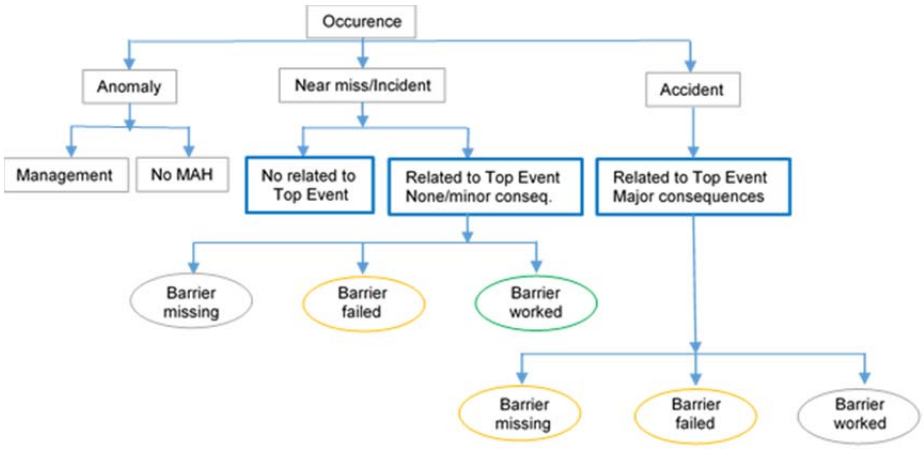

Figure 1: The diagram for classifying operative experiences

The boxes correspond to the types of occurrences and their relations with respect to the top event and the consequences. The blue box, labelled as "*No related to Top Event*", is the OE not directly concerning a top event, but important because highlight dangerous situations. For example, some OE report loss of containment of tanks collecting meteoric water, due to exceptional rainfalls. These events do not involve hazardous substances, but are worthy of note because involving service components that, if out of service, may lead to interruption of plant operation or to worst consequences. The second blue box ("*Related to Top Event-None/minor consequences*") contains events considered as precursors of top events, but without effects or with minor consequences; while the third one ("*Related to Top Event-Major consequences*") classifies the major accidents. The ellipses indicate the behavior that items of the CS report may have had in the event, i.e. the barriers missed, failed or worked well; the different colors indicate their commitment, green and yellow mean, respectively, positive and negative involvement of the barrier, grey a minor involvement. The barriers, concerning technological, operational and organizational aspects, play different roles including prevention, protection and mitigation of consequences. The OE's report a detailed event description, thus to extract information on which barriers failed or worked to stop any evolution toward a major accident. Unfortunately, not all causes are explicitly mentioned, often an interpretation by the expert is required. Since the barriers and their behavior are the key point, which the search is based on, starting from the CS report, a preliminary list of the measures adopted was compiled. The Table 1 shows a non-exhaustive list of safety technical barriers. The first two columns refer to preventive ones, while the other two describe those for mitigating the consequences. Operation describes the functionality, while Device column provides with some examples.

Table 1: Safety barriers

Preventive barriers		Protective barriers	
Operation	Device	Operation	Device
Regulate	All types of valve	Containment	Basin, curb
Measure/Control	Level gauge, pressure gauge, thermometer, flow meter, procedure	Detect	gas detector, sniffer
Alarm	High, very high, low, very low of a parameter (i.e. level, temperature, flow, pressure)	Release	Rupture disk, relief valve
Insulate	Jacket, wrap, painting, insulation, seal	Emergency	System block

5. First results

The methodology was applied to the OE's archive for a couple of specific industrial types of establishments: refineries and chemical process plants. For each case study, firstly all the documents are classified according to the above definitions of anomaly, near miss or incident. Next, combinations of different concepts, including events, equipment, technical and organizational measures, are used for checking the most frequent occurrences. The events occurred mainly deal with the losses of containment, i.e. leakage, overflow, involving several types of equipment, e.g. lines, tanks, exchangers, pumps, or instrumentation, e.g. valves, alarms, measure devices. Most of these documents specify which barriers failed and which worked well to prevent or stop escalation of consequences; a few reports have such a short description to be difficult to understand the scenario in which the event occurred. According to the methodology, the search activity into the OE archive is an iterative process that combines different concepts to find out the most frequent similar occurrences. Tables 2 and 3 show the results and the concepts adopted for looking into refineries and chemical establishments documents archive. The columns mean: the type of event, the equipment involved, the direct cause identified, which barrier failed, which barrier worked well; the first and the last columns show the identification of the type of near miss ID and the number N° of documents found, respectively. Three digits compound the ID: event, equipment and cause concepts. The key to reading it is that each row corresponds to a cluster of near misses with a strong similarity based on those concepts. The number inside the round brackets states the restriction of pertinent documents.

5.1 Case study 1: refineries

The archive contains 77 OE's of which 14 anomalies, 60 near misses and 3 incidents, only the last two sets are considered for the search purposes. The near misses related to the "*loss of containment on a line*" (ID 1.1.1, 1.1.2, 2.1.3) counts 17 documents; the corrosion/erosion is the most relevant cause, of which 5 are corrosion under insulation. Five documents refer to other causes, e.g. wrong maintenance operations or activities, classified as organizational. The 3.7.0 and 4.7.0 rows (*Loss or fire occurred at other equipment*) are useful for near misses counting but are meaningless for knowledge extraction, since correspond to different cases from each other.

Table 2: Near misses clusters for case study 1

ID	Event	Equipment	Cause	Barrier failed	Barrier worked well	N°
1.1.1	Drip/Leakage	Line	Corrosion under insulation		Control procedure (3)	5
1.1.2	Drip/Leakage	Line	Organizational	Procedure	Control procedure (2)	5
1.2.3	Drip/Leakage	Flange	Corrosion		Control procedure (1)	2
1.2.4	Drip/Leakage	Flange	Failure	Gasket	Control procedure (1)	2
1.3.5	Drip/Leakage	Exchanger	Maintenance		Control procedure (1)	2
1.4.4	Drip/Leakage	Tank	Failure	Draining system	Control procedure (1)	2
2.1.3	Leakage/Loss	Line	Corrosion/erosion			7
2.2.6	Leakage/Loss	Flange	Overpressure	Pressure control		3
2.3.4	Leakage/Loss	Exchanger	Failure	Gasket		3
2.4.1	Leakage/Loss	Tank	Corrosion under insulation			2
3.4.4	Release	Tank	Failure	Level measurement	Explosive sensor (1)	3
3.4.2	Release	Tank	Organizational	Procedure	Basin (1), level meas. (1)	2
3.5.4	Release	Pump	Failure		Gas detector (1), procedure (1)	4
3.6.4	Release	Valve	Failure	Maintenance (1)		3
3.7.0	Release	Other				3
4.1.7	Fire	Line	Hot operations (2) Contamination (2)		Emergency procedure (4)	4
4.5.8	Fire	Pump	Leakage		Emergency procedure (3)	3
4.3.8	Fire	Exchanger	Leakage, failure/defect	Gasket (1)	Emergency procedure (3)	3
4.8.3	Fire	Furnace	Corrosion		Emergency procedure (2)	2
4.7.0	Fire	Other			Emergency procedure (3)	3

The most frequent causes deal with equipment failures (17 reports) and the corrosion, counted into 16 documents of which 7 are corrosion under insulation. Classified as organizational cause, there are 9 near misses related to wrong procedure application or incorrect workers behaviors. The group 3.4.2 contains near misses in which the barriers, i.e. the basin of containment and the level gauge worked well; but in one case the procedure for tank remediation was not correctly applied and the hazardous substance spilled inside the basin, in the other case the alarm was not recognized by the workers. The control procedure, daily applied in the refineries, counts 9 explicitly mentions in the reports for early detection of a drip or leakage of hazardous substances. Level gauge failure caused overfilling problems of tanks in three near misses, but in one case, a sensor detected the unusual quantity of flammable vapors. The near misses and incidents related to fire outline the activation of the emergency procedure for blocking the evolution of the event.

5.2 Case study 2: chemical process plants

The archive contains 221 OE of which 82 anomalies, 126 near misses and 13 incidents. All events involving the same type of equipment and with the largest number of occurrence are considered; for those that it is not possible identify the same equipment, a classification, based on preventive or protective barriers that failed or well worked, is proposed. Table 3 shows results for near miss linked to equipment. The near misses related to the "*loss of containment on a valve*" (ID1.2.1, 1.2.2, 3.2.1, 3.2.2, and 4.2.2) and to the "*loss of containment on a line*" (ID 1.1.1, 1.1.2, 2.1.1, and 3.1.2) count respectively 20 and 15 documents. In the first case, valve failure is the most relevant cause identified in 12 documents; in the second one, organizational aspects are more numerous and identified into 10 documents. The causes of near misses, dealing with the equipment, are organizational ones (30) and technical failures (26). Organizational critical issues mainly relate to missing or not applied procedures (10), aspects of the inspection and maintenance (15) and training (4). Technical failures involve broken valves (11), measure controls and inspection (8), broken gaskets and flanges (4) and wrong design (3).

Table 3: Near misses clusters for case study 2 – equipment

ID	Event	Equipment	Cause	Barrier failed	Barrier worked well	N°
1.1.1	Release	Line	Organizational	Procedure (3), maintenance (1)	Emergency procedure (2)	4
1.1.2	Release	Line	Failure	Project (3)	Basin (2)	3
1.2.2	Release	Valve	Failure	Valve (4)	Emergency procedure (1)	4
1.2.1	Release	Valve	Organizational	Training (4), procedure (1)	Basin (1)	5
1.3.3	Release	Tank	Corrosion	Maintenance (3)	Basin (2)	3
1.3.2	Release	Tank	Failure	Level measurement (2)		2
1.4.1	Release	Reactor	Organizational	Procedure (3), maintenance (1)	Gas detector (1)	4
1.4.2	Release	Reactor	Failure	Measure controls (2)	Emergency procedure (1)	2
2.1.1	Drip/Leakage	Line	Organizational	Maintenance (6)	Basin (2)	6
3.1.2	Leakage	Line	Failure	Gasket (2)	Emergency procedure (2)	2
3.2.2	Leakage	Valve	Failure	Valve (3)		3
3.2.1	Leakage	Valve	Organizational	Procedure (3)		3
3.5.1	Leakage	Pump	Organizational	Maintenance (4)	Emergency procedure (1)	4
3.5.3	Leakage	Pump	Corrosion	Degradation analysis (2)	Detector (1)	2
3.6.1	Leakage	Flange	Organizational	Maintenance (3), degradation analysis (1)	Inspection (1)	4
3.6.2	Leakage	Flange	Failure	Flange (2)		2
4.2.2	Overflow	Valve	Failure	Valve (4), inspection (1)	Emergency procedure (1)	5
4.3.2	Overflow	Tank	Failure	Level measurement (3)	Basin (1), emergency procedure(1)	3
5.4.0	Fire	Reactor		Unsuitable materials (2), insulation (1), seal (1)	Emergency procedure (3)	4

The Table 4 shows the events, not included in Table 3, based on the type of behavior of barriers involved. In the case of release, the most numerous events are due to the failure of preventive barriers (inspections, procedures, maintenance); the causes of drip/leakage events concern organizational aspects, too. Overflows are due to failures related to technical aspects (malfunctioning of pumps or damaged seals). The results also point out the positive role of the emergency procedures.

Table 4: Near misses clusters for case study 2 – barriers

Event	N°	Barrier failed	Cause	Barrier worked well
Release	24	Inspection (10), procedure (7), maintenance (6)	Organizational	Emergency procedure (5)
Drip/Leakage	5	Maintenance (3), degradation analysis (2)	Organizational	
Overflow	8	Procedure (3), pump (3), gasket (2)	Failure	Emergency procedure (5)
Fire	12	Maintenance (5), procedure (4), project (3)	Failure	

6. Conclusions and future developments

The use of text-mining systems or search engines to exploit an accident database is not new; but their use to near misses was not trivial. Even though a unified format is adopted throughout Italy, the variety and the quality of those documents affect the knowledge extraction. In the present study, just a couple of types of process was considered. The results for the chemical plants are more complex than the ones of the refineries, because the first ones include less standardized industrial activities and different substances. The analysis of the real cases represents a valuable support to improve training, risk analysis, safety document management. The structured outcomes can provide operators and inspectors with indications and suggestions useful for different industrial contexts. Every year a new inspection national campaign is planned, thus in a few years many thousands documents will be, hopefully, collected, so that to provide the Italian Seveso stakeholders with a trustable source of information about accident prevention.

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